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Abstracts of the 60th Annual Conference of the German Society of Biomedical Engineering, 6–8 October 2026, Augsburg

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Angaben zur Veröffentlichung / Publication details:

Zaunseder, Sebastian, Julia Welzel, and Thomas Wendler. 2026. "Abstracts of the 60th Annual Conference of the German Society of Biomedical Engineering, 6–8 October 2026, Augsburg." *Biomedical Engineering / Biomedizinische Technik* 71 (s1): 1–321. https://doi.org/10.1515/bmt-2026-1001.

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VDE DGBMT

BMT 2026

6–8 October 2026 | Augsburg/Germany

60TH DGBMT ANNUAL CONFERENCE

BRIDGING ENGINEERING AND COMPUTER SCIENCES FOR BETTER HEALTH

ABSTRACT BOOKLET

https://doi.org/10.1515/bmt-2026-1001

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Prof. Dr.-Ing. Sebastian Zaunseder, Chair for Diagnostic Sensing, University of Augsburg, and Member of the Executive Board of the DGBMT

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AI-Driven Modeling of Modulated Magnetoelectric Magnetic Field Sensors

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Introduction

Modulated magnetoelectric (ME) sensors enable detection of weak, low-frequency magnetic fields. However, their performance depends on a high-dimensional parameter space in which magnetic, electric, and mechanical properties interplay with readout electronics and operating conditions. This complexity makes sensor design and operating point selection challenging. To address this, we propose artificial neural network (ANN) surrogate models as a step toward an AI-driven methodology for modulated ME sensors.

Methods

Using experimental data from a ΔE-effect-based modulated ME sensor, we trained three task-specific ANN models to predict admittance, noise spectral density (NSD), and signal amplitude at 5 Hz from excitation amplitude, excitation frequency, and magnetic bias flux density. Training data contained 495 admittance spectra, 75 NSD curves, and signal points. These models were then used to estimate the limit of detection (LOD) and support operating point optimization under realistic constraints.

Results

The ANN surrogates accurately reproduce sensor behavior across the parameter space. The admittance model achieves excellent accuracy with 90^{th} percentile nRMSE of 0.178% for magnitude and 0.114% for phase. The NSD model reaches a few percent errors overall and 90^{th} percentile of 1.93%, while the signal model attains a 90^{th} percentile relative absolute error of around 5.01%. Based on these predictions, the limit of detection (LOD) is well captured over the full operating regime with a minimum of $0.36\ \mathrm{nT}/\sqrt{\mathrm{Hz}}$. The surrogate models further enabled rapid global, constrained, and multi-objective optimization, including Pareto-front analysis identifying operating points where the LOD cannot be lowered without reducing signal amplitude.

Conclusion

These results demonstrate that ANN surrogates can provide accurate, practical models for modulated ME sensors and support non-trivial optimization tasks infeasible from measurements alone. Although demonstrated here for a ΔE-effect sensor, the approach is transferable to other ME sensor concepts and operating principles, representing a step toward digital twins for application-driven sensor optimization.

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Laser-based additive manufacturing of patient-specific permanent and bioresorbable implants

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Introduction

In recent years, additive manufacturing (AM) of patient-specific implants has advanced from fundamental research towards series production. Yet, for permanent as well as bioresorbable implants, there are still many open research questions, such as reducing stress-shielding effects or hydrogen evolution, that need to be addressed. To bridge the gap between research and clinical application, the research unit 5250 (project no. 449916462) addresses the laser-based powder bed fusion (PBF-LB/M) of permanent titanium and bioresorbable magnesium implants. This contribution provides insight into the manufacturing process and properties of complex dental lattice implants.

Methods

In the first funding period, titanium implants were investigated with the aim of developing a stiffness-reduced implant with a unit-cell-based lattice structure design leading to reduced stress shielding and improved implant lifetime. Within the second ongoing funding period, PBF-LB/M of magnesium-based bioresorbable structures for bone and soft tissue regeneration in the jaw are investigated. For both materials, investigations on the impact of the fabrication process on resulting properties of intricate lattice structures are carried out.

Results

Utilizing the design freedom of PBF-LB/M, dental titanium implants with a buttress design and a complex inner structure were developed. A gyroid structure with a strut diameter of 350 µm and a minimal macropore size of 650 µm is investigated in detail. Mechanical testing confirmed that implants can be manufactured exhibiting reduced stress-shielding while retaining the necessary mechanical properties for the load case. Additionally, first designs of magnesium-based resorbable structures could be manufactured by PBF-LB/M down to feature sizes of 150 µm.

Conclusion

AM holds the potential of individually tailoring the mechanical properties of complex structures. For permanent dental implants, the highly promising approach to reduce stress-shielding by adjusting the stiffness of a complex inner structure was successfully demonstrated. The first highly complex structures for jawbone and soft tissue regeneration are presented.

Acknowledgments

The authors gratefully acknowledge the funding by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) for the research unit 5250 “Mechanism-based characterization and modeling of permanent and bioresorbable implants with tailored functionality based on innovative invivo, in-vitro and in-silico methods” (project no. 449916462)

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Effect of Ultra-Conformable Coatings on CMUT Behaviour in Biological Environments

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Capacitive-micromachined ultrasonic transducers (CMUTs) are promising wireless-power sources for deep-seated active implanted medical devices; yet their membranes are not made for implantation, and therefore require the application of a biocompatible coating to protect the patient as well as the membranes. This work investigates a thin (≈ 65 µm), medical-grade silicone (PDMS) encapsulation as a simple, biocompatible protection layer. Three PCB-mounted CMUT batches were examined: (i) uncoated (A1), (ii) coated with MED-1000 (B1), and (iii) coated with MED2-4213 (C1). Digital holographic microscopy (DHM) quantified membrane displacement in air (dry) and in 5 mL phosphate-buffered saline (wet). In PBS the uncoated CMUT showed severe corrosion and a mean displacement of 1.05 ± 0.96 nm, whereas both silicone-coated devices retained a mean displacement of ≈ 2.5 nm (≈ 44 % of the dry value) with no visual damage. A brief hydrophone test confirmed that the coating does not attenuate the dominant ~10 MHz acoustic component. The thin PDMS layer therefore provides corrosion protection, preserves membrane dynamics, and offers acoustic-impedance matching (≈ 1.5 MRayl), supporting its use as a low-cost encapsulant for CMUT-based wireless power transfer in liquid environments.

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Designing Trust, Autonomy, and Acceptance in AI-Based Clinical Decision Support Systems: A Comparative Experimental Analysis

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Introduction

Artificial intelligence-based clinical decision support systems (AI CDSS) have the potential to improve clinical decision-making and patient outcomes, yet their adoption in practice remains limited. Prior research highlights trust in AI and concerns about professional autonomy as central barriers to implementation. While explainability and system integration can increase trust by reducing uncertainty, they may simultaneously challenge professional identity and decision authority. At the same time, perceived usefulness has been identified as the primary driver of technology acceptance, although it is shaped by autonomy-related concerns, particularly among physicians. This study integrates two experimental investigations to examine how AI-CDSS design features jointly influence trust, autonomy-related perceptions, and acceptance across physicians, patient, and future potential patients.

Methods

The analysis combines and compares findings from two vignette-based experimental studies. The first study (n = 292) employs a 2 × 2 × 2 factorial design manipulating explainability (AI recommendation explained vs not explained), integration depth of recommendation into the clinical workflow (detailed vs no detailed clinical treatment recommendation), and system-induced accountability of a physician in relation to the AI recommendation (system required a signature vs no signature) to assess their effects on trust and professional identity threat among physicians. The second study consists of three experiments across patients (n = 209), potential future users (n = 1062), and physicians (n = 185), manipulating AI-CDSS system type (hybrid vs. autonomous) and recommendation risk (lifestyle vs. medical) (2 x 2 factorial design) to assess their effects on professional autonomy, perceived usefulness, and intention to use. Regression-based mediation and sequential mediation models (SPSS PROCESS Macro) were applied using bootstrapping procedures.

Results

Results from Study 1 show that AI explainability has a strong positive effect on trust in AI ($b = .51$, $p < .001$), while also increasing perceived professional identity threat ($b = .35$, $p < .05$) among physicians. Trust is negatively associated with identity threat ($b = -.14$, $p < .05$) and partially mediates this relationship. A high clinical workflow integration further increases trust ($b = .26$, $p < .01$), whereas accountability mechanisms significantly increase perceived identity threat ($b = .34$, $p < .05$). Results from Study 2 indicate that perceived usefulness is the strongest predictor of intention to use across all stakeholder groups (patients: $b = .93$, $p < .001$; potential future patients: $b = .88$, $p < .001$; physicians: $b = .80$, $p < .001$). However, the underlying mechanisms differ. Among patients and potential users, hybrid systems increase intention to use primarily through higher perceived usefulness (patients: $b = .30$, 95% CI [.09, .49], potential future atients: $b = .13$, 95% CI [.06, .20]) with no significant effect on professional autonomy anticipantions. In contrast, among physicians, hybrid systems reduce perceived autonomy loss ($b = -.64$, $p < .001$), which in turn increases perceived usefulness ($b = -.25$, $p < .001$), resulting in a significant sequential mediation effect. Across all groups, a medical recommendation (vs. lifestyle recommendation) increases autonomy-related concerns but does not directly reduce perceived usefulness or intention to use.

Conclusion

AI-CDSS acceptance is shaped by the interplay of trust, perceived usefulness, and professional autonomy-related concerns. AI design features exhibit ambivalent effects, simultaneously enabling and constraining adoption. Successful implementation requires aligning system design with professional expectations, particularly by preserving physician decision authority while demonstrating clear clinical value.

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Sensory feedback is essential for natural and reliable bionic-hand control, yet most myoelectric prosthetic hands provide limited or no tactile feedback, and users are forced to rely on visual grip regulation. Vibrotactile feedback is a compact and non-invasive solution, but many existing systems require costly hardware, provide coarse spatial resolution, or lack objective validation of vibration sensing. This study developed and evaluated a low-cost vibrotactile armband that conveys fingertip-specific contact location and force magnitude. Five coin-type vibration motors were spatially distanced on the armband and driven using pulse width modulation at 60% and 90% duty cycles to simulate low- and high- force contact respectively. System performance was evaluated using 1) objective vibration measurements via five accelerometers coupled to each motor, and 2) subjective testing with 20 able-bodied participants under blindfolded, noise-masked conditions. Frequency-domain analysis of the accelerometers' signals showed a dominant peak for the activated motor, and reduced amplitudes at neighbouring motor sites. The participants identified the stimulated finger with 75% and 94% accuracies at low and high force levels, respectively. They could discriminate pinch from grip patterns with 85% accuracy. The combined objective-subjective validation supports the feasibility of this affordable armband-based feedback for bionic-hand systems.

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Parametrised Dynamic Contrast-Enhanced MRI through Implicit Neural Representations

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Introduction

Dynamic contrast-enhanced MRI (DCE MRI) enables non-invasive assessment of tissue perfusion and vascular permeability through kinetic modelling of contrast agents. The extended Tofts model describes tissue microvasculature via kinetic parameters: volume transfer constant, rate constant, intravascular volume fraction, and extracellular volume fraction. Conventional curve fitting (CF) is computationally intensive and noise-sensitive, while deep neural networks require large datasets. We hypothesise that implicit neural representations (INRs) achieve equivalent accuracy to CF with improved spatial coherence, without population-level training data.

Methods

A light-weight neural network (SIREN, Gaussian Fourier Features encoding) maps spatial coordinates to voxel-wise Tofts parameters by minimising MSE between model-predicted and measured concentration-time curves, requiring no ground-truth parameter maps. Iliac artery (for image-derived input function), prostate and tumour segmentations were obtained from co-registered PET/CT images and refined by a medical expert, with DCE MRI volumes aligned to the CT via a multi-stage deformable registration pipeline. Retrospective evaluation data included 13 patients with histopathologically confirmed prostate cancer (local ethics committee approved).

Results

INR-based estimation achieved reconstruction accuracy equivalent to CF in both prostate and tumour regions ($p \gg 0.05$). Despite CF yielding numerically lower mean MSE (prostate INR: 0.0071 ± 0.005 vs. CF 0.0052 ± 0.004; tumour: INR 0.0090 ± 0.008 vs. CF 0.0063 ± 0.005), parameter maps were smoother for INR in the prostate ($p \leq 0.003$) with Laplacian energy reduced by 3–70× and consistently higher Moran's I across all parameters (range: INR 0.84–0.86 vs. CF 0.70–0.79). INR inference was ~7 times faster than CF (INR: 39.4 ± 14.0 s; CF: 293.2 ± 163.0 s).

Conclusion

Our findings demonstrate the potential of INRs for personalised, data-efficient, spatially coherent kinetic modelling in DCE MRI. The proposed framework operates on single-patient acquisitions, producing high-resolution smooth kinetic parametric images, and offers a computationally tractable alternative to CF.

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Robot-assisted in-situ endomicroscopic dynamic OCT diagnostics to reduce cholesteatoma recurrence

Introduction

In current surgical procedures for the removal of cholesteatomas, the average recurrence rate following the initial surgery is approximately 13%. Every surgery carries the potential risk of nerve damage as well as infections of the surrounding tissue including the CNS. The goal of the surgery is to completely remove the cholesteatoma while preserving healthy tissue. This feasibility study investigates the use of robot-assisted, endomicroscopic, dynamic OCT imaging for in-situ differentiation between healthy tissue and cholesteatoma tissue, with the goal of performing resection in a more targeted and tissue-sparing manner and reducing the recurrence rate.

Methods

Twenty surgical procedures are scheduled, during which each patient undergoes two measurements of the cholesteatoma capsule and one measurement of the surrounding tissue. Two samples are collected for a qualitative comparison with histological sections. The system developed for the study comprises an OCT measurement system (supercontinuum laser, OCT, customized spectrometer), an OCT probe (fiber-based interferometer, galvanometer scanner, custom-designed GRIN lens optics) and a holding system (industrial robot, in-house developed control software). All components have individual MDR type approval, the study was approved by the Ethics Committee.

Results

Until June 2026, measurements had been successfully performed on 10 patients. Both in the 2D preview and in the post-processed dynamic images, it was possible to distinguish between healthy and pathological tissue. Robot-assisted stabilization largely enabled stable images, although motion artifacts caused by blood flow, among other factors, posed a challenge. The additional measurement and preparation time extended the duration of the surgery by approximately 30 minutes and was deemed clinically acceptable.

Conclusion

Successful in-situ measurements of cholesteatoma and healthy tissue were performed. The next step is to reduce the size of the OCT probe and implement automated measurement using a robot, including compensation for tissue movement.

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Additive Manufacturing of Dental Implants: Development and Mechanical Characterization

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Introduction

Additive manufacturing, particularly laser powder bed fusion, has emerged as a promising technology for producing dental implants, offering potential advantages including design freedom and patient-specific customization. However, questions remain regarding the mechanical stability of additively manufactured implants compared to conventional designs.

Methods

A dental implant system, comprising an implant body, a conical abutment, and an abutment screw, was developed from Ti-6Al-4V alloy. The implant body was additively manufactured, while the abutment and abutment screw were machined. Mechanical performance was evaluated by quasi-static compression tests and cyclic loading in accordance with ISO 14801.

Results

Under quasi-static loading, the maximum force was 737 N. Under dynamic fatigue testing using the staircase method, a mean fatigue strength of 298 N was determined. Failure occurred predominantly at the abutment screw and in the implant neck region.

Conclusion

The findings demonstrate that additively manufactured dental implants exhibit reliable mechanical stability under simulated clinical conditions. Thus, these additively manufactured implants represent a promising alternative to conventionally fabricated commercial implants, combining mechanical reliability and potential for patient-specific customization.

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Fast and Robust 3D Reconstruction of Anatomical Cavities: A Pre-Processed Instant-NGP Pipeline for Monocular Endoscopy

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Introduction

Neural Radiance Fields (NeRF) have emerged as an alternative to the traditional photogrammetric methods for three-dimensional reconstruction, offering superior structural and textural fidelity. However, monocular endoscopic imaging presents significant challenges, including narrow anatomical structures, non-uniform illumination, motion blur, and sparse image sequences. These factors degrade reconstruction quality, introducing artifacts in conventional NeRF pipelines. While specialized endoscopic approaches exist, they prioritize reconstruction fidelity over efficiency, often requiring hours of training and limiting their practical usability.

Methods

We propose a preprocessing-driven pipeline built on Instant-NGP that improves robustness without requiring specialized NeRF architectures. Our approach applies a dedicated preprocessing step before neural training including reprojection to a pinhole model, sharpness-based frame filtering using Laplacian variance, and neural pose estimation via a self-supervised model with brightness normalization to recover SfM-consistent camera poses under challenging illumination. Each of these remaining frames is weighted during training.

Results

We validated our pipeline using high-fidelity, custom-made 3D models of the human lung and knee joint to simulate realistic clinical scenarios, as well as a sparse colon sequence from the Endomapper dataset. The reconstructions were completed in approximately five minutes using 14,000 training iterations. Increasing Laplacian variance thresholds showed to improve structural consistency and reduce artifacts, yielding visually coherent reconstructions with improved texture preservation compared to unfiltered inputs, while significantly reducing training time relative to the specialized methods.

Conclusion

We present a robust and efficient NeRF-based pipeline for endoscopic reconstruction that mitigates common failure points through preprocessing, neural pose estimation, and adaptive weighting. While the method improves reconstruction quality under challenging conditions, it remains sensitive to rapid camera motion and requires sufficient scene coverage for optimal performance.

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Robustness of Multi-Phase CT Classification: A Reproducibility Study

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Introduction

Contrast-enhanced is widely used in computed tomography (CT) to characterize lesions, where classify the contrast-phase accurately is critical. Before clinical deployment, such models must be evaluated on external data that may differ in label space or acquisition protocols. This study evaluates a multi-phase CT phase-classification method based on organ-specific intensity features in external dataset with reduced granularity.

Methods

The dataset comprises 179 thorax CT scans categorized into three phase labels: non-contrast (n = 77), arterial (n = 34), and portal venous (n = 68), with class imbalance. An experienced radiologist provided the annotations, used as reference labels while acknowledging inter-reader variability. The evaluated model was originally trained on five phases (non-contrast, arterial, portal venous, nephrographic, delayed) on a separate cohort and not retrained on the external data. Five-phase predictions were mapped to the three-phase label space by merging portal venous, nephrographic, and delayed phases, as these classes were not separately annotated in our dataset. Two evaluation schemes were examined: (1) strict three-class evaluation, in which any deviation from the reference label was counted as an error, and (2) grouped remapping. To address imbalance and quantify variability, stratified balanced bootstrap sampling over 100 iterations was performed, and balanced bootstrap macro F1 was used as the primary metric.

Results

Balanced bootstrap macro F1 was the primary metric. Among the evaluated random forest (RF) and gradient boosting (GB) models with mean or k-nearest neighbor (KNN) imputation, RF with mean imputation achieved the best performance, with a strict macro F1-score of 0.700 (accuracy = 0.670) and a remapped F1-score of 0.723 (accuracy = 0.765). Bootstrap estimates were stable (strict: 0.676 ± 0.016; remapped: 0.702 ± 0.018). Mean macro F1-scores for the remaining imputed models were 0.678 (RF-KNN), 0.570 (GB-KNN), and 0.484 (GB-mean).

Conclusion

These findings indicate label harmonization modestly improves performance under label-space mismatch without altering model behavior.

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Differentiation of stress and physical activity in wearable ECG signals using fuzzy entropy metrics

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Introduction

Stress detection using Electrocardiography (ECG) signals are considered as a direct measure of the autonomic nervous system activity, becoming increasingly sensitive to stress-induced physiological changes. Heart Rate Variability features extracted from the ECG signal may result in a similar physiological response for both stress and physical activity. Alternatively, entropy-based metrics capture inherent morphological dynamics and can be used to detect stress from ECG signals.

Methods

This study employs fuzzy entropy features to distinguish stress from rest (baseline) and physical activity conditions in real time. The ECG signals are collected from 36 participants using a data acquisition system. The acquired signals are preprocessed and normalized to remove noises, artifacts and heart rate effects. Further, it is downsampled to 250Hz to reduce computational complexity for real time analysis and fuzzy entropy features are extracted.

Results

Results show that fuzzy entropy exhibits reduced value in stress condition compared to the baseline which may be due to increased sympathetic activity and also indicates statistically significant ($p<0.05$) results between them. Further, analyzing the time window for effective discrimination of stress and physical activity reveals that 5s window demonstrates consistent distinctions between them, and can be considered for real-time stress analysis.

Conclusion

Thereby, the fuzzy entropy feature can be used for effective discrimination of stress from physical activity using ECG signals.

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Dual-Stream Self-Attention Prototype Learning for Interpretable EEG Sleep Stage Classification

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Introduction

Accurate sleep staging from electroencephalography (EEG) relies on both spectral power distributions and transient time-domain events. While deep learning can handle this complexity, most models remain obscure to clinicians who rely on well-defined biomarkers like K-complexes and slow-wave activity to classify sleep stages. Prototype-based self-attention approaches offer an intrinsically interpretable alternative, yet the existing implementation generates explanations exclusively in the raw time domain, omitting spectral features such as delta power critical for N3 staging.

Methods

We extended a self-attention prototype architecture with a parallel power spectral density (PSD) stream, enabling concept generation in both the time domain and interpretable frequency bands. An additional contiguity constraint supplements the existing locality regularisation to encourage time-series attention heads to select locally connected windows corresponding to distinct biomarker events. This in turn enables a fourfold kernel reduction, narrowing the hidden receptive field behind each selected position from 400ms to 90ms, reflecting the scale of discrete EEG waveform features. To allow comparison with the time-only approach, experiments were conducted on the Sleep-EDF-20 dataset (20 subjects, 39 recordings) as five-class classification across three 15%-holdout splits.

Results

Across the test splits, the dual-stream model achieved 0.76 ± 0.05 accuracy (mean ± SD), 0.69 ± 0.05 precision, and 0.72 ± 0.03 recall, comparable to the time-only baseline (0.76 ± 0.01, 0.70 ± 0.01, 0.69 ± 0.02). PSD attention heads consistently specialised for N3, a sleep stage whose defining delta-band signature cannot be explicitly characterised by time-only prototypes. Contiguity enforcement and the reduced kernel ensured prototypes reflected sparse, biomarker-aligned selection rather than implicitly broad coverage.

Conclusion

Adding a frequency stream and tightening time-series prototype selection improve the clinical alignment of prototype-based EEG explanations at comparable classification performance. Future priorities include hierarchical time-frequency embeddings, integration of multi-channel spatial information, and nested cross-validation on larger multi-site datasets for cross-cohort generalisation.

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A Distance-Independent Magnetic Performance Factor (MPF_z) for MEMS Cantilever B-Field Markers

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Introduction

We present the quantitative evaluation of a MicroElectroMechanical System (MEMS) cantilever resonator with monolithically integrated Neodymium Iron Boron (NdFeB) powder magnets at its tip for compact generation of a time-dependent magnetic field. These MEMS are developed to serve as compact, low-size, low-power B-field markers alternatively to coils-based markers, e.g. for precise robotic manipulator alignment in assembly lines or surgical.
The PowderMEMS process allows the integration of the powder magnets into precisely engineered cavities. By applying a low-amplitude sinusoidal voltage at a predefined frequency to a piezoelectric layer, the cantilever is driven at its mechanical resonance, causing the embedded micromagnets to oscillate in space and resulting in a time-varying magnetic flux density. The hypothesis is that such B-field markers can provide stable, low-power, narrowband field generation and that their performance can be objectively quantified using a distance-independent metric.

Methods

This miniaturized B-field marker for biomagnetic sensing applications consists of a piezoelectric cantilever carrying a 13×13 array of micromagnets (magnetic dipole moment ≈ 140 µAm²), which was driven at mechanical resonance (1.34 kHz). The resulting magnetic flux density was measured inside a magnetically shielded room (BMSR-2.1) using a 304-channel Superconducting QUantum Interference Device (SQUID) system for evaluation purposes. A Magnetic Performance Factor ($MPF_z = b_z \cdot d^3$) was introduced to enable device comparison independent of sensor distance, thereby relating device design aspects to measurements.

Results

At 88 mm source-detector-distance, a B-field marker prototype generated a stable amplitude of 240 pT at 750 mV excitation. After an initial 2.7% decay over 2.5 h, the signal stabilized, with a standard deviation of 18 fT. At 228 mm ≈ 10 pT remain detectable. The experimentally derived MPF was 1.54 × lower than theoretical dipole estimates, indicating model–experiment deviations. Prototypes with reduced displacement angle exhibited proportionally lower MPF_z values.

Conclusion

This study fills the gap in quantitative benchmarking of MEMS-based B-field markers. The introduced MPF provides both a key metric for comparison and a design-oriented figure-of-merit for optimizing magnet moment, geometry, and excitation. The demonstrated stability and narrowband operation enable future integration within a broad field of biomedical applications where coil-based markers are impractical.

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Zarrow: A modular Framework for Clinical Cohort Construction and Machine Learning Benchmarking on Multimodal Medical Datasets

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Introduction

AI model development in clinical research is hindered by a lack of reproducibility, heterogeneous data formats, and a lack of pipelines to construct standardized cohorts. While public datasets like MIMIC provide a valuable data resource, the conversion of the raw relational tables into analysis ready datasets results in error-prone and time-consuming pipeline redevelopments. The extension of datasets to integrate new modalities like waveforms, ECG, X-ray, or text notes further increases the complexity of this process.

Methods

We present a modular Python framework for standardized reproducible clinical cohort construction and machine learning dataset building. The framework allows for flexible cohort definition through composable filtering operations. It supports scalable processing and downloading through chunk data loading, and efficient storage through Zarr format for large scale datasets. The framework is designed to process multiple data modalities including static tabular data and time-series. For multimodal data integration, the framework avoids unnecessary full dataset re-downloads by allowing incremental data access and reusing the previously constructed clinical cohorts.

Results

We demonstrate the framework's use on MIMIC-IV by building a cohort of patients with acute myocardial infarction based on ICD codes. From this cohort, a downstream dataset is derived, integrating demographic variables, laboratory measurements, and defining 28-day mortality endpoint based on admission and death timestamps. The resulting pipeline fully automates the process getting from raw data to a dataset which can be plugged into machine learning and deep learning frameworks.

Conclusion

This work provides an extensible framework to standardize clinical data processing across multiple datasets for machine learning workflows. By reducing the implementation overhead, the framework eases faster and more reliable implementation of machine learning models in healthcare. Our first demonstration focused on demographic variables and laboratory measurements. Future works direct at multimodal, i.e. signals' and images', integration and representation learning approaches.

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Investigations on Phasor Analysis for Classification of Skin Using Hyperspectral Imaging

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Introduction

For the examination of skin tissue, skin tissue perfusion indices, and dermatological conditions, precise classification of skin type and melanin content is essential for accurate interpretation of results. Several studies have demonstrated that melanin content significantly affects these outcomes. Skin classification can be performed using RGB images by applying the Individual Topology Angle (ITA). The results derived from RGB bands for the ITA are influenced by the specific imaging device and the hyperspectral bands used to generate the images. Calculating ITA from Hyperspectral Imaging (HSI) data often neglects a substantial portion of the spectral information. Phasor analysis, a well-established method for fluorescence data interpretation, was examined to derive a measure based on the complete spectral dataset, rather than just a select few bands.

Methods

The application of Phasor analysis was evaluated utilising HSI measurements obtained from double-layered skin-mimicking optical tissue phantoms composed of agarose, blood, and synthetic melanin at varying concentrations to simulate different skin types. Additionally, data from human volunteers with diverse skin tones were incorporated. Phasor coordinates for the entire spectra were determined by applying a discrete Fourier transform to the spectra and by directly transforming the spectral data to calculate the sine and cosine components of the Phasor coordinates. Phasor values were compared with ITA and other data extracted from HSI investigations.

Results

The spectral phasor analysis demonstrated robust validity across both synthetic tissue phantoms and human skin measurements. The selected melanin concentrations (0.002–0.02%) realistically represent the physiological range of human skin, confirmed by the overlap and matching spectral shape between phantom and volunteer measurements.
The observed logarithmic behaviour of the phasor components aligns with the Lambert-Beer law, with melanin's preferential absorption of short wavelengths (blue/green) producing a spectral redshift that accounts for the characteristic saturation curves in the polar representation. A significant linear correlation with the established ITA reference method further confirms the practical applicability of the phasor parameters as an objective measure of skin tone. The dominant role of the sine component (s-component) over the cosine component (g-component) in capturing spectral variance reflects the underlying physical properties of the system rather than a methodological limitation.

Conclusion

Phasor analysis demonstrates significant potential and stability for examining and investigating skin tissue. Furthermore, it may serve as an intermediate parameter for extracting specific skin properties. Spectral and Phasor analysis results also demonstrated that the double-layered skin-mimicking phantoms can serve as potential calibration phantoms for extracting melanin content. Future analysis will further investigate the effects of skin tissue perfusion, blood content and oxygenation in relation to melanin content.

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Low-Latency Multi-DOF BCI Control of a MEG-Compatible Pneumatic Hand Exoskeleton

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Introduction

Brain–computer interface (BCI)-controlled exoskeletons are promising tools to trigger motor recovery after stroke or spinal cord injuries. However, BCI control based on electroencephalography (EEG) – the most accessible approach to measure brain activity – provides limited decoding accuracy. In contrast, optically pumped magnetometer (OPM)-based magnetoencephalography (MEG) can achieve higher spatial resolution and decoding accuracies. Yet, to date, there is no integrated system available for OPM-MEG-based BCI control of a multi-degree-of-freedom, magnetically inert hand exoskeleton. Here, we established such a system and demonstrated its robust application.

Methods

An FDA-approved, commercially available exoskeleton hand control system (Syrebo SY-BR09AE, Siyi Intelligent Technology) was used and linked to a custom-made Python-based software. The exoskeleton supports independent single-finger actuation and the execution of predefined hand poses through programmatic access to the exoskeleton control unit. The software simplifies Bluetooth Low Energy (BLE) communication with the control unit by abstracting low-level operations (e.g., binary command encoding) into high-level commands, enabling faster and more interpretable control. Its architecture is modular, with a defined API that separates hardware-specific communication from control logic, thereby enabling interoperability with the BeamBCI framework – an open-source multipurpose BCI software.

Results

The exoskeleton control module enables low-latency BLE control of the pneumatic exoskeleton worn by a BCI user inside a magnetically shielded room (MSR) under MEG-compatible conditions. It allows execution of a wide range of hand configurations with independent single-finger control, making it suitable for rehabilitative applications.

Conclusion

This work addresses a gap in MEG-compatible BCI development by introducing a suitable pneumatic exoskeleton and implementing a software interface that enables low-latency, multi-degree-of-freedom motor feedback, thereby advancing clinical MEG-BCI pipelines. Given its high spatial and temporal resolution, OPM-MEG has strong potential to enable finer-grained motor rehabilitation. Future work will prioritize open-source dissemination and clinical validation of the OPM-based MEG-BCI system across patient cohorts.

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Conductive Filaments as Freely Formable Heating Elements

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Introduction

Thermic research in clinical applications, such as skin or chronic wound assessment, lacks sufficient high-quality thermal image data for machine learning. Thermal models offer a cost-effective solution by enabling easy data generation. For this, 3D-printable conductive filaments could provide flexible heating elements. This work presents initial attempts to create and analyze them regarding electrical and thermal properties.

Methods

A conductive TPU filament (FilaFlex Conductive) was used to 3D-print bulk and planar specimens. Electrical contacts were implemented via embedded brass threads or conductive copper and fabric tapes. Impedance was measured over 20 Hz to 2 MHz using an LCR meter, and DC resistance was approximated. Thermal behavior was assessed by applying 24 V and recording infrared images over 5 minutes to evaluate heating performance and homogeneity.

Results

The conductive filament shows a stable resistance of ~400 Ω across a wide frequency range. Under applied voltage, heating occurs but is non-uniform, with higher temperatures at the ends (≈37.1 °C) than the center (≈33.8 °C). Tape-based contacts significantly influence performance: red tape exhibits high resistance (~2.2 kΩ), while black (~680 Ω) and gray (~500 Ω) tapes perform better. However, all configurations show non-uniform heating, with strong temperature gradients near contacts. Gray tape provides the most balanced thermal distribution, though inhomogeneities remain.

Conclusion

This study investigated a conductive filament regarding its electrical and thermal behavior and evaluated different connection strategies using brass threads and conductive tapes. While the filament shows promising intrinsic properties, all tested contact methods suffer from high contact resistance, leading to non-uniform heating dominated by interface losses. Among them, gray tape performed best with the lowest impedance and most homogeneous heating. Improved electrical contact design is required to enable its use as freely formable heating elements for thermal models and potentially therapeutic use.

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Lower Limb Morphological Analysis for Sleep Posture Estimation using 3D LiDAR

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Introduction

Accurate sleep posture estimation can be achieved using 3D LiDAR by focusing exclusively on lower-limb morphology, as leg orientation provides significant discriminative features. This targeted approach reduces computational overhead while strengthening privacy by eliminating the need for full-body point cloud reconstruction.

Methods

This study investigates classification of four important sleeping postures (supine, prone, right lateral, and left lateral) by isolating lower-limb morphology. Spatial data are recorded from subjects (N=15) using Light Detection and Ranging (LiDAR) sensor, with the preprocessing pipeline involving tilt correction, outlier removal, specific Region of Interest (ROI) selection to isolate the legs and sequential sampling to minimize computational latency. The classification was performed using a PointNet-based framework and validated exclusively through Leave-One-Subject-Out (LOSO) cross-validation to ensure model generalization across different individuals.

Results

Experimental evaluation confirms that lower-limb morphology provides sufficient spatial features for robust posture discrimination, yielding a mean LOSO accuracy of 99.76% across the four classes.

Conclusion

By utilizing the sample size of 1024 points, the model successfully maintained high-fidelity classification while processing a significantly smaller anatomical subset, effectively eliminating the redundancy of full-body point clouds.

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Characterization of Viscosity-Dependent Magnetic Nanoparticle Dynamics Using a Magnetoelastic Surface Acoustic Wave Sensor

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Introduction

Magnetic nanoparticles (MNPs) enable sensitive detection of environmental changes and are widely used for biosensing applications. The AC susceptibility (ACS) of MNP reflects medium properties such as the viscosity. While the dependence of MNP relaxation on viscosity is well established, its characterization using magnetoelastic surface acoustic wave (SAW) sensors has not yet been reported. These compact sensors offer the broadband magnetic sensing required for ACS, and can be operated in an unshielded, uncooled environment.

Methods

The dynamic magnetic response of the investigated superparamagnetic nanoparticles is governed by Brownian relaxation, which depends on the MNP hydrodynamic volume V_H and the viscosity η of the surrounding medium. The characteristic relaxation time is given by:

$$\tau_\mathrm{B} = \frac{3\eta V_\mathrm{H}}{k_\mathrm{B}T},$$

where k_B is the Boltzmann constant and T the temperature. To investigate the viscosity dependence of MNP rotational dynamics, ACS measurements were performed using a magnetoelastic SAW sensor. Frequency sweeps from 40 Hz to 10 kHz were conducted for MNP samples with varying viscosities at a constant excitation field of 100 µT, with the MNP sample positioned 3 mm from the sensor. Measurements were referenced to a paramagnetic Dy_2O_3 sample and fitted using the Cole-Cole model.

Results

Increasing viscosity slowed the rotational relaxation of the MNPs, resulting in a shift of the susceptibility spectrum toward lower frequencies. The characteristic relaxation frequency decreased from approximately 311 Hz in phosphate-buffered saline to around 120 Hz at 30% glycerine at constant MNP concentration, reflecting the strong influence of the surrounding medium on particle dynamics.

Conclusion

This study shows that magnetoelastic SAW sensors resolve viscosity-dependent Brownian relaxation of MNPs and demonstrates the potential for compact, unshielded biosensing. Embedding MNPs in hydrogel matrices could enable future in situ monitoring at surgical interfaces, such as early detection of anastomotic leakage, with ongoing work focusing on functionalized particles for selective biomarker detection.

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Unshielded ACS Measurements of Magnetic Nanoparticles Using a Gradiometric Optically Pumped Magnetometer: A Pilot Study

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Introduction

Magnetic nanoparticles (MNPs) are widely employed in biomedical applications, where their magnetic response provides key information for characterization. AC susceptibility (ACS) measurements probe their dynamic magnetic behavior under low alternating excitation fields (< 100 μT) which enable their characterization in the linear response regime. In this context, Optical Magnetic Gradiometer (OMG) sensors offer high magnetic sensitivity in the low-frequency range, comparable to SQUIDs, while operating without the need for cryogenic cooling, making them attractive for biomedical applications.

Methods

In this pilot study we compared ACS measurements of magnetic nanoparticles using a main gradiometric pickup coil and an OMG sensor. The magnetic response of a 50 μL water-diluted MNP sample (BNF micromod, $d_H = 80nm$, 10 mg/mL iron concentration) was directly transduced by a main gradiometric pickup coil, which is connected in series to a second gradiometer placed in correspondence with the OMG sensor; the MNP response is then sensed by the OMG sensor via flux transformer. A Twinleaf OMG was used in this work with a 1 kHz sampling rate, corresponding to a Nyquist limit of 500 Hz. The amplitude spectral density was evaluated by sweeping the exciting magnetic field from 10 to 50 μT at a fixed exciting frequency of 275 Hz. Considering a one-side band frequency of 10 Hz for the noise estimation, the signal to noise ratio (SNR) for the corresponding peak was calculated as:

$$SNR = 20log_{10}\left(\frac{\sqrt{\hat{S}_{B,f_{exc},MNP}} - \sqrt{\hat{S}_{B,f_{exc},Background}}}{\sum_{f=265}^{285}\frac{\sqrt{\hat{S}_{B,f_{exc},Background}}}{20}}\right)$$

Results

For each measurement the background signal was subtracted from the MNP signal, and by linearly increasing the field the induced signal of MNPs also tends to increase linearly ($R^2 = 0.99$) with a peak of about 100 nT/sqrt(Hz). In the configuration with OMG sensor and flux transformer the SNR at 50 μT and 275 Hz is about 36 dB while for the gradiometric coil configuration without OMG the SNR is much lower and drops to about 1.2 dB.

Conclusion

These preliminary results demonstrate that the use of an OMG sensor combined with a gradiometric sensing coil (flux transformer) significantly enhances the signal from a water-diluted MNP sample. This specific architecture enables low-frequency MNP detection with improved SNR in an unshielded environment. The observed SNR increase of about 35 dB highlights the advantages of ACS measurements with OMG sensors in terms of sensitivity and noise performance.

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Development and Evaluation of a 3D Printed Knee Model for Simulating Partial Meniscus Resection

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Introduction

A novel knee model has been developed to give medical engineering students hands-on experience with medical devices at an early stage in their studies. This simulator enables the training of partial meniscus resection with real endoscopic instruments. The developed knee model was systematically evaluated in a study.

Methods

Based on image data from the Visible Human Male, the modular knee model was manufactured utilising a stereolithography printer. The simulator allows students to perform the most essential steps of a partial meniscus resection. In the study, the test subjects performed an endoscopic examination with a hook probe, surgical removal of the damaged portion of the meniscus using an arthroscopic punch, recovery of the fragments using a grasping forceps, and smoothing of the remaining meniscus with a shaver.

Results

In the study, all ten test subjects from the Bachelor's degree programmes in "Medical Engineering" and "Biomechanics and Engineering" successfully completed the partial meniscus resection procedure on the simulator and subsequently completed a questionnaire comprising eight questions. The mean rating of the workshop was 1.6 (German school grading system). This indicates that the utilisation of the simulator in a workshop is a beneficial method to enhance students' comprehension of fundamental concepts, including the coordination of instruments with only indirect vision in endoscopy and the specific procedure of meniscus partial resection.

Conclusion

This work demonstrates the feasibility of using 3D printing technology to fabricate endoscopy simulators derived from radiological image data. The study demonstrated that the use of endoscopy simulators enhances students' comprehension of the particular challenges encountered by surgeons in the field of endoscopy, with a focus on the coordination of instruments in circumstances where only an indirect view of the surgical site is available. Furthermore, the workshop facilitated an enhanced comprehension of partial meniscus resection.

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Exploratory multimodal assessment of anticipatory gait adaptations during obstacle negotiation for lower-limb assisitive systems

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Introduction

Anticipatory gait adaptations are essential for safe obstacle negotiation. This exploratory study investigated the feasibility of a multimodal approach combining EEG, EMG, and IMU signals during overground walking, with the aim of identifying initial trends in potential markers of anticipatory gait adaptations.

Methods

Eight healthy participants walked along a corridor and stepped over a predefined obstacle during overground walking. A multimodal approach was used to capture neural, muscular, and kinematic aspects of gait. From EEG, changes in oscillatory brain activity were analyzed, with a focus on alpha and beta band activity to assess cortical involvement. From EMG, muscle activation patterns of four selected lower-limb muscles were extracted and compared with respect to activation timing and amplitude. From IMU data, kinematic parameters such as gait symmetry and step variability were derived to characterize movement adaptations. These measures were compared between steady walking and the phase immediately preceding and during obstacle negotiation to identify anticipatory gait adaptations.

Results

EEG showed a reduction in oscillatory power, particularly in the alpha band, prior to the obstacle, indicating increased cortical involvement. EMG revealed stable activation timing with amplitude modulations during approach and crossing, while IMU-based measures indicated increased asymmetry and variability.

Conclusion

Anticipatory gait adaptations were detectable across neural, muscular, and kinematic domains. While each modality provided relevant information, their combination improved robustness and interpretability. The findings highlight the potential of multimodal sensing for early detection of gait adaptations and the development of adaptive control strategies in lower-limb assistive systems. Due to the exploratory nature and small sample size, further studies are required to validate these results.

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Multi-channel SQUID-MEG of cortical population spikes

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Introduction

Multi-channel superconducting quantum interference device (SQUID) magnetoencephalography (MEG) systems with noise levels around 2 fT/√Hz are unable to detect high frequency cortical spiking activity (> 450 Hz) without averaging. In this work, we show the first results of an ultrasensitive multi-channel SQUID-based MEG device capable of detecting spatially resolved measurements of high frequency somatosensory evoked responses (hfSERs) at the single-trial level with an average empty room noise level of approximately 470 aT/√Hz achieved.

Methods

Simulations were performed to estimate the spatial pattern of these hfSERs and verify whether the spatial coverage of the sensor head was sufficient. Novel hexagonal pick-up loops were designed to give an optimal noise performance while adhering to the physical limitations of the ultra-low noise dewar. A SQUID reset was implemented to enable recordings with as high a feedback resistance as possible in our SQUID circuit, negating the noise contribution from the analog to digital converter. MEG recordings were performed with multiple subjects undergoing median nerve stimulation to elicit hfSERs.

Results

First recordings show the sensor head is large enough to detect the both the positive and negative lobes of dipolar field of the hfSERs, confirming the results of our simulations. The device's noise level is also low enough to detect these hfSERs at a single-trial level and they are demonstrated to have topographically different responses. The SQUID reset was also shown to further improve the noise performance in the measurement system.

Conclusion

Through careful design and innovation, we have built an ultrasensitive multi-channel SQUID sensor. This enables spatially resolved single-trial measurements of hfSERs, allowing analysis of the output pathway of neuronal processing at a macroscopic level. While the system was optimised for measuring hfSERs, other cerebral cortex activations can now also be investigated. This represents a leap forward in non-invasive biomagnetic measurements.

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Medical Wearables: From Smartwatches to Smart Patches with Microfluidics and Microneedles

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Introduction

Wearables have evolved from simple activity trackers to networked, intelligent assistive systems that continuously capture biosignals and environmental parameters. In healthcare, they are gaining relevance as they support the implementation of predictive, preventive, personalized and participatory (P4) medicine and can relieve pressure on healthcare systems. This contribution provides an overview of medical wearables, key enabling technologies and their integration into digital healthcare.

Methods

An overview was conducted based on current scientific literature, market analyses and regulatory documents. The focus is on medical wearables classified as certified medical devices, including their sensor technologies, energy supply, communication technologies, AI-supported data analysis and application with a particular focus on smart patches. In addition, recent developments in integrating wearable data into the German electronic patient record (ePA) and German digital health applications (DiGA) are summarized.

Results

Medical wearables include, among others, smart bracelets, smartwatches, hearing aids, continuous glucose monitoring (CGM) systems and smart patches. Advances in sensor technology, energy efficiency, connectivity and artificial intelligence enable increasingly accurate and user-friendly long-term monitoring. Smart patches, typically realized in an adhesive patch form factor, support continuous monitoring via ECG, temperature and biochemical sensing, in some systems they are enhanced by microfluidics and microneedles to access biomarkers in sweat or interstitial fluid. First systems have already obtained regulatory approval. In parallel, digital care pathways are emerging in which wearable data are selectively transferred via approved DiGA into the ePA and are envisioned for research and data-driven care management.

Conclusion

Wearables are becoming an important pillar of individualized healthcare. Key technologies such as multimodal sensing, microfluidics-based smart patches, energy-efficient embedded systems and AI-driven data analysis form the basis for new clinical applications. For widespread adoption, validation of novel measurement principles, interoperable data standards and clear strategies for integrating wearable data into ePA- and DiGA-based care pathways remain major challenges.

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Patient-specific bioresorbable 3D-printed load-bearing continuous fiber-reinforced polymer osteosynthesis implants

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Introduction

This study investigates individualized 3D-printed bioabsorbable load-bearing continuous fiber-reinforced polymer osteosynthesis implants. The literature review addresses existing methods in implant design, material selection and simulation of fracture healing and algorithms optimizing and predicting the mechanical properties of the continuous fiber-reinforced polymer composites (CFRPC) in the additive manufacturing process. Trends in osteosynthesis fixation research indicate that matching the implant stiffness to the elastic modulus of bone improves treatment outcomes and showcase other advantages of fiber-reinforced bioresorbable polymer CFRPC. 3D-printers facilitate the fabrication of highly customized and functionally optimized osteosynthesis implants.

Methods

In this study, an experimental fiber module was used to 3D-print fiber- reinforced PLA-CoPET tensile specimens. To characterize the mechanical properties and fiber-matrix interface of polymer core–sheath fibers and matrix, an analysis via scanning electron microscopy (SEM) and mechanical testing were administered. The processing of experimental data is implemented in Python.

Results

The mean elastic modulus increased from 104 MPa to 504 MPa for CoPET tensile specimens reinforced with 30% PLA/PLGA fibers. The SEM images show the non-reinforced specimens's tensile behavior is ductile, the deposited polymer melt in separate lines break apart during fracture, whereas the heavily reinforced specimens show brittle fracture. The SEM images also show good adhesion of the fibers when overprinted with polymer and the deformations of the single core fibers after 3D-printing and sample preparation. The SEM-based interface evaluation and the single-fiber pull-out approach provide useful qualitative and micromechanical information towards prediction of the load-bearing behavior of the final implant.

Conclusion

he main limitation of this study is that it depicts an early manufacturing stage, using CoPET as a model matrix material. The fiber placement was not optimized. The mechanical characterization was limited to uniaxial tensile loading. For load-bearing absorbable osteosynthesis with high stiffness, additional bending, torsion, fatigue, degradation, and fixation-specific tests are required. Continuous fiber reinforced thermoplastic polymers are promising for additively manufacturing patient-specific bioresorbable 3D-printed load-bearing continuous fiber-reinforced polymer osteosynthesis implants.

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Magnetic Tactile Sensor Glove for High-Resolution Hand Kinematics and Grip Pattern Acquisition

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Introduction

Accurate acquisition of hand kinematics and tactile interaction remains a key challenge in human–machine interfaces, surgical robotics, and digital medicine. Existing glove-based systems rely on optical, inertial, or resistive sensing and are limited by occlusion, drift, or insufficient spatial resolution. We propose an additional magnetic tactile measurement principle supporting existing sensor gloves for enabling high-resolution capture of finger motion and grip-induced deformation patterns.

Methods

The system integrates flexible magnetoresistive sensor arrays into a textile glove. Miniaturized magnetic markers are positioned at anatomical landmarks of the fingers and palm. Contact areas are instrumented to capture deformation-based grip signatures inspired by cylindrical tactile interfaces with spatially distributed sensing. Sensor data are processed in real time to reconstruct joint kinematics, micro-gestures, and force-related deformation patterns.

Results

The approach enables simultaneous acquisition of fine-grained finger kinematics, grip configuration, and spatial interaction patterns. Magnetic sensing allows contact-independent tracking while supporting indirect pressure estimation via deformation mapping. The system design supports thin, flexible, and low-power wearable implementation.

Conclusion

Magnetic tactile sensing provides a robust add-on and potentially also as an alternative to existing glove technologies by combining high sensitivity, occlusion robustness, and ergonomic integration. The proposed concept establishes a foundation for next-generation interfaces in surgery, telemanipulation, rehabilitation, and immersive human–machine interaction.

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Novel method of measuring magnetically induced Forces

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Introduction

MRI-scanners use a strong magnetic field to operate. This field can induce forces and torque on medical devices and patient implants. Those forces can be dangerous for patients under some conditions. In order to guarantee patient safety all medical devices and implants need to be tested and certified before they are allowed to be operated in the magnetic field. Several guidelines and international standards are in place in order to govern and regulate this process. Especially the recommended string method is susceptible to human error and measurement inaccuracies. This paper shows a novel approach to measure such forces and enhance measurement accuracy and repeatability.

Methods

A system was developed which uses a toothed belt and linear bearings in order to move a platform with a test object trough the magnetic field of an MRI-scanner. The system is driven by an electric motor and the required torque is measured. Additionally, the magnetic field of the scanner is measured and then converted to the magnetic field gradient. The magnetically induced force as a function of the magnetic field gradient is then calculated by converting the measured torque into a pulling force on the test object.

Results

The calculated values are in good agreement with values derived from the string measurement method, which is described in the corresponding guidelines. The measurement accuracy and repeatability are as good as or better than with the standard measurement method.

Conclusion

A novel approach to measure magnetically induced force on medical devices and implants was developed. The system minimizes the potential for human error by automating most of the measurement and post processing. All measured data show improved repeatability compared to standardized measurements. The system can achieve a significantly better precision and repeatability compared to the standardized method if low forces are measured.

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Log-polar image mapping for CNN-independent rotation and scale invariant brain tumor classification

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Introduction

Convolutional neural networks (CNNs) are widely used for biomedical image classification tasks such as tumor detection and classification. However, their performance often degrades when test images differ geometrically from the training data, particularly under rotation and scaling. While data augmentation can improve robustness to such variations, it increases training complexity and does not provide an inherently invariant representation.

Methods

We investigated a preprocessing-based approach using a log-polar transformation to improve robustness to rotation and scaling. This transformation maps rotations and scalings in Cartesian space to translations in log-polar space, allowing standard CNNs to better handle such variations without requiring architectural modifications. Multiple architectures, including ResNet50, ResNet101, DenseNet121, EfficientNet-B0, and a compact CNN, were evaluated on the BRISC brain tumor classification dataset. Models were trained with varying levels of rotation and scaling augmentation and tested on both untransformed and systematically transformed data to assess robustness under controlled geometric perturbations.

Results

Across all evaluated architectures, log-polar preprocessing consistently improved robustness to unseen rotational and scaling transformations. Compared with standard training, performance remained more stable as transformation magnitude increased. Combining log-polar preprocessing with data augmentation further enhanced robustness and resulted in near-invariant behavior for some architectures. At the same time, standard models often retained slightly higher accuracy on untransformed test data, indicating a trade-off between robustness and peak performance under ideal conditions.

Conclusion

Log-polar preprocessing provides a simple and effective way to improve geometric robustness while retaining standard CNN architectures. The approach may be particularly attractive in scenarios where robustness to geometric variation is important and lightweight models are desirable, for example in edge-AI applications. However, its effectiveness depends on accurate image centering and should be further evaluated on additional datasets, architectures, and transformation types.

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Fusion of Multimodal Unobtrusive Vital Signs for Detection of Atrial Fibrillation

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Introduction

Atrial Fibrillation (AF) is the most common cardiac arrhythmia. In contrast to contact-based ECG, unobtrusive monitoring techniques enable at-home and long-term monitoring but are more susceptible to noise and motion artifacts. Thus, they are often measured using multimodal setups and combined via signal fusion to increase reliability.

Methods

Data were recorded in a clinical study during rest in a supine position using a mattress-integrated sensor system, comprising one capacitive ECG (cECG), two ballistocardiography (BCG), and a reflective PPG (rPPG) with two NIR wavelengths. A total of 40 geriatric patients (18 permanent AF, 22 sinus rhythm) were recorded for 30 minutes. Ground truth labels were obtained from clinician annotations based on Holter ECG recordings. All unobtrusive signals were bandpass-filtered and segmented into 10 s windows. The proposed network architecture consists of a convolutional layer and residual block for signal specific feature extraction, followed by a shared 2D residual block and convolutional layer for feature level fusion. Finally, one multi-path mamba block with adaptive path weights processes the temporal features which are used by a fully connected layer for the final decision. Subject-wise stratified five-fold cross-validation was conducted and feature ablation were applied to access the signal importance.

Results

The proposed network achieved an F1-score of 0.76±0.08 and an AUROC of 0.88±0.05, which indicates an overall robust prediction performance. Analysis of the input signal impact revealed normalized feature importance of 0.21±0.11 for the cECG, 0.20±0.08 and 0.23±0.10 for PPG1 and PPG2, and 0.17±0.07 and 0.19±0.058 for BCG1 and BCG2.

Conclusion

In this work, multimodal unobtrusive signals from a mattress-integrated sensor system were fused using a Mamba architecture for AF detection in geriatric patients. Signal importance analysis revealed highest contribution of the PPG2, followed by cECG, PPG1, and both BCG signals.

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Electrospun SLIPS Coatings for Controlled Local Drug Release on Implant Surfaces

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Introduction

Implant-associated inflammation and bacterial colonization remain major challenges limiting the long-term performance of medical devices. Local drug delivery from implant surfaces offers a promising strategy to enhance therapeutic efficacy while minimizing systemic side effects. Slippery liquid-infused porous surfaces (SLIPS), particularly when combined with electrospun fiber mats, provide a multifunctional platform enabling both anti-adhesive properties and tunable drug release.

Methods

Electrospun polycaprolactone (PCL) fiber mats were fabricated and infused with silicone oil (20 cSt, 350 cSt) to generate SLIPS coatings. Model drugs (dexamethasone and ciprofloxacin) were loaded with two strategies: incorporation into the polymer matrix and dispersion within the lubricant phase. Surface properties were characterized via contact and sliding angle measurements, while morphology and drug distribution were analyzed using scanning electron microscopy and Raman spectroscopy. Drug release profiles were quantified under physiological conditions using UV–Vis spectroscopy.

Results

Electrospun PCL fiber mats exhibited homogeneous, bead-free morphologies with fiber diameters ranging from ~1-4 µm depending on drug incorporation. All samples formed stable SLIPS with non-wetting behavior (contact angles >90°) and sliding angles between 15° and 25°, slightly increasing with lubricant viscosity. Polymer matrix-loaded systems showed sustained and homogeneous drug release over 24–72 h without pronounced burst effects and only minor differences between fiber architectures. In contrast, lubricant-loaded systems exhibited a strong initial burst release within the first hours followed by reduced release rates. Increasing lubricant viscosity consistently decreased cumulative drug release across all systems, indicating an additional diffusion barrier. Raman spectroscopy confirmed homogeneous drug distribution in matrix-loaded fibers, whereas lubricant-loaded systems showed higher spatial variability.

Conclusion

Electrospun SLIPS coatings enable precise control over drug release behavior through modulation of loading strategy and lubricant properties. Polymer-based loading is suitable for sustained delivery, whereas lubricant-based loading supports rapid initial release. This versatility highlights the potential of SLIPS coatings as multifunctional implant surfaces for tailored local therapies.

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A concept for waste reduction and more sustainable medical device design

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Introduction

The amount of medical waste has increased dramatically due to the widespread adoption of single-use devices. Nowadays, a new type of healthcare waste is spreading: single-use electronic devices. Several devices are contaminated after use, and the standard treatment is thermal recycling. But in times of material shortages and rising environmental challenges, new solutions for this problem have to be discussed. In this paper, we introduce a concept to transform this contaminated waste into an attractive business of reuse and recycling.

Methods

The current situation regarding the increase in single-use devices and their classification in waste groups was researched. Upcoming EU regulations and their requirements as part of the new European circular economy action plan were compared with those. A concept for a circular approach to contaminated valuable waste was developed and described.

Results

Based on the concept of waste management, some recommendations for sustainable implementation in healthcare facilities were given. The first step is to embed it into the healthcare facility's philosophy. Besides the technical challenges, standardized processes are needed, as well as structured cooperation with specialized partners from the recycling industry. Inuitiv-to-use solutions have to be implemented in the facilities, and staff have to be trained and motivated. A key role can lie with a new kind of in-house recycling service providers. They could offer a waste collection service, including a change in waste classification to allow safe handling in recycling or repossessing. To allow successful circular approaches, the product design should be adapted.

Conclusion

Sustainability will be required in the future due to several regulations. We have to think about new designs now. A financial burden is the best driver to realize a sustainable product. If all partners save money and the product remains safe and performant, we can realize more sustainable products.

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Laprasense - a simple tool to acquire sensor data from medical instruments

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Introduction

Future applications, such as artificial intelligence in healthcare, especially in surgery, are based on data. Therefore, cost-effective, easy-to-integrate sensor concepts are needed to collect this data. Vibroacoustic sensing provided by SURAG Medical has already shown promising results as an attachable sensor technology for multiple applications, including needle punctures, intravascular interventions, robotic surgery and arthroscopic palpation. To attach sensors to a broad range of medical instruments, distinct adapter solutions must be designed. Some medical instruments, like Laparoscopic tools, already have connectors, for example, for cables for electrosurgery. The Laprasense concept utilises these connectors for sensor integration.

Methods

A new cable-based sensor was developed and integrated into a distinguished housing and adapter concept. Thus, the sensor can easily be connected to a standard 4mm monopolar electrosurgery pin. The system was tested under lab conditions on a piece of porcine muscle tissue. Therefore, first, the tissue was palpated and tapped to simulate soft interactions. Then, electrosurgical cutting and coagulation interactions were performed. All vibroacustic data were stored for evaluation.

Results

We developed the Laprasense concept. It integrates a vibroacoustic sensor into an adapter that can be connected to the monopolar electrosurgery pin of laparoscopic instruments. With this setup, even subtle interactions during palpation along tissue fibres are detectable in the vibroacoustic signal. During electrosurgical interactions, the dynamics of the cooking process at the instrument tip are detectable. Differences in cutting and coagulation mode are measurable. The signal transmission is not disturbed by the generated high-frequency power.

Conclusion

The Laprasense system was tested in an initial lab study and demonstrated superior sensitivity and high resistance to interference in electrosurgical applications. Already, the data from these initial experiments show clearly identifiable events without any post-processing. The recorded data stream is rich in information that can be explored in depth through advanced signal processing.

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Influence of Electropolishing Electrolytes and Post-Processing Cleaning on the In Vitro Cytotoxicity of Cobalt–Chromium and Titanium Alloys

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Introduction

Surface treatment of metallic medical implants plays a critical role in determining their performance, longevity, and interaction with surrounding biological tissues by governing surface properties. Electrochemical processes such as electropolishing can introduce variability depending on electrolyte composition and post-processing cleaning, potentially affecting biocompatibility. Therefore, systematic evaluation of these parameters is essential to ensure clinically safe implant surfaces.

Methods

In this study, cobalt–chromium (CoCr) and titanium (Ti) samples were subjected to a two-step surface treatment consisting of grinding and electropolishing using different alloy-specific electrolytes, followed by defined cleaning procedures. The influence of electrolyte selection and post-processing cleaning on cytotoxicity was investigated using standardized in vitro methods.
Extracts were prepared according to established protocols and evaluated using XTT assays on human (MRC-5) and murine (L-929) fibroblast cell lines. Cell morphology and viability were additionally assessed via light microscopy. Controls included stainless steel as a negative control and copper as a positive control.

Results

All samples remained below the cytotoxicity threshold defined by ISO 10993-5, indicating overall biocompatibility of the applied surface treatments. However, CoCr samples processed with one electrolyte exhibited borderline cytotoxicity in human MRC-5 cells, which was significantly reduced after an additional rigorous cleaning step. In contrast, murine L-929 cells showed lower sensitivity and no comparable effect. These findings demonstrate that cytotoxic responses depend on both electrolyte composition and post-processing cleaning, as well as the selected cell model.

Conclusion

Overall, the results highlight the necessity of case-specific evaluation of electropolishing parameters and cleaning procedures. The study emphasizes that standardized post-processing may not always be sufficient and that both process chemistry and cleaning effectiveness must be considered when assessing the biocompatibility of implant materials.

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From Brainwaves to Soundwaves: A Modular hdEEG Framework for Multichannel Phase-Targeted Acoustic Stimulation

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Introduction

Slow waves in deep sleep support memory consolidation and metabolic waste clearance, making them a promising target for intervention. Phase-targeted acoustic stimulation (PTAS) modulates slow-wave activity by delivering brief auditory stimuli locked to specific phases of ongoing slow oscillations, but current real-time implementations typically rely on a single frontal detection electrode and therefore ignore the spatially diverse, sometimes local nature of slow waves.

Methods

This work presents a modular stimulation framework that uses high-density electronecephalogram (hdEEG) as input and therefore supports phase-specific auditory stimulation based on detection electrodes in different regions. It supports multiple EEG devices and freely configurable data processing and stimulation protocols. For illustration and to test fesability one example processing protocol was implemented. Additionally, based on the established amplitude threshold (AT) approach a new multichannel compatible phase estimation method was developed iteratively by substituting the fixed with a moving threshold to account for interscalp amplitude differences. The methods were backtested on a public sleep hdEEG dataset and their performance considering stimulation count, accuracy and precision was anlyzed.

Results

Results show that the multichannel PTAS system runs effectively and is feasible for future studies. The phase estimation method with a dynamically adjusting threshold is promising and can give a much more even stimulation count across the scalp than those with a fixed threshold. The accuracy and precision however hold potential for improvement.

Conclusion

Overall, this work lays the technical foundation for future research about nature and functionality of location dependent slow waves.

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Liquid Gallium-Based, Ultra-Soft PEDOT:BF4-Coated Ultra-soft Multielectrode Arrays for Neural Implantation and In Vivo Neural Recording

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Introduction

Implantable microelectrode arrays are crucial tools in neuroscience to study neural functions as well as disorders like Parkinson's disease, epilepsy, and spinal cord injuries. Despite advancements in neuro-device technology, challenges persist with rigid-metal-based arrays. These devices often cause mechanical mismatches with brain tissue, leading to chronic inflammation, tissue damage, and compromised performance. There is increasing interest in developing flexible electrodes to mitigate these issues.

Methods

Our approach to bridging the mechanical mismatch gap involves utilizing gallium-based electrodes for flexible neural implants. Gallium-based materials offer several advantages, including soft mechanical properties, minimal cytotoxicity, and excellent electrical conductivity. Gallium electrodes are initially rigid for implantation but phase into a liquid state post-insertion due to their low melting point, reducing the mechanical mismatch with neural tissue. We electrochemically deposited conductive polymer poly(3,4-ethylenedioxythiophene), PEDOT, doped with tetrafluoroborate (BF4) to contain the liquid gallium, preserve its electrochemical properties, and enhance the device biocompatibility. PEDOT: BF4 demonstrates excellent electrochemical and thermochemical performance, low impedance, and good biocompatibility.

Results

This study presents a liquid-metal-based, ultra-soft, PEDOT: BF4-coated multielectrode array for in vivo applications. Our findings indicate that these gallium-based, PEDOT: BF4-coated multielectrode arrays have improved electrochemical performance over metal-based arrays and can successfully record LFP and neural signals in a live rat. We extensively characterize the material properties, electrochemical properties, thermal stability, and morphology of PEDOT:BF4-coated gallium electrodes, demonstrating their structural integrity and long-term electrochemical stability over a 5-week in vitro study. Acute in vitro and in vivo experiments to validate the neural signal recording capabilities of our multielectrode array.

Conclusion

Our research marks a significant advancement in the development of soft implantable neuro-electronics. Future work will optimize electrode density, explore advanced fabrication techniques, and assess long-term functionality to enhance device efficacy and biocompatibility. Flexible gallium-based neuro-electronics show strong promise for advancing both research and clinical applications in neuroscience.

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Coronary artery distensibility after stent implantation – an *in vitro* mock artery study based on optical coherence tomography

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Introduction

Atherosclerosis as well as stent implantation alter the elastic properties of the blood vessel, leading to localized stiffening of the arterial segment. Quantitative description of the radial distensibility is crucial for adequate modelling during simulation as well as in *in vitro* experiments. The primary objective was to determine radial distensibility of silicone mock arteries in both unstented and stented configurations to derive an appropriate model describing the distensibility reduction induced by stent implantation.

Material and methods

An artificial mock artery (Dynatek Labs, USA) with an inner diameter of 2.8 mm mimicking the elastic properties of a coronary artery was stepwise pressurized with the help of a centrifugal pump (BPS-i30, Levitronix, Switzerland) and controlled by a pressure sensor (86A, Measurement Specialities, USA). At every pressure step between 60 mmHg and 160 mmHg (Δp = 20 mmHg) an intravascular optical coherence tomography (IV-OCT, ILUMIEN Optis, Abbott Medical, USA) measurement was performed to derive the luminal diameter. To model the coronary artery after ingrowth of a stent into the arterial wall, a commercially available stent (3.0/20 mm) was expanded and positioned outside the mock artery. Subsequently, the IV-OCT measurements were repeated. Diameter based relative distensibility was calculated according to ASTM F2744-24.

Results

Diameter change with increasing intra-arterial pressure revealed an almost linear behavior for the mock vessel only resulting in a distensibility of 5.0±0.2 %/100 mmHg. The mock vessel with stent showed only minor diameter changes, resulting in a much smaller distensibility of 0.8±0.4 %/100 mmHg.

Conclusion

Distensibility for the mock artery only was in good agreement with the manufacturers technical data (5-7 %/100 mmHg). Test results of the mock vessel with surrounding stent were in good agreement with previous results of our group dealing with porcine arteries four years after implantation of a permanent drug eluting stent (0.8±0.2 %/100 mmHg). In conclusion, positioning the stent outside the mock artery seems to be a good approach when simulating the ingrowth of the stent after implantation.

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EIT reconstruction parameters' impact on ventilation monitoring features

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Introduction

Electrical Impedance Tomography (EIT) enables continuous, non-invasive, real-time monitoring of pulmonary ventilation at the bedside, making it valuable for patients undergoing mechanical ventilation, where inhomogeneous ventilation distribution can contribute to ventilator-induced lung injury. EIT image reconstruction requires solving an ill-posed inverse problem governed by several algorithmic parameters. These involve regularisation type, noise thresholding, and mesh resolution, whose influence on clinically derived ventilation features, such as the Global Inhomogeneity index (GI), Centre of Ventilation (CoV) and regional ventilation delay (RVD), remain poorly characterised. This study systematically investigates how the reconstruction parameters of the GREIT algorithm, as implemented in the pyEIT framework, affect the ventilation monitoring features extracted from thoracic recordings.

Methods

Thoracic EIT recordings were acquired from 31 adult subjects using a Dräger PulmoVista 500 system with 16 electrodes, during volume-controlled mechanical ventilation. A maximal low flow manoeuvre (MAX-LFM, corresponding to the application of four litres per minute during inhalation, while keeping the exhalation spontaneous) was performed, and the inspiratory phase was retained for analysis. Five GREIT reconstruction parameters (*lamb, p, perm, s* and *ratio*) were each independently modulated at three perturbation levels ($\pm 10\%, \pm 25\%, \pm 50\%$) from the pyEIT v.,1.2.4 default baseline, yielding 31 reconstruction configurations. For each configuration, 19 functional ventilation features were extracted from the resulting image sequences, including statistical descriptors of RVD and fROI geometry, as well as impedance-based indices (GI, CoV). Parameter sensitivity was quantified using a normalised influence score combining effect magnitude and cross-record sign consistency via their product.

Results

The *ratio* parameter dominated all others by a wide margin, achieving a total influence score of 16.43, which is more than four times that of the next ranked parameter, *s* (3.64). The remaining three parameters (*lamb, p, perm*) showed comparatively lower influence scores. The parameters *lamb* and *perm* produced numerically identical results across all conditions, indicating that they modulate the reconstruction matrix through the same computational pathway, an implementation-specific consequence of Jacobian normalisation under a homogeneous background model in pyEIT. The magnitude of feature modulation scaled monotonically with the degree of parameter perturbation across all five parameters, confirmed by Spearman's rank correlations exceeding $|r| = 0.9$ for most feature-direction combinations.

Conclusion

These findings demonstrate that GREIT reconstruction parameters differ in the degree to which they influence EIT-derived features, with the *ratio* parameter exerting by far the strongest effect. The redundancy between *lamb* and *perm* suggests an underlying structural overlap in their roles within the reconstruction matrix computation. These results highlight the critical importance of standardising reconstruction settings, particularly the ratio parameter, prior to any fROI-dependent feature extraction, and suggest that reconstruction configurations should be explicitly reported in clinical and research applications of EIT-based ventilation monitoring.

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Assessing Single-trial performance of OPMs towards a Closed Loop Brain-Computer Interface

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Introduction

Neural oscillations in the alpha range (~8-12 Hz) have been studied for over 100 years but are still not fully understood. They are the dominant rhythm in the human brain but absent in common animal models such as rodents. Most research therefore relies on correlational analyses, relating spontaneous alpha phase and amplitude to stimulus processing and behavior - an approach prone to spurious associations and reduced statistical power.
Closed-loop brain-computer interfaces (BCIs) offer progression from correlational to experimental approaches, enabling direct targeting of specific phases and amplitudes, allowing causal inference, but requiring high single-target signal-to-noise ratios (SNR). We therefore assessed whether novel neuroimaging sensors, optically pumped magnetometers (OPM) improve single-trial performance critical for BCI development.

Methods

An auditory steady-state paradigm was applied in 23 healthy participants, where 100 trials of 1s 40 Hz amplitude modulated tones were presented. Neural activity was recorded using parallel EEG-OPM measurements using a combined cap featuring 54 EEG electrodes and 10 OPM sensors in a magnetically shielded room. The data was filtered between 5 and 60 Hz, and a spatial filter based on canonical correlation was applied, maximizing the covariance between single trials and the trial average for each participant and condition. SNR was calculated as the ratio between maximum power at 40 Hz and average power between 20 and 38 as well as 42 and 48 Hz.

Results

We showed that SNRs of OPMs significantly exceeded those of EEG recordings in total ($F(1,20) = 22.65$, $p < .001$) with significant post-hoc tests even on the single-trial level ($p = .044$).

Conclusion

OPMs are strong candidates for closed-loop BCIs incorporating state-dependent stimulation. As a next step, a BCI will be implemented using a HEDscan system (FieldLine) and a pipeline to deliver stimuli with relative timing to the individual alpha cycle will be developed.

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Can Intraoperative Therapeutic Window Data Predict Chronic Contact Selection in Deep Brain Stimulation?

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Introduction

Deep brain stimulation (DBS) programming relies on selecting electrode contacts that maximize clinical benefit while minimizing side effects. The therapeutic window (range of current yielding symptom improvement without adverse effects) is a key criterion in this decision, yet its quantitative role in clinical contact selection remains underexplored. This study investigated the influence of the therapeutic window recorded intraoperatively (ITW) on chronic contact selection and evaluated its predictive value for DBS programming.

Methods

Intraoperative stimulation test data from 37 Parkinson's Disease patients were analyzed to com-pute ITW at multiple positions along the implantation trajectory. These positions were mapped to chronic electrode contacts, which were labeled as chronically chosen or not chosen. The relationship between ITW and contact selection was assessed using ranking analyses, nonparametric comparisons, and a Bayesian hierarchical logistic regression model. Predictive performance was evaluated using leave-one-out cross-validation.

Results

Clinically chosen contacts exhibited significantly larger ITWs than non-chosen contacts. ITW was a significant determinant of contact selection but explained only a limited proportion of variance (~10%). Prediction of chronic contact selection based on ITW showed moderate predictive performance (Area Under the Receiver Operating Characteristic Curve ROC-AUC = 0.73, Area Under the Precision–Recall Curve PR-AUC = 0.61).

Conclusion

These findings demonstrate that ITW significantly contributes to clinicians' programming decisions and may serve as useful component of automated contact selection frameworks. At the same time, the low explained variance indicates that ITW is insufficient as a standalone, reliable chronic contact predictor and should be combined with other biomarkers.

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Laminar Airflow and Temperature Controlled Airflow ventilation in operating rooms compared “At Rest”

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Introduction

Infection control in an operating room requires management of microbial burden in the air. Especially during surgeries susceptible to infections, such as orthopedic surgery, a controlled clean environment is essential to prevent SSIs. One system that is currently of great interest, particularly in Europe, is temperature-controlled airflow technology (TcAF). To measure and compare the effectiveness of the two ventilation systems, experimental measurements were carried out with particles “at rest”.

Methods

The study evaluated Laminar Airflow (LAF) and Temperature-controlled Airflow (TcAF) ventilation systems under standardized “at rest” operating-room conditions using two particle-based measurement methods. An uncontrolled multisource contamination setup and a controlled single-source setup were used to assess particle distribution, recovery time, and protection index throughout the operating room. Particle counters were placed in both the protected zone and periphery to capture differences in airflow behavior and contamination removal.

Results

Both systems effectively maintained cleanliness in the protected surgical zone, although TcAF demonstrated superior performance in the peripheral areas. Compared with LAF, TcAF achieved higher protection indices and reduced contamination nearly twice as fast in the periphery. TcAF reduced airborne contamination more effectively in peripheral areas and demonstrated more robust airflow unaffected by obstacles.

Conclusion

The findings confirm that while both ventilation systems sufficiently protect the sterile field, TcAF provides markedly better contamination control in the overall operating room. Its faster recovery times and higher periphery protection indicate a more effective whole-room ventilation strategy. Therefore, TcAF offers significant advantages for ensuring a safer surgical environment by minimizing airborne contamination throughout the entire operating theater.

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Blood Coagulation Monitoring by Magnetic Particle Spectroscopy

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Introduction

The sensitivity of Magnetic Particle Spectroscopy (MPS) to the nanoparticle's environment offers a promising approach for continuous blood coagulation assessment, with the potential to complement established point-of-care methods like activated clotting time in cardiovascular medicine. With the anticipated magnetic particle imaging (MPI)-guided interventional procedures, MPS-based coagulation monitoring could enable integrated analyses using the same contrast agent already present for imaging. This would provide additional assessment capabilities, particularly in clinical settings where current coagulation monitoring methods represent the established standard of care.

Methods

A compact MPS system was used to assess the feasibility of continuous coagulation monitoring. The device operates at a frequency of 25 kHz with an excitation amplitude of 20 mT, providing measurements every 15 seconds. Blood samples (475 µL) from five healthy volunteers were mixed with Resotran® (25 µL) at concentrations matching clinical bolus applications and underwent continuous MPS monitoring for 45 minutes. Signal analysis focused on fifth-harmonic amplitude trajectories, combined with temperature monitoring. Validation experiments included anticoagulant testing (EDTA, Heparin, Citrate) and mechanical stress assessment to confirm coagulation-specific signal changes.

Results

The system demonstrated robust performance achieving signal-to-noise ratios of over 255 compared to the mean background signal. Coagulating blood samples exhibited inverted sigmoidal signal decay to 62.1% ± 2.0% of the initial amplitude, enabling the assessment of quantitative coagulation kinetics. Anticoagulated samples exhibited a substantial decrease in total signal variation (ranging from 0.01 to 0.21 µAm² versus 0.44 ± 0.06 µAm² for untreated samples), thereby substantiating the coagulation-specific detection. Temperature effects were evident, with a 5°C temperature reduction in one sample markedly altering coagulation dynamics.

Conclusion

This study demonstrates the feasibility of MPS for continuous coagulation monitoring, thereby creating unique opportunities for integrated diagnostic workflows. In MPI-guided interventions, this would enable automatic real-time coagulation monitoring without additional contrast administration, potentially advancing interventional radiology while broadening MPS applications in bioanalytical diagnostics.

Author statement

Research funding: This work (published in full under DOI: 10.2147/IJN.S561511) was funded by the University of Lübeck (LACS04-2025), the EU and the State Schleswig-Holstein (LPW-E1.1.1/1536, 124 20 002 and LPW21-L/2.2/262, 125 24 009). Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complied with all the relevant national regulations and institutional policies and was performed in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board (approval no. 2024-176_2).

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An Open-Source Framework for Advanced IVOCT Analysis Using Deep Neural Networks

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Introduction

Intravascular optical coherence tomography (IVOCT) is an established imaging modality for the assessment of coronary artery diseases, offering micrometer-scale resolution of vascular microstructure, stent deployment, and plaque composition. However, quantitative interpretation of IVOCT datasets remains challenging, largely due to the limited availability of accessible, flexible, and cost-effective analysis tools. This work presents initial results of an open-source deep learning-based framework for automated IVOCT analysis currently under development.

Methods

An open-source software framework for automated IVOCT analysis based on deep learning integrates convolutional neural network–based segmentation and detection models for lumen boundary delineation, stent strut localization, and plaque characterization. A dedicated convolutional architecture has been designed to improve robustness and precision in stent strut detection. In addition, the framework incorporates an interactive graphical user interface enabling visualization, manual annotation, and automatic analysis, while supporting user integration and fine-tuning of custom models. An annotated IVOCT dataset is also being curated to enable model training, benchmarking, and comparative evaluation.

Results

Preliminary functionality demonstrates the feasibility of automated lumen segmentation, stent strut detection, and plaque characterization with further parameter calculations within a unified software environment. While lumen segmentation showed near-perfect performance, stent strut detection achieved a precision–recall AUC of 0.941 ± 0.015 and a test-set F1-score of 91.6%. Plaque segmentation reached an AUC of 0.983 ± 0.010, with a test-set Dice score of 85.4% and an IoU of 74.6%. The modular design enables interactive exploration of results and allows users to adapt, replace, or integrate custom models.

Conclusion

The proposed open-source framework provides an extensible tool for automated IVOCT analysis. By combining modular deep learning methods with a curated dataset, it supports reproducible evaluation, targeted model refinement, and methodological comparison, facilitating translation into research and clinical workflows.

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Planar Bending of Flexible Instrument Shafts: Modeling and Experimental Validation

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Introduction

The increase in osteoporotic fractures in the complexly shaped pelvis requires innovative, minimally invasive instruments. Conventional instruments often reach their limits when navigating complex bone structures. Flexible, cable-controlled instruments offer great potential for the precise, three-dimensional guidance of implants.

Methods

This paper presents a static model for describing the planar bending of cable-controlled, small-diameter, metallic flexible hollow shafts. For that, the bending behavior of the shafts was studied and implemented using a four-point bending test. In addition to geometric deformation, the model also takes into account friction losses according to the Capstan equation. Validation is carried out on a physical demonstrator.

Results

The experimental investigations confirm the correlation of the trajectories of specific marker points with the model. However, high deviations are found in the calculated bending radii, which increase with increasing shaft stiffness. The simulation underestimates the actual bending radius, which is due to unaccounted torsional couplings, varying bending stiffness, and underestimated friction effects.

Conclusion

The presented model serves as an initial methodological basis for the design of flexible medical instruments in the low stiffness range

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Towards Robotic SPECT for Parathyroid Imaging: A Simulation Framework for Optimizing a Dual Small-Field-of-View Detector Head

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Introduction

Compact handheld gamma cameras enable close-surface freehand single-photon emission computed tomography (fhSPECT), as demonstrated for parathyroid adenoma localization. Operator-driven acquisition however introduces reproducibility concerns. Robotic fhSPECT ensures systematic surface coverage, and extending to a dual-head configuration offers shorter acquisition times or reduced administered activity through complementary angular views per trajectory pass, albeit tighter workspace constraints. Yet the optimal dual-head configuration for this anatomically constrained application has not been studied. We present a simulation framework for evaluating dual small-field-of-view detector head configurations for robotic fhSPECT in parathyroid imaging with 99m-Tc-MIBI, generalizable to other detector configurations and fhSPECT applications.

Methods

Anonymized SPECT/CT data from three patients were used to compare dual small-field-of-view detector head configurations. Personalized robot trajectories were derived from patient CT surfaces, and Monte Carlo-based forward projections were simulated with added Poisson noise. MLEM reconstructions were evaluated to compare nine configurations: a single-head reference, seven fixed dual-head offsets ($\alpha = 0°–60°$ with 10° increments), and an active configuration where dual-heads vary the angular offset while following the trajectory. Submandibular glands and the parathyroid gland were evaluated per patient using centroid error, NCC, SSIM, and relative uptake ratios.

Results

All dual-head configurations outperformed the single-head reference across localization, image similarity, and uptake ratio metrics. Among fixed-offset configurations, $\alpha = 60°$ performed best for submandibular gland reconstruction and uptake ratio accuracy, while smaller offsets better preserved parathyroid localization. The active configuration performed best on the clinically relevant parathyroid target, with the lowest centroid error (1.0 mm), highest NCC (0.88), and lowest Submandibular/Parathyroid uptake ratio error (1.4%).

Conclusion

The active configuration represents the most promising acquisition strategy for robotic fhSPECT in parathyroid imaging. Results represent an upper bound under the matched-model condition, and the three-patient cohort limits generalizability. Phantom validation with the physical system is the next step toward clinical translation.

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Transparency Control for an Orthopedic Knee Exoskeleton Using a Velocity-Based Disturbance Observer

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Introduction

This work addresses the development of a controller for a commercially available orthopedic knee exoskeleton integrated with a brushless DC motor and IMUs to provide transparent motion. The novelty is then defined by the achievement of safe human–robot interaction using a minimal hardware add-on for commercial orthosis, avoiding additional force/torque sensors while ensuring smooth and accurate motion as a fundamental prerequisite for assistance-as-needed control strategies.

Methods

The system is built on a commercial knee brace integrated with a BLDC actuator, two IMUs, and embedded computation units. A velocity-based Disturbance Observer (DOB) is implemented within a ROS2/ros2_control architecture, operating at 800 Hz. Using the motor angular velocity and the motor current I_q, the DOB estimates the friction disturbance and compensates it by producing a torque command. The advantage of the DOB is the model-free algorithm capable of working in real time, adapting beforehand the responsiveness with a tuned low pass filter on the angular velocity signal. A comparative evaluation is performed against a LuGre friction model, calibrated through nonlinear least-squares identification using dedicated velocity excitation profiles.

Results

Experimental validation shows that the DOB achieves more accurate torque estimation in dynamic conditions compared to the LuGre model, with RMSE reduced by 22,7% (0.150 Nm vs 0.194 Nm) and MAE reduced by 31,1% (0.115 Nm vs 0.167 Nm), showing improved dynamic friction estimation and higher responsiveness.

Conclusion

The proposed DOB-based control strategy enables an efficient transparency control for knee exoskeletons using the filtered motor angular velocity to compute a torque command (without external torque sensor). While outperforming a classical LuGre friction model in dynamic scenarios, the method remains limited in quasi-static conditions, where interaction torque cannot be reliably estimated due to the high noise of the motor current signal.

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Beyond Correlation: Causal Brain-Heart Coupling During Sleep Arousals via Convergent Cross Mapping

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Introduction

Sleep arousals are transient transitions from deeper to lighter sleep stages that elicit simultaneous cortical and autonomic responses. While prior studies reported statistical associations between electroencephalogram (EEG) activity and heart rate variability (HRV), the directional causal structure of brain-heart coupling during arousals remains unexplored. In this work, we investigated the direction and temporal dynamics of brain-heart coupling during sleep arousals using bidirectional Convergent Cross Mapping (CCM) which detects directional causal interactions in nonlinear dynamical systems.

Methods

We analyzed polysomnographic recordings from 53 healthy participants of the Montreal Archive of Sleep Studies. From single-channel EEG (Cz) and ECG, we extracted EEG amplitude envelopes for delta (0.5-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), and beta (12-30 Hz) frequency bands, and derived HRV series from R-peak intervals. We extracted event-locked 120-s segments centered on arousal onset and computed bidirectional CCM using 30-s windows with a 1-s step to obtain time-resolved coupling across segments. We validated coupling significance against phase-randomized surrogate thresholds. We defined directional asymmetry as the difference between brain-to-heart and heart-to-brain CCM values and evaluated band-specific changes in directional asymmetry using a linear mixed-effects model.

Results

Brain-to-heart coupling exceeded the surrogate threshold throughout the time steps, while heart-to-brain coupling surpassed it after arousal onset (except in the theta band), with its transient post-onset increase. This increase was most pronounced in the alpha and beta bands. Brain-to-heart coupling dominated across all frequency bands and time steps. Heart-to-brain coupling increased significantly across all EEG bands starting in the pre-arousal period and returned toward baseline post-arousal.

Conclusion

Our findings indicated that while brain-driven control remains dominant, arousals induce a transient increase in heart-to-brain coupling, highlighting the importance of nonlinear, directional methods to studying brain-body interactions.

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Uncovering Sympathetic Activation During Sleep Arousals with Electrodermal Activity

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Introduction

Sleep arousals are brief interruptions in sleep, commonly accompanied by sympathetic activation. These activations have been demonstrated using cardiovascular markers. However, these markers are not specific to sympathetic activation and instead reflect a combination of sympathetic and parasympathetic activity. Electrodermal activity (EDA), a well-established marker of sympathetic activity, offers a more targeted alternative for characterizing sympathetic responses, but has not been explored for sleep arousal analysis. This work investigates whether EDA can capture and characterize sympathetic activation in response to sleep arousals.

Methods

We analyzed wearable EDA recordings from 100 adults from the DREAMT dataset collected during overnight sleep. To identify the sleep-specific dominant EDA frequency for capturing sympathetic fluctuations, we divided the relevant frequency (0.01-0.95 Hz) into 8 bands and selected the dominant bands preceding the steepest relative power decline. With variable-frequency complex demodulation, we decomposed the EDA signal into narrowband components and reconstructed the dominant bands using the Hilbert transform. From the reconstructed signal, we extracted maximum and minimum amplitudes, minimum-maximum amplitude difference, standard deviation of the signal, and peak count. We evaluated feature changes from 10 s before arousal onset to 60 s after arousal end and compared them with control segments from stable sleep. We evaluated temporal dynamics and the influence of arousal duration using linear mixed-effects models, which account for multiple arousals per subject and between-subject variability.

Results

EDA frequency analysis identified the 0.01-0.045 Hz range to be dominant during sleep. Amplitude-based EDA features increased following arousal onset and persisted up to 40 s. Sympathetic responses appeared as clustered burst activity and amplitude amplification. Long arousals (>11 s) elicited statistically significant responses ($p<0.05$), whereas brief arousals (<=11 s) produced no significant changes.

Conclusion

Our findings demonstrate that EDA captures sustained sympathetic response following arousals, offering a selective alternative to cardiovascular markers for investigating autonomic changes during sleep.

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Shape Memory Alloy-Based Mechanism for Locking Wearable Robots

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Introduction

Hand exoskeletons are becoming increasingly important. The literature presents variouse concepts for improving kinematics regarding space requirements, weight, movement trajectory and power potential. However, only a few concepts for saving energy in endurance tasks have been investigated yet. Active locking devices, such as ratchets and locks, show promise. This work examines whether a heart-shaped cam-mechanism combined with shape memory alloys (SMA) is suitable for keeping an exoskeleton in position without any loss of force.

Methods

The research objective is the design and layout of the locking mechanism. Particular attention is paid to the notch geometry, connecting rod and SMA. A prototype is created and experimentally characterised in terms of stroke and maximum blocking torque. An optical analysis is performed to determine the stroke. Blocking torque is determined by increasing the antagonistic load iteratively.

Results

The locking concept employs a spring-loaded bolt engaging with a gear which can be released using a pre-tensioned SMA wire. To keep the bolt in position (open/locked) without supplying energy, a heart-shaped notch is carved into the bolt. A connecting rod, which is attached to the exoskeleton and actuates one finger, engages with this notch. The heart-shaped notch has two stable positions, from which the connecting rod can only be released by a new impulse from the SMA onto the bolt. Characterisation of the prototype shows that the mechanism in the specified configuration (20x10x10 mm^3) can produce a stroke of 2.7 mm and withstand a force of 10 N.

Conclusion

The investigations show that SMA is capable of actuating the mechanism and that the mechanism can generate sufficient stroke to lock/unlock the system. In addition, the obtained torque can be maintained, which corresponds approximately to the driving force of a finger in a power grip. The concept is considered promising and will be optimised and characterised in further work.

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PSG-Based Subtypes of Obstructive Sleep Apnea Identified by Cluster Analysis in the Berlin Cohort of the European Sleep Apnea Database (ESADA)

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Introduction

Obstructive sleep apnea (OSA) is a clinically heterogeneous disorder. Patients with similar disease severity differ in symptoms and nocturnal oxygenation. However, OSA is still primarily classified according to AHI thresholds, which may not fully reflect the diversity of clinical presentations in OSA. In this study, we applied cluster analysis using clinical and PSG variables to explore heterogeneity in OSA.

Methods

Patients with OSA were included in this monocenter observational study. Unsupervised clustering (k-means clustering) based on clinical characteristics and polysomnographic parameters was performed to explore patterns of heterogeneity in OSA.

Results

A total of 248 patients were included in our study. After clustering analysis, three clusters were identified. Cluster 1 (n = 29, 11.7%, Obese hypoxic OSA) showed the highest AHI and oxygen desaturation index (ODI), the lowest mean saturation oxygen（SaO_2）and lowest minimal SaO_2, the highest body mass index (BMI) and Epworth Sleepiness Scale scores (ESS), and the youngest mean age. Cluster 2 (n = 157, 63.3%, Mild OSA) had the lowest AHI and ODI, the highest mean SaO_2, the highest minimal SaO_2, and the lowest ESS. Cluster 3 (n = 62, 25%, Older hypoxic OSA) included predominantly patients with severe OSA and showed high AHI and ODI, reduced oxygenation, intermediate BMI and ESS, and the highest mean age. By conventional AHI severity classification, differences were observed in objective measures of disease severity, whereas ESS did not differ between groups.

Conclusion

Three clusters with differing clinical and polysomnographic characteristics were identified among patients with OSA. These findings may provide additional insight into the heterogeneity of OSA.

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Cross-Site Generalizability of ECG-Derived Biological Age for Cardiovascular Risk Stratification

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Introduction

Biological age reflects the functional state of the heart and can differ from chronological age, providing a useful indicator of cardiovascular health. This difference, estimated from electrocardiogram (ECG) signals as ECG-derived biological age, has emerged as a promising digital biomarker for cardiovascular risk stratification. However, the ability of such models to generalise across hospitals and to leverage complementary clinical context such as electronic health records (EHR) remains unclear.

Methods

This work presents a multi-task convolutional transformer that jointly estimates ECG-age, predicts ICD-coded risk for myocardial infarction (MI), stroke, and heart failure (HF), and computes a mortality hazard score from 12-lead ECG signals combined with temporal ICD histories, an aspect largely unexplored in prior ECG-derived biological age. The model is trained exclusively on Massachusetts General Hospital (MGH) data from the Harvard-Emory ECG Database and evaluated on the complete Emory University Hospital (EUH) cohort (n=998,844) without any domain adaptation.

Results

On this unseen cohort, the model achieves an age prediction mean absolute error of 9.97 years (Pearson r = 0.64), with AUROCs of 0.675 (MI), 0.676 (HF), 0.656 (stroke), and 0.580 (mortality C-index=0.582). Saliency analysis highlights QRS-complex and T-wave regions, consistent with known cardiac ageing patterns. Subgroup analysis shows broadly equitable performance across race and age groups (AUROC range 0.505 - 0.721). A clinical reasoning module translates model outputs into structured risk narratives for patient-level interpretation.

Conclusion

These findings position ECG-derived age and risk prediction as a generalisable digital biomarker for large-scale cardiovascular screening and early risk stratification.

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User-Driven Balance Assistance via Gyroscopic Torque Transformation in a Wearable GyroPack

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Introduction

Degenerative ataxia often impairs balance during standing and walking, increasing fall risk and reducing mobility and quality of life. Existing assistive devices such as walkers can improve safety, but they are often bulky and offer limited dynamic support. To address this limitation, we investigate GyroPack, a lightweight wearable balance-assist device actuated by control moment gyroscopes (CMGs). In contrast to conventional actuation strategies that directly generate corrective torques in the sagittal and coronal planes, this work proposes a human-in-the-loop concept. The device provides a gyroscopically induced cue, and the user's voluntary response to this cue is transformed into stabilizing assistive torques through gyroscopic coupling.

Methods

A model of the human-GyroPack system was developed to describe the coupling between trunk angular motion and gyroscopic torque generation. The key idea is to interpret the device-induced torque as a sensory cue that prompts a voluntary response from the user, which in turn produces rotational motion about the pitch and roll axes through gyroscopic coupling. Based on this principle, we formulated a human adaptation model and a directional torque representation, and analyzed how the gyroscope configuration affects the direction of the assistive torque. As a first conceptual investigation, the presented results are based on model-based analysis and simulation of the human-GyroPack interaction.

Results

The analysis shows that GyroPack does not work as a stand-alone assistive device, but rather as a human-device cooperative interface that can transform a modeled user response into stabilizing torque. The generated torque direction is determined by the gyroscope configuration, while the torque magnitude depends on the user's response amplitude and adaptation behavior in the proposed interaction model. Importantly, the resulting torque remains beneficial for balance as long as the user produces rotational motion in response to the induced cue. This insight also relaxes the requirements on the slow configuration control loop and highlights the potential of shared control between human and device.

Conclusion

The proposed concept suggests a new strategy for balance assistance in wearable gyroscopic devices. In contrast to the conventional CMG actuation mechanism, the GyroPack works as a cross-axis torque transformation interface by converting the user's active motion response into stabilizing torques. These findings provide a theoretical basis for an interactive balance-assist strategy and motivate future validation through human-subject experiments, including studies with people with balance impairments.

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PECSA Net: Pupil Segmentation Using Attention Integrated Encoder based Multi Level Feature Extractor for Analysis of Ocular Dynamics

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Introduction

Pupillometry is considered as an emerging technique for analyzing the dynamical variations of pupil structure non-invasively. Delineation of the pupil region from ocular images plays a crucial role in the prediction of micro expressions and subtle variations during analysis. Occlusions, deformations, and motion artifacts are more prevalent during the capture of micro-ocular expressions and often resulting in a suboptimal pupil mask with minimal structural similarity.

Methods

This proposed study introduces a Swin incorporated modified encoder-decoder paradigm, “PECSA Net” for reliable segmentation of the pupil region. The local features including boundaries and edges, are captured through convolutional layers in PECSA Net. Moreover, the contextual features including the overall spatial relationship within the ocular images, are captured using the deeper layers consist of an attention-enhanced multiscale contextual information module.

Results

The Eexperimental results on CASIA dataset shows that the framework achieves superior performance in occluded conditions compared to conventional neural network-based approaches with a dice score of 0.97. Further the model is validated with a multifaceted eye tracking dataset captured using high speed camera to evaluate the generalization capability achieving a dice score of 0.79. Extensive architecture-based ablation studies are also carried out to identify the significance of each component of PECSA Net. The obtained dice shows a higher structural similarity during validation, underscoring the significance of PECSA Net.

Conclusion

The reliable segmentation of pupil region during extensive evaluation of proposed model on unseen data sets highlights the generalization capability of PECSA Net as a potential framework for pupil segmentation during real time applications. Thus, the proposed model can be utilized as a framework for pupil segmentation during the measure of pupil dynamics.Thus, by integrating attention enhanced multi-level feature extractor with an encoder-decoder paradigm, the proposed study provides a robust segmentation under challenging conditions, enabling reliable extraction of features for analysing the pupil dynamics.

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Towards miniature quantum sensors for early coronary artery disease detection

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Introduction

Magnetocardiography (MCG) offers a non-invasive approach for detecting cardiac electrophysiological abnormalities, with strong potential for early diagnosis of coronary artery disease (CAD). Recent advances in optically pumped magnetometers (OPMs) have enabled high-sensitivity measurements without cryogenic cooling and dedicated infrastructure. However, current commercial OPM systems remain bulky and are typically operated in shielded environments, limiting their clinical scalability. In this work, we present the development of miniature OPM quantum sensors targeting mobile and scalable MCG systems for early CAD detection, building on recent advances in microfabricated vapor cells and integrated quantum sensing technologies.

Methods

We developed a compact OPM architecture based on microfabricated alkali vapor cells and optimized optical and electronic subsystems. The sensors were designed with a focus on miniaturization, low power consumption, and robustness to environmental noise. Experimental validation is performed in unshielded conditions. The performance of the miniature sensors is benchmarked against commercial OPM systems under comparable conditions. Signal acquisition and post-processing pipelines are implemented to extract cardiac magnetic signals and assess signal quality metrics.

Results

First miniature OPM sensor prototypes have been assembled and subjected to initial qualification measurements. These preliminary tests demonstrate the detection of magnetic signals and indicate sensitivity levels that are promising with respect to MCG applications. Ongoing system integration with a dedicated electronic control system and forthcoming measurements will further assess the achievable sensitivity and benchmarking against commercial systems. Overall, these early results highlight the potential of miniaturized quantum sensors for future MCG measurements outside shielded environments.

Conclusion

This work seeks to demonstrate the feasibility of miniature OPM-based quantum sensors for MCG applications in unshielded conditions. The presented approach paves the way toward mobile and scalable diagnostic systems for early CAD detection. Future work will focus on system integration, multi-sensor arrays, denoising and clinical validation.

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Immersive 3D Simulation vs. Physical Models in Training Novices for Laser-based Endourological Procedures - Research Protocol for a Randomized Controlled Trial

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Introduction

Simulation-based learning is a valuable component of medical training. Immersive 3D simulations and physical simulations are commonly used in this context. The efficacy of immersive 3D simulation training in enhancing procedural skills and their transfer has been well-documented. In contrast, physical simulators offer the advantage of haptic feedback. Nevertheless, there is little direct comparative evidence between these two simulation modalities, and such evidence often fails to address cognitive, motivational and perceived learning outcomes, which also have an effect on learning outcomes. The objective of this study is to ascertain the disparities in procedural performance in conjunction with cognitive load, motivation, and perceived learning when instructing novice trainees in endourological laser-based procedures employing immersive 3D simulation and physical simulation.

Methods

We will conduct a single-center, two-group randomized controlled trial with 100 medical students (a priori power analysis in G*Power). Each participant will complete one training session on either an immersive 3D simulator or physical simulator followed by one post-training test on the physical simulator. Technical performance will be assessed using a blinded, Objective Structured Assessment of Technical Skills (OSATS) based composite including efficiency, safety and task completion. Furthermore, we will measure motivation, cognitive load, and perceived learning. To analyze group differences in the primary and secondary outcomes we will use independent sample t-tests.

Results

We will begin recruiting participants in April 2026. Data collection is expected to take place from May through July 2026. The data will then be analyzed and can be presented in September 2026.

Conclusion

By integrating technical performance with cognitive, motivational, and perceived learning outcomes this study will clarify not only whether, but also how, immersive 3D and physical simulation differently support learning in endourological training. Furthermore, it aims to inform the evidence-based development of simulation curricula in medical education.

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Modulating Respiration with Sensory Wearables – Early Insights

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Introduction

Healthcare professionals, particularly surgeons, face high rates of acute stress and burnout that can compromise well-being and patient safety. This study establishes a foundation for a real-time breathing-regulation system designed to mitigate intraoperative acute stress.

Methods

Semi-structured interviews with four surgical stakeholders were conducted to identify user requirements and acceptance criteria for in-OR wellbeing technology. Based on these insights, five tactile (TS) and four visual (VS) stimuli were designed to guide breathing toward five cycles per minute using temporal modulation of actuator intensity. A within-subject formative evaluation exposed participants to all stimuli while wearing a bHaptics TactSuit X16. Wellbeing and adequacy were rated on seven-point Likert scales and stimulus scores derived. Data were analysed with mixed-design ANOVAs.

Results

Interview participants (two experienced surgeons, two aspiring surgeons) emphasised discretion and non-intrusiveness as key requirements for the system. Non-clinical evaluation participants (7 female, 6 male) rated tactile stimuli higher than visual stimuli. Participants reported tactile cues as more prominent and preferred lower tactile intensities for prolonged use. Statistical analyses revealed a significant main effect of tactile stimulus and of break inclusion, and a significant main effect of visual stimulus.

Conclusion

This work demonstrates the feasibility of a breathing-regulation system for intraoperative stress reduction and its conceptual acceptability to end users under defined constraints. The findings identify tactile stimulation as the most promising modality for integration into a prototype. Future work must validate physiological efficacy in real time and evaluate deployment within authentic OR workflows.

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SoftFIB - Seeing the unseen
Biology meets technology

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Introduction

Scanning electron microscopy (SEM) with low energy focused ion beam (FIB), called SoftFIB, is introduced as a novel platform approach for high-resolution investigation of the interactions between thin-film neural implants and the surrounding nervous tissue. Current knowledge gaps include a lack of integrated analysis of material-tissue interfaces, limited insight into cellular responses at these interfaces, and insufficient cross-sectional (cs) visualisation of neural implants embedded in complex tissue environments. We aim to obtain detailed cs views that reveal how different cell types interact with both the electrode material and its insulating substrate.

Methods

The study employs a fully digital ultra-high-resolution field-emission SEM equipped with FIB and a Pt gas-injection system (GIS). Tissue samples are resin-embedded and stained prior to analysis, allowing for nanometer-scale characterization in both 2-D and 3-D. Particular attention is given to preserving the delicate implant-tissue interface despite challenges such as large volume mismatches between stiff implant materials (e.g., polyimide, metal) and soft neural tissue, and tissue shrinkage during processing. The workflow includes careful sample preparation, FIB milling to expose cross-sections, and subsequent imaging.

Results

The SoftFIB system successfully generates high-quality cs images of neural implants, revealing fine structural details of the devices. Methodologies, preparation strategies and protocols were developed to preserve the material-tissue interface being able for further analysis. Preliminary visualisations demonstrate the ability to resolve individual cells and their compartments in direct contact with neural implants.

Conclusion

SoftFIB represents a powerful, multimodal tool for bridging critical gaps in the understanding of neural implant-tissue interactions. By delivering cs insight into structural aspects of implanted electrodes and the material-tissue interface, the platform paves the way for more informed design and robustness of thin-film neural implants. Future work will expand quantitative analyses, validate findings across diverse implant geometries, and integrate the technique into routine pre-clinical evaluation pipelines.

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Neural Network-Based Quantification of Microbial Surface Coverage on Implant Materials

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Introduction

Fluorescence microscopy is widely used to analyze co-culture and *in situ* grown biofilms. However, quantification of image-derived parameters is challenging because of overlapping signals from microorganisms, human cells, and background noise. This study developed a neural network-based workflow to measure microbial surface coverage on titanium implant materials in such images.

Methods

Confocal images were obtained from an *in vitro* co-culture model and an *in situ* splint study. After automatic preprocessing of the green fluorescence channel, images were analyzed using one of three routes depending on image quality: thresholding alone, thresholding after manual substraction of interfering regions, or combined segmentation with two custom Cellpose models (CP_I for individual bacteria and CP_M for microcolony detection). Segmentation outputs were manually corrected and used to calculate microbial surface coverage.

Results

CP_I achieved a best test accuracy of 0.68, outperforming the best pretrained Cellpose model (0.15). In the *in vitro* model, estimated microbial surface coverage was 3.47% on top surfaces versus 0.05% on lateral implant surfaces. In the *in situ* dataset, 176 images were analyzed: 14 by thresholding alone, 79 by thresholding plus substraction, and 83 by the combined dual-model workflow. CP_I reached an accuracy of 0.63 for small regions, and CP_M reached 0.74 for larger microcolonies. Mean microbial coverage increased from 27.81% on day 2 to 71.88% on day 8, and the workflow reduced manual correction time by 70.13%.

Conclusion

This study presents a practical semi-automated workflow for quantifying microorganisms in images containing co-localized bacteria and human cells, where classical methods perform poorly. The approach supports more efficient analysis of implant-associated biofilms and related co-culture systems, although additional high-quality training images and optimized microscopy may further improve accuracy and facilitate fully automated analysis.

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Material Evaluation of Biomimetic Atherosclerotic Plaque Analogues

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Introduction

Atherosclerosis is characterized by progressive plaque accumulation within arterial walls, leading to stenosis or thrombotic occlusion. Native atherosclerotic plaques consist primarily of fibrous tissue, lipid cores, calcium deposits, and macrophages. The development of novel endovascular treatment methods and devices, such as stents, requires realistic phantom materials that replicate both the structural composition and mechanical properties of pathological tissue. This study presents the evaluation of low-cost, non-toxic materials as analogues for atherosclerotic plaque components, prioritizing anatomically realistic X-ray attenuation coefficients and deformation behavior.

Methods

Two plaque analogue formulations were developed using cost-effective materials. The first recipe consisted of gelatin (mimicking fibrous tissue), gypsum (mimicking calcifications), butter or ghee (mimicking lipid core), and water. This composition represents pathological intimal thickening and fibrotic plaques containing less than 10% calcium. A second formulation was developed using flour, salt, butter, and water, based on established tissue-mimicking CT phantom compositions. Both formulations were characterized using CT imaging to quantify X-ray attenuation coefficients, which were compared to clinical reference data for native atherosclerotic tissue. Material hardness testing was performed to verify that mechanical properties fell within physiologically relevant ranges for soft tissue and calcified plaque components.

Results

CT imaging analysis demonstrated that both plaque analogue formulations exhibited X-ray attenuation coefficients comparable to clinical reference values for native atherosclerotic tissue. Hardness characterization confirmed that the mechanical properties of both formulations were within physiologically relevant ranges, providing realistic deformation behavior suitable for interventional device testing.

Conclusion

This study demonstrates that realistic atherosclerotic plaque analogues can be fabricated using low-cost, readily available materials. Both formulations provide anatomically accurate X-ray attenuation properties and appropriate mechanical characteristics, making them valuable tools for medical imaging research and therapeutic device development.

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Navigating Barriers into Technology: Interpretations and Strategies for Dealing with Discouraging Factors in the Educational Biographies of PhD Researchers

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Introduction

Against the backdrop of declining STEM enrolment in Germany and persistent gender disparities in technology-related fields, this contribution examines barriers in the educational biographies of people who nevertheless entered the field and remained in technology research. The focus is on discouraging factors during career choice and early study phases, and on how these factors were interpreted and navigated.

Methods

The contribution draws on narrative biographical interviews with 13 early-career researchers in Germany working in technology research. Participants also completed a card-sorting task on ten career-choice factors identified in prior research, ranking them by importance and by whether they remembered them as encouraging or discouraging. The analysis concentrates on factors that were perceived as discouraging on average and complements the rankings with interview narrations.

Results

Most factors were remembered as encouraging. Two factors emerged as more ambivalent or discouraging: Gender Identity Fit and Competence Beliefs. Gender Identity Fit was especially discouraging for some female participants because of low representation, lack of role models and a sense of non-belonging, while others described this same mismatch as triggering defiance and persistence. Competence Beliefs were discouraging across genders and were shaped by uncertainty, unclear expectations and the image of technology as difficult. Two recurring ways of navigating this barrier emerged: reframing competence through learning experiences and normalizing uncertainty through peer interaction.

Conclusion

Even successful entrants encountered substantial barriers early on. This hints at circumstances and factors that may also keep others from staying in, or even entering, technology-related fields. Addressing competence beliefs, visible representation and early peer-supported learning may help make pathways into technology more inclusive, especially because initially aversive factors were sometimes remembered as turning into sources of motivation through reinterpretation.

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Crush resistance simulation of a self-expanding polymer microstent for the treatment of Fallopian tube occlusions

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Introduction

Proximal Fallopian tube occlusions contribute significantly to female infertility, while current treatments such as in-vitro fertilization and tubal surgery remain costly and limited in success. This study evaluates biodegradable polymers (PLLA, PLGA and PLLA-co-CL) for a self-expanding microstent by combining tensile testing, differential scanning calorimetry (DSC), and finite element modeling to assess material behavior and crush resistance for temporary tubal implantation.

Methods

PLLA, PLGA and PLLA-co-CL were processed into solvent-cast films and laser-cut specimens for thermal, mechanical, and numerical evaluation. DSC determined glass transition temperatures and crystallinity, while tensile testing provided material parameters for bilinear and multilinear finite element models assessing crush resistance of a microstent design under 50% radial compression between two parallel plates.

Results

DSC confirmed the highest crystallinity and glass transition temperature for PLLA, followed by PLGA and PLLA-co-CL. Tensile testing revealed high stiffness for PLLA and PLGA, whereas PLLA-co-CL showed markedly lower modulus but high ductility. Finite element simulations demonstrated superior crush resistance for PLLA, moderate performance for PLGA, and pronounced plastic deformation for PLLA-co-CL under compression.

Conclusion

This study established a simulation-driven workflow for evaluating crush resistance of biodegradable polymer microstents for Fallopian tube recanalization. Tensile characterization enabled experimentally derived material modeling of PLLA, PLGA, and PLLA-co-CL. The results demonstrated pronounced material-dependent structural differences and highlighted the importance of experimentally derived parameters for reliable simulation-based optimization of temporary biodegradable microstent designs.

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Oxygenator deterioration in a standardized in vitro setup: pressure drop, CT-based clot burden, and hemolysis

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Introduction

Clotting is a major technical complication in ECMO, and the oxygenator is a principal site of thrombus formation. Its hollow-fiber architecture provides a large surface for gas exchange but simultaneously exposes blood to foreign material and non-physiological flow conditions, thereby promoting inflammatory and prothrombotic responses. Progressive clot deposition within the fiber bundle reduces effective membrane surface area, impairs gas exchange, increases hydraulic resistance, and raises trans-oxygenator pressure drop, thereby characterizing oxygenator dysfunction as a progressive, multifactorial process that includes hemocompatibility-related blood damage. Standardized in vitro models that enable controlled induction and assessment of oxygenator deterioration are therefore needed. The present study evaluates a dedicated in vitro setup designed to investigate progressive oxygenator deterioration and characterize the associated functional and structural changes.

Methods

A standardized continuous dual-loop in vitro test circuit was used to investigate deterioration of a Terumo CAPIOX FX05 oxygenator under controlled conditions. Experiments were performed with three liters of heparin-anticoagulated porcine whole blood per run. Blood conditions were adjusted to predefined physiological target ranges based on DIN EN ISO 7199. Progressive obstruction was induced by hourly administration of 40 mg hollow glass microspheres. Functional assessment comprised intermittent pre- and post-oxygenator blood sampling at 30-min intervals and continuous monitoring of hydraulic and blood-gas-related parameters. In addition, unused reference and experimentally stressed oxygenators underwent post hoc computed tomography (CT; SOMATOM Definition Edge, Siemens Healthineers). CT datasets were analyzed in MATLAB for volumetric clot-burden estimation and spatial mapping of suspected clot regions. Feasibility was assessed by the framework's ability to induce progressive obstruction and detect corresponding changes in pressure drop, hemolysis, and CT-derived clot burden.

Results

Four experimental runs were analyzed, with a mean duration of (272 ± 51) min. The framework reproducibly induced progressive obstruction in all runs. Mean pressure drop increased from (61.82 ± 9.55) mmHg at baseline to (232.55 ± 6.01) mmHg before run termination, indicating progressive fiber-bundle obstruction. CT-based analysis identified suspected clot volumes between 14.27 mL and 48.99 mL, with preferential accumulation in central oxygenator regions and lower clot burden near the outlet. Mean hemolysis index increased from (0.07 ± 0.03) % at 30 minutes to (1.51 ± 0.58) % at run termination, indicating progressive hemocompatibility-related blood damage.

Conclusion

The proposed in vitro setup enabled controlled induction of progressive oxygenator deterioration. Combined assessment of pressure drop, hemolysis, and CT-derived clot burden provided complementary functional and structural evidence of deterioration and enabled multimodal characterization in vitro.

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In situ curing sytem for electrospun silicone elastomers in hydrophobic coatings

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Introduction

Porous, hydrophobic coatings made from electrospun silicone fibers offer potential for reducing fibrotic capsule formation on cochlear implant electrode arrays by exhibiting cell-repellent behavior. However, electrospinning silicone elastomers remains challenging due to their liquid precursor state, which may lead to loss of fiber structure. Effective curing strategies are therefore required to stabilize fibers during formation. This study introduces a novel in situ curing method combining heat radiation and conduction, along with a parameter study to evaluate its effects on process stability and fiber morphology.

Methods

An in situ curing unit was developed by combining a ceramic heat emitter and a heated plate collector. In the electrospinning process, the silicone elastomer Sylgard 184 was first diluted in tetrahydrofuran and then precured for a duration of 295 minutes at 40 °C. This procedure was implemented to modify the rheological characteristics of the solution. In a fractional factorial parameter study, the influence of the four process parameters voltage, cannula-to-collector distance, flow rate, and heat emitter power on process stability and fiber morphology was evaluated.

Results

The curing system described herein enabled the production of homogeneous silicone fiber nonwovens with preserved fiber structure and connected fiber interspaces. The parameter study demonstrated that fiber diameter is significantly affected by the applied voltage, distance and heat emitter power. These parameters were identified as control factors for tailoring fiber morphology. Compared to previous approaches that are based on heat conduction, the developed system improved curing efficiency and supported the formation of multilayered fiber structures.

Conclusion

The developed in situ curing method enables the electrospinning of silicone elastomers, thereby addressing the significant limitations associated with inadequate curing. The identified process parameters enable targeted control of fiber characteristics, facilitating the design of functional coatings. Future work will investigate the effects of these fibers on fibroblast proliferation and metabolic activity.

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Radiomics-based Prediction of Lung Artery Thrombus: Influence of Sex on Feature Selection and Performance

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Introduction

Disease progression and symptoms are reported to be correlated to different factors, one of them often being the sex of the patient. Limited understanding of the variations in regard to the patients' sex can lead to bias in diagnosis and treatment. Especially in acute pulmonary embolism (APE), these differences are still not sufficiently investigated.

Methods

We performed a sex-stratified analysis of APE patients from the same study cohort: i) 200 patients' computer tomography (CT) images (100 female, 100 male) comprising manual segmentations of the thrombus; ii) 427 patients with automatically segmented CT images (182 female, 243 male). For the prediction of 30d-mortality and globular protein troponin for both databases, the image features of the arterial thrombus were extracted with the radiomics library in python and later on normalized with a ZScore as well as reduced with a Pearson correlation analysis (coefficient > 0.85). After a feature reduction with 12 selection methods, multiple performance metrics were calculated with 12 classification methods.

Results

We were able to achieve a weighted F1-Score of up to 0.9626 for the prediction of the mortality in 3D. The sex-stratified analysis resulted in higher metric values for the cohort of only female patients. The examination of the combined cohort showed the lowest results. While comparing the selected features, we found different image properties contributing to the prediction based on the patients' sex. These features also influenced the highest achieving classification methods.

Conclusion

We were able to demonstrate an influence of the patients' sex on our analysis. The calculations of only female patients resulted in the highest values, whereas the combined analysis produced decreased outcomes. Patients presented different thrombus compositions based on their sex, resulting in varying image properties. These results demonstrate the importance of further sex-stratified studies in regard to acute pulmonary embolism.

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Removal of residual acetone from metal ion release systems based on silicone films

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Introduction

Metallic implants such as hip and knee endoprostheses can release wear particles and metal ions (nickel, cobalt, chromium), which accumulate in adjacent tissues and trigger inflammatory responses, oxidative stress, and compromised biocompatibility. Reliable in vitro model systems simulating controlled ion release are essential to study these mechanisms. Silicone serves as an ideal matrix polymer due to its biocompatibility, biostability, and diffusion-controlled release properties. However, acetone, which is used as a processing solvent, must be completely removed, as residual solvent may alter material microstructure and release kinetics, compromising experimental reproducibility.

Methods

This study presents a method for complete acetone removal from silicone samples with and without incorporated cobalt ions, verified by high-performance liquid chromatography (HPLC). Silicone films were prepared per manufacturers instructions, with cobalt samples produced by adding $CoCl_2*H_2O$ in acetone to the silicone base material. Firstly, samples were acetone-saturated, then subjected to vacuum evaporation. Residual acetone was extracted, derivatized with 2,4-dinitrophenylhydrazine, and quantified via an isocratic HPLC method using acetonitril and water as solvent.

Results

Saturated samples showed artificially high acetone levels, exceeding the highest standard concentration. Vacuum evaporation reduced residual acetone to the reported calibration range. Pure silicone reached solvent values at blank level after incubation at 100 °C for 72 h; cobalt-containing samples required 100 °C for 96 h. Cobalt ions impeded evaporation, likely through intermolecular interactions.

Conclusion

The developed protocol ensures solvent-free silicone matrices for reproducible cobalt release studies. Complete acetone removal prevents confounding effects in in vitro assessments and meets quality requirements for biomedical implant research. This method supports reliable investigation of metal ion biocompatibility and advances silicone-based drug delivery system development.

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Targeted Cepstral Jitter Modeling Using Lightweight Neural Networks for Real-time Auditory Feedback Modulation

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Introduction

Real-time auditory feedback modulation requires signal representations that enable perceptually effective voice-quality control under strict latency constraints. This work investigates a cepstrum-based approach for modulating hoarseness-related roughness in sustained vowels. The method is motivated by an analysis of hoarse vowel recordings showing two characteristic short-term properties: a specific distribution of frame-wise jitter values and a pronounced negative autocorrelation at lag 1.

Methods

The processing pipeline operates on the excitation-related cepstrum derived from linear predictive coding and modifies the first cepstral peak to introduce jitter-like instability. Frame-wise peak shifts are generated by a lightweight gated recurrent unit trained on normalized jitter sequences from hoarse sustained vowels. To improve temporal dependency and distributional realism, the final system combines deterministic GRU predictions with a statistical residual noise component. The method was integrated into a real-time processing chain with an overall latency of approximately 20 ms.

Results

Analytical evaluation shows that the modulated signals reproduce the target short-term jitter properties of hoarse vowels well on average. In particular, the generated cepstral peak shifts match the characteristic distribution and preserve the intended negative lag-1 autocorrelation. The averaged cepstrum of the modulated signals also exhibits the lower and broader main peak associated with hoarse phonation. However, natural hoarse vowels show more structured temporal organization, including stable intervals, more unstable regions, and abrupt local disruptions, whereas the generated modulation remains more uniform. A listening study further indicates that the method increases perceived roughness and hoarseness, but does not fully reach natural hoarse speech and reduces perceived naturalness due to technical artifacts.

Conclusion

The lightweight GRU is adequate for modeling local jitter dynamics under real-time constraints. However, limitations of the cepstral representation, restricted reconstruction, and insufficient modeling of vowel-dependent and longer-term temporal structure currently prevent its use for real-time hoarseness induction in auditory feedback paradigms.

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Towards a Model-Based Digital Twin for Gait Analysis in Parkinson-Related Assessment

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Introduction

Step-width variation and foot-placement-related measures are relevant for Parkinson-related gait assessment, but they are difficult to derive robustly from compact wearable sensor setups. Previous work based on body-worn magneto-electric sensors demonstrated the potential of wearable spatial sensing, yet remained limited to proxy quantities and did not provide a continuous kinematic body representation. This work presents a work-in-progress transition toward a model-based digital twin-oriented framework for wearable gait analysis.

Methods

The proposed framework combines a modular processing chain, a hierarchical kinematic skeleton model, and a planned recursive state-space estimation approach for pose reconstruction from wearable sensor signals, particularly from inertial and magnetoelectric modalities. A central design decision is the use of a shared model structure for both simulation and online processing. The kinematic model represents parent-child segment relations and configurable sensor assignments, while the digital twin provides a biomechanically consistent representation from which clinically relevant gait parameters can later be derived.

Results

The current implementation provides the modular software architecture, the hierarchical kinematic model, configurable sensor assignment, patient-specific segment adaptation and integration of pose-estimation and state-space concepts into the existing processing chain. The pipeline up to the kinematic-model stage is functional and has been verified at the software level. In addition, the model can already be driven by recorded motion data, enabling replay of gait sequences within the digital twin environment. However, the final state vector, detailed process and measurement models, the Kalman-based recursive estimator, IMU integration, inertial sensor simulation, and gait-parameter derivation remain under development. No human measurements or quantitative validation are reported at this stage.

Conclusion

The framework establishes an architectural and methodological basis for model-based interpretation of wearable gait data in Parkinson-related assessment. It creates a foundation for future pose reconstruction and derivation of clinically relevant gait parameters such as step width variation and foot placement.

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PPGNet: Deep Multiple Instance Learning for Automated Hypertension Detection in OSA Patients Using PPG Signals

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Introduction

Systemic hypertension is a common cardiovascular comorbidity in patients with obstructive sleep apnea, with the two conditions sharing well-established physiological overlap. Despite being the gold standard diagnostic tool for sleep apnea, polysomnography recordings are rarely leveraged for cardiovascular risk assessment. Existing approaches relying on short signal windows fail to capture the sustained hemodynamic patterns that characterize the relationship between the two conditions. This work introduces PPGNet, a deep learning framework that uses full-night photoplethysmography signals from routine polysomnography to automatically detect established hypertension without requiring additional instrumentation.

Methods

Sixty-two overnight recordings from 33 OSA patients (17 hypertensive, 16 normotensive) were obtained from the European Sleep Apnea Database (ESADA). PPG signals sampled at 100 Hz were segmented into 30-second instances and grouped into 30-minute bags enriched with sleep stage and apnea event annotations. A dual-branch 1D convolutional neural network extracted both morphological and pulse wave features from each instance. These instance-level embeddings were aggregated through a gated attention Multiple Instance Learning pooling mechanism, producing recording-level predictions via majority voting.

Results

Using Leave-One-Patient-Out cross-validation, PPGNet achieved an AUROC of 86.72%, AUPRC of 88.01%, accuracy of 79.03%, sensitivity of 83.33%, specificity of 75.00%, and an MCC of 0.5842. Attention-based analysis confirmed that the model consistently weighted segments reflecting arterial stiffness and impaired vasomotor responses during apnea, pointing to physiologically grounded rather than spurious discrimination between the two patient groups.

Conclusion

PPGNet demonstrates the feasibility of deriving hypertension-related cardiovascular signatures from overnight PPG signals collected during standard sleep studies. The framework offers a practical, interpretable pathway for integrating cardiovascular risk stratification into routine sleep evaluations as a secondary outcome, with no need for additional hardware or patient burden.

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Frequency-domain Based Optimization of Voxel Networks for Non-invasive Magneto-anatomical Mapping

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Introduction

Cardiac arrhythmias are a leading cause of sudden death worldwide. Non-invasive magneto anatomical mapping seeks to identify arrhythmogenic regions by reconstructing cardiac current densities from external magnetic sensors. An alternating two-stage state-space estimation and parameter optimization scheme has been proposed. While all pass filter networks have proven promising for this, they suffer from convergence issues in three-dimensional voxel models. Here we extend this framework by performing state estimation and parameter optimization in the frequency domain, enabling reliable parameter recovery for larger voxel structures and improving spatial resolution towards clinical applicability. A simulation shows the feasibility of the approach.

Methods

The myocardium is discretised into equally sized voxels. Connectivity between voxels is encoded via gain and delay parameters $\mathbf{p}$, forming a complex valued, discrete, linear state space system with dynamic matrix $\mathbf{A}(\mathbf{p})$. A Kalman filter provides an optimal state estimation given measured magnetic signals. Parameter optimization alternates between (i) Kalman based state estimation and (ii) gradient descent parameter updates on a fully differentiable cost function that penalizes the squared error between simulated and reference magnetic outputs. In simulation 50000 gradient descent iterations are performed.

Results

The optimization shows successful convergence of the system. The Kalman state estimates consistently yielded lower error than the uncorrected forward model throughout the optimization process. The final estimated current density distribution closely matches the reference simulation, demonstrating that the approach can accurately recover parameters in larger cardiac voxel networks.

Conclusion

The frequency domain optimization scheme overcomes previous convergence limitations and achieves reliable cardiac current density reconstruction in more complex 3D voxel models. This paves the way toward clinically relevant spatial resolution for non-invasive magneto-anatomical mapping. Future work will address robustness to different noise levels and types, scalability for even larger voxel counts, and further refinement of the optimization algorithm to accelerate convergence.

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From SERF-OPM-Detectors to High-Performance Multichannel Systems for Biomagnetic Sensing

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Introduction

Multichannel Spin-Exchange-Relaxation-Free Optically Pumped Magnetometer Magnetoencephalography (SERF-OPM-MEG) systems enable non-cryogenic, on-scalp neuroimaging with dense sensor arrays and flexible sensor placement, while still requiring magnetically shielded environments and/or active field compensation to ensure reliable operation. Current commercial systems allow detection and localization of weak biomagnetic signals from stimulated brain regions, muscles, or nerve bundles, particularly when sensors are positioned close to the source. Advanced signal processing techniques can mitigate magnetic interference and parasitic signals. However, in contrast to other multichannel sensing modalities (e.g., MRI, audio systems, phased arrays, SQUID-MEG), system-level engineering challenges in SERF-OPM arrays remain insufficiently addressed. This contribution focuses on the transition from highly sensitive detectors to robust multichannel sensing systems.

Methods

Sensor clusters of commercial multichannel SERF-OPM systems were characterized using the already introduced test bench DALAC, which was operated inside the Berlin Magnetically Shielded Room 2.1 at PTB in Berlin. This enabled the accurate placement of multiple sensors within a homogeneous magnetic test field under controlled conditions and the systematic evaluation of system-level characteristics.

Results

System-level limitations were identified across multiple domains. Transfer characteristics varied over time, frequency, and between channels. Cross-axis projection error and cross-field sensitivity reduced the effective channel count, the number of usable trials, and overall data quality. Missing or insufficient anti-aliasing filtering resulted in spectral artifacts, while steep filtering introduced increased settling times. In addition, timing mismatches between sensor, stimulus, and auxiliary channels require explicit characterization and compensation, or, at minimum, accurate specification to ensure correct temporal alignment and timing. These effects collectively limit system performance and consistency in multichannel operation. Non-synchronized, low-bit-rate, multichannel data processing introduces latency and additional delays, which limit real-time BCI applications. This issue is particularly problematic with auditory or tactile feedback, which has already been addressed in other commercial multichannel systems.

Conclusion

Despite high intrinsic sensitivity, current SERF-OPM systems lack the system-level robustness required for multichannel operation. The identified limitations and associated improvement potentials are well understood from a system engineering perspective but are not yet systematically addressed by current manufacturers. Awareness of these limitations is essential to avoid misinterpretation of biomagnetic measurements and to ensure reliable and reproducible data analysis.

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Data Synthesis Improves 3D Myotube Instance Segmentation

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Introduction

Myotubes are multinucleated muscle fibers serving as key model systems for studying muscle physiology, disease mechanisms, and drug responses. Quantitative morphological analysis, such as diameter, length, and branching structure, requires accurate three-dimensional instance segmentation. However, existing pretrained biomedical segmentation models fail to generalize to this domain due to the absence of large annotated myotube datasets and the complex, elongated morphology of myotubes.

Methods

We propose a geometry-driven synthesis pipeline to generate realistic 3D myotube data. Individual instances are modeled using polynomial centerlines with locally varying radii, branching structures, and ellipsoidal end caps derived from real microscopy observations. Synthetic volumes are rendered with realistic noise, optical artifacts, and CycleGAN-based domain adaptation to reduce the gap to real imaging data. We train four variants of a compact 3D U-Net, including models with and without self-supervised (SSL) encoder pretraining and domain adaptation, using only synthetic data.

Results

We evaluate all models on sparsely annotated real data using Injective Panoptic Quality (IPQ). The combination of SSL pretraining and domain adaptation achieves the best performance (0.22), significantly outperforming both non-adapted and non-pretrained variants, as well as three established zero-shot segmentation models. Ablation results indicate that neither SSL nor domain adaptation alone yields substantial improvements, but their combination leads to a strong synergistic effect.

Conclusion

Our results demonstrate that geometry-driven synthetic data, combined with SSL and domain adaptation, enables effective instance segmentation in annotation-scarce biomedical domains. The approach provides a scalable alternative to manual annotation and can be extended to similar filamentous structures such as nerve fibers or mycelium networks.

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Bridging the gap between in vitro and in vivo toxicity testing: 3D tissue models for nanomedicine metrology

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Introduction

The expanding field of nanomedicine has introduced promising therapeutic modalities. However, precise assessment of nanoparticle distribution and accumulation within target tissues remains a critical limitation. Widely used two-dimensional (2D) cell culture systems and animal models often lack translational relevance to human physiology, underscoring the demand for advanced, ethically sound and human-representative testing platforms. Scaffold-based tissue engineering enables the generation of reproducible three-dimensional (3D) constructs from human cells that better recapitulate the structural and functional complexity of native tissues. This study evaluates the suitability of such 3D engineered tissues as platforms for investigating tissue-level dosimetry of clinically relevant metal oxide nanoparticles supporting metrological standardization efforts for nanomedicine.

Methods

In this work, conventional 2D cultures were systematically compared with 3D tissue-engineered models derived from primary human fibroblasts (healthy phenotype) and A549 lung carcinoma cells. Both systems were exposed to selected metal oxide nanoparticles, including iron oxide (IONPs), hafnium oxide (HfO_2NPs), and upconversion nanoparticles (UCNPs). The 3D constructs were maintained under conditions designed to emulate physiological microenvironments, enabling more representative nanoparticle–cell interactions. Cytotoxic effects were quantified using AlamarBlue assays and Ki-67 immunohistochemical analysis across varying nanoparticle concentrations.

Results

The data reveal a consistent concentration-dependent decrease in cell viability across both model systems. Compared with the 2D models, the 3D models showed reduced relative cell viability, but HfO_2NPs at 50 µg/ml remained within the acceptable range despite reductions of 15.1% in primary fibroblasts and 12.9% in A549 cells. UCNP caused reductions of 8.1% in primary fibroblasts and 10.2% in A549 cells. The small diameter IONPs showed only minor reductions in cell viability and were considered non-cytotoxic, while large diameter IONPs caused reductions of 16.5% and 18.9% in primary fibroblasts and were therefore classified as weakly cytotoxic for this cell type. These differences likely arise from the enhanced structural organization and more physiologically relevant characteristic of 3D cultures.

Conclusion

Collectively, these findings highlight the advantages of scaffold-based 3D tissue models as predictive tools for nanomedicine evaluation, offering improved relevance over traditional in vitro approaches. The future integration of such systems with organ-on-chip technologies holds strong potential for advancing personalized and patient-specific nanomedicine assessment.

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FemTech-Fibers: Lactid-releasing for a healthy vaginal environment

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Introduction

Worldwide, almost one-third of the women of childbearing age suffer from bacterial vaginosis. This condition causes the sensitive vaginal microbiome to become unbalanced, leading to a decrease in lactic acid bacteria and a significant rise in the vaginal pH level. Such a disturbance of the vaginal flora can lead to urogenital infections, abscesses, or premature births. Guideline-based treatment with antibiotics results in a relapse rate of around 50 %. Therefore, fibers have been developed for use in panty liners that regulate the pH level in the vagina by releasing L-lactide. The lactide is released into the physiological environment within a few minutes in a moisture-controlled manner. This helps maintain a healthy pH level.

Methods

Three different fiber materials were investigated. Two fiber materials were spun from a compound of polymer and lactide. The third were viscose fibers coated with lactide.
The samples were placed in simulated vaginal fluid and its change of the lactat-concentration and the pH value were compared.

Results

The tests with simulated vaginal fluid showed that lactide-loaded and coated fibers can reduce the pH value from an value of over 4.6 to a value of 3.4 within 15 minutes. Lactate concentration does not correlate with the pH value and therefore cannot be used as an in vitro measurement method.

Conclusion

The fibers developed showed an almost immediate reduction of the pH value to a relevant range.
Further research projects will continue to pursue this promising approach toward a preventively effective panty liner. A realistic vaginal test model should be developed to optimize the textile materials.

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Influence of Airway Resistance Model Selection on NIV Bench Testing

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Introduction

Bench testing of non-invasive ventilators (NIV) relies on mechanical lung simulators that enable controlled and reproducible evaluation of ventilator performance. Although linear (R) and parabolic (R_p) airway resistance models are established and widely used in such simulators, their equivalence under realistic NIV conditions has not yet been investigated.

Methods

In this study, three NIV scenarios, representing low (R5/R_p5), medium (R20/R_p20), and high (R50/R_p50) airway resistance, were assessed using numerical simulations and experimental measurements. Flow- and volume-based metrics were employed to compare the resulting respiratory patterns.

Results

Expiratory triggering behavior showed only small differences between resistance models in the low and medium resistance ranges, but measurable deviations occurred under high-resistance conditions. In contrast, substantial and systematic differences were observed in tidal volume and peak inspiratory and expiratory flows: parabolic resistances consistently produced higher volumes, higher peak flows, and more symmetric flow profiles.

Conclusion

These findings demonstrate that linear and parabolic resistance models do not behave interchangeably under realistic NIV conditions. The authors propose that bench-testing protocols should explicitly specify the airway resistance model and consider its interaction with the applied breathing pattern to ensure accurate ventilator performance assessment and comparability across studies.

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pH sensitive, magnetic nanocomposites for biosensing applications using magnetic particle spectrometry

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Introduction

The investigation of magnetic nanoparticles (MNPs) for various applications, including biosensing, drug delivery and magnetic particle imaging, represents an emerging field of research in medical engineering. Integrating MNPs into Hydrogels is promising for medical applications such as implantology and drug delivery. Recent advances demonstrate that the magnetic signal measured with magnetic particle spectrometry (MPS) is influenced by the interaction of MNPs with their environment. In this work we present a magnetic nanocomposite for contactless pH sensing. This offers the prospect of enhanced diagnostic capabilities, such as monitoring pH sensitive treatment conditions in gallstone disease.

Methods

To achieve pH sensitive behavior, MNPs (d=50 nm, Synomag-D®, Micromod, Rostock, Germany) were surface coated with the amino acid glycine. The synthesized particle system was characterized by electrophoretic mobility and dynamic light scattering (Litesizer DLS 500, Anton Paar GmbH, Ostfildern-Scharnhausen, Germany), which enabled the determination of the zeta potentials and hydrodynamic diameter across a range of pH values. In Addition to this, the magnetic response of the nanocomposite was evaluated by MPS (Fraunhofer IMTE, Lübeck, Germany) at the respective pH values.

Results

Our results show a pH dependent behavior of the zeta-potential and hydrodynamic diameter of the functionalized nanoparticles. Analysis of the dynamic magnetization behavior revealed different spectral decays of the magnetization amplitude between pH 5 and pH 7. The ratio of the harmonic amplitude (H_11/H_41) dropped significantly by approximately 29%. Considering the hydrodynamic diameter (pH 5: 110 nm and pH 7: 267 nm), we suggest an altered magnetic relaxation behavior of the nanocomposite.

Conclusion

The Investigation aims to provide a fundamental explanation of the pH sensing mechanism based on the dynamic magnetization behavior of glycine-functionalized nanoparticles. The integration of this nanocomposite into a hydrogel could subsequently be used as a fabrication material for soft, magnetic microrobots for medical applications.

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Design and Setup of a Multispectral VIS-NIR Camera System

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Introduction

A multispectral camera system based on a SWIR industrial camera is designed as a platform for measurements of vital parameters such as heart rate, SpO2 and tissue components like haemoglobin, water, fat and others.

Methods

A SWIR industrial camera in the wavelength range 400–1700 nm is combined with two approaches for wavelength selection. Firstly, LED illumination with ten discrete wavelengths, secondly, a motorized filter wheel with eight optical bandpass filters. Both options aim to cover the whole camera wavelength sensitivity range. A microcontroller-based control unit was developed that serves as an interface between the PC, LED strips, filter wheel, and camera. The illumination, filter wheel and camera are synchronized via trigger signals, and a compact PC interface configures and starts measurement sequences. Time-multiplexed LED recordings enable video-based analysis of pulsatile signals.

Results

Initial reference images with test subjects show that both approaches deliver spectrally separated and consistent image data. LED illumination enables higher system framerates than the filter wheel set-up allowing remote photoplethysmography (rPPG) for heart-rate and S_PO_2 measurements. The filter-wheel approach requires only simple halogen illumination and may support tissue-component discrimination. Achieving uniform illumination across the different LED wavelengths remains a challenge and requires further adjustment.

Conclusion

A robust multispectral VIS-NIR camera system based on selective illumination and alternatively optical filters was built for systematic measurement series. The LED approach enables fast pulsatile measurements for heart rate and SpO2, whereas the filter wheel offers simpler illumination for tissue analysis. Even though adaptations are still needed, both approaches support further studies on vital parameters and tissue components.
The extended spectral range (1000–1700 nm) is expected to provide access to spectral signatures of additional tissue constituents that are not observable within the conventional visible and near-infrared range. The design can be adapted at a later stage to address specific requirements.

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Impact of pad position and polarity on transcutaneous pacing efficacy in a porcine model

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Introduction

Transcutaneous cardiac pacing (TCP) is an established non-invasive therapy for the treatment of bradyarrhythmias. While both anterior-posterior (AP) and anterior-lateral (AL) pad placements are used in clinical practice, their comparative efficacy and impact of electrode polarity remains largely unexplored.

Methods

In this experimental study, TCP was performed in 22 anesthetized domestic pigs. Using a randomized crossover design, each animal underwent pacing in four configurations: AP and AL, each with standard and reversed polarity.
Pacing current was increased stepwise until mechanical capture was achieved. Capture thresholds and capture rates were recorded for each configuration.

Results

Mechanical capture was achieved in a high proportion of AP configurations, both in standard (84 %) and reversed polarity (58 %). In contrast, AL placement showed reduced capture success in standard (5 %) and reversed (0 %) polarity. Capture thresholds varied between configurations and ranged from 70 to 150 mA.

Conclusion

Both pad position and polarity influence the efficacy of TCP in our study. AP positioning was associated with higher capture rates compared to AL. These findings suggest that pad positioning plays a central role in TCP performance.

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Heart Rate Asymmetry in Disorders of Consciousness

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Introduction

Disorders of consciousness include unresponsive wakefulness syndrome (UWS), defined by absent awareness, and minimally conscious state (MCS), characterized by fluctuating yet reproducible signs of awareness. Distinguishing these two conditions is clinically essential yet remains highly error-prone using standard behavioral assessments. Cardiac autonomic regulation is governed by bidirectional brain-heart interactions that are differentially disrupted across consciousness levels, positioning electrocardiography (ECG) signals as a promising non-invasive diagnostic modality.

Methods

This study examines whether Heart Rate Asymmetry (HRA) features derived from resting-state ECG Poincaré plots can distinguish MCS from UWS patients.

Results

Our results reveal statistically significant differences in multiple HRA features. Absolute Spearman's rank correlation coefficients of these features to Coma Recovery Scale - Revised scores indicate moderate monotonic relationships ($|r| = 0.42$ for total HRA; $|r| = 0.47$ for long-term HRA).

Conclusion

These findings indicate that nonlinear cardiac features carry diagnostic information beyond what standard heart rate variability analysis provides.

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AI Cube: A Multidimensional Taxonomy of AI-based Applications in Professional Nursing

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Introduction

Artificial intelligence (AI) is increasingly embedded in digital health infrastructures, reshaping clinical workflows and the organisation of professional care. In nursing, AI applications encompass clinical decision support, predictive analytics, natural language processing, augmented reality, sensor-based monitoring, and robotic assistance. These technologies differ fundamentally in their computational paradigms, implementation environments, and functional relationships to nursing work. Existing international reviews consistently document this heterogeneity while revealing the persistent absence of a shared classificatory framework, a gap with direct consequences for systematic evidence synthesis, comparative research, and governance-oriented evaluation of AI deployment in nursing contexts.

Methods

The AI Cube was developed as a conceptual-deductive taxonomy following the systematic method for taxonomy development in information systems proposed by Nickerson, Varshney, and Muntermann. The development process was primarily deductive: axes were derived from established theoretical frameworks in machine learning, human-computer interaction, and nursing science, and subsequently validated against the empirical literature on AI in nursing. Formal ending conditions, specifically mutual exclusivity and collective exhaustiveness, guided the iterative development process.

Results

The AI Cube classifies AI applications in nursing along three orthogonal axes: implementation space (X-axis, X1–X5: from screen-based information systems to cyber-physical robotic systems), AI intensity (Y-axis, Y0–Y4: from rule-based systems to generative AI with agent architectures), and domain of professional nursing practice (Z-axis: Z1 Interaction, Z2 Reflection, Z3 Intervention, Z4 Organisation and Coordination). A complementary Governance Matrix cross-tabulates AI autonomy (A0–A3) with clinical criticality (R0–R3), enabling risk-differentiated deployment evaluation independent of AI intensity. Six exemplary applications illustrate the taxonomy's analytical utility, demonstrating that systems commonly labelled "AI in nursing" occupy structurally distinct positions across all three axes.

Conclusion

The AI Cube provides a multidimensional classificatory framework for AI applications in professional nursing, supporting systematic evidence synthesis, research gap identification, and governance-oriented evaluation. Empirical validation through systematic mapping studies constitutes the logical next step.

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Digital care, results and findings from CARE REGIO

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Introduction

Modern technologies are increasingly becoming a focus of health and care sciences, not least due to the growing shortage of skilled workers and the simultaneous rise in the number of people requiring care in Germany. Modern technologies are believed to have the potential to improve the quality of care provision. The CARE REGIO project, funded by the Bavarian State Ministry of Health, Care and Prevention, has established a leading region for modern care technologies in Bavarian Swabia. Kempten University of Applied Sciences leads the consortium, which comprises the universities of Augsburg, Kempten and Neu-Ulm, as well as the University of Augsburg and Augsburg University Hospital.
Sustainable approaches to improving care have been developed. The aim is to provide significant relief for care professionals and family carers, whilst supporting those in need of care in maintaining their independence.

Methods

The project was implemented across six sub-projects: network coordination, the Nursing Data Lake, digitisation of the nursing handover report, assistive systems focused on fall prevention, NursingWiki, and academic support, including ethical, legal and social issues. As part of this, specific measures to improve the framework conditions and processes were implemented and evaluated under real-world conditions. Different methods were used for each sub-project, such as surveys, expert interviews, focus groups and many more.

Results

Each sub-project delivered usable and transferable results, meaning that CARE REGIO makes a lasting contribution to the digital transformation of care and can be regarded as a successful pilot project.

Conclusion

The aim is to provide digitally supported, patient-centred care. The work carried out in the sub-projects demonstrates how and in what specific ways digital technologies can provide concrete support to carers, those in need of care and their relatives, or prevent impending dependency on care. The experience and insights gained will result in recommendations for future implementations.

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A Marker-Based Registration Approach for the Fusion of Ultrasound and 3D Surface Scans

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Introduction

The fusion of ultrasound (US) imaging with three-dimensional (3D) surface scanning enables the combination of internal anatomical and mechanical tissue information with external body geometry. This is particularly relevant for residual-limb assessment in prosthetic care, where soft-tissue condition and external geometry jointly influence socket design and patient comfort. However, accurate registration remains challenging due to fundamentally different imaging principles, separate coordinate systems, limited shared anatomical features, and soft-tissue deformation during acquisition.

Methods

This paper presents a marker-based workflow for spatially consistent fusion of B-mode US, shear wave elastography (SWE), and 3D structured-light surface scans. Consecutive 2D US images were spatially mapped into a common coordinate system using DICOM-embedded probe pose information. Markers were visible in both modalities and detected automatically in US images using a YOLO-based object detection model. Corresponding marker coordinates were used for rigid point-based registration to align the US coordinate system with the surface model, and the resulting transformation was applied to both B-mode US and SWE data.

Results

Evaluation on a phantom, a healthy subject, and a transfemoral amputee demonstrated the effectiveness of the proposed workflow. The YOLO-based detector achieved a precision of 0.96 and an mAP@0.5 of 0.93, enabling reliable marker localization in US images. Rigid registration yielded mean fiducial registration error values ranging from 4.47 to 5.26 mm, and fused visualizations confirmed spatially consistent alignment of internal anatomical structures and tissue elasticity information within the 3D surface model.

Conclusion

The presented workflow demonstrates the technical feasibility of marker-based fusion of US, SWE, and 3D surface scans, enabling reproducible spatial visualization of internal tissue properties within the 3D surface model. This lays the foundation for improved clinical tissue assessment in prosthetic care. Future work will address non-rigid registration strategies that account for soft-tissue deformation to meet the accuracy requirements of quantitative clinical applications.

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Learning Anatomical Variability: Statistical Shape Models for Vertebral Joint Pose Estimation

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Introduction

Non-rigid medical image registration is essential for longitudinal analysis of spinal structures, yet standard intensity-based methods risk anatomically implausible deformations when applied to joints. Constraining such registration to biologically realistic deformations remains an open challenge, particularly for the spine, where complex intervertebral kinematics must be respected.

Methods

We present a data-driven framework combining Statistical Shape Models (SSM) and Active Shape Models (ASM) with kernel Principal Component Analysis (kPCA) to learn and encode vertebral shape variability from CT data. Using 2,627 vertebrae from 234 patients drawn from the VerSe dataset, segmentation masks were converted to surface meshes and preprocessed via Laplacian smoothing. Iterative Closest Point (ICP) registration with explicit scale normalization was applied prior to Coherent Point Drift (CPD)-based landmark correspondence, establishing 500 homologous points per vertebral group. A kPCA model with RBF kernel was trained per group to capture non-linear shape variation. New shapes are reconstructed by projecting into the learned latent space, constraining parameters to anatomically plausible ranges, and inverting the transformation back to world coordinates. Vertebral orientation was estimated via PCA-based local coordinate frames with permutation correction to ensure global consistency across the spine.

Results

Scale normalization prior to ICP yielded a statistically significant mean alignment improvement of 0.83 ± 1.75 mm across all vertebral groups (Wilcoxon, $p < 0.05$). The ASM reconstruction achieved a weighted global mean error of 7.55 ± 2.25 mm on the held-out test set, with per-vertebra errors ranging from 4.82 mm (T2) to 17.51 mm (L5). Intervertebral orientation variability was quantified at $6.77° \pm 7.94°$, $7.88° \pm 9.21°$, and $7.38° \pm 11.16°$ for the x-, y-, and z-axes respectively.

Conclusion

The proposed framework demonstrates that statistical shape priors can robustly encode vertebral morphology and joint pose distributions from routine CT data, providing a foundation for anatomically constrained non-rigid registration in longitudinal spine imaging.

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SANE – Schema-aware Natural-language Evaluation of Biological Data

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Introduction

High-throughput microscopy generates large, structured datasets capturing cellular responses to pharmacological perturbations, but accessing these datasets typically requires SQL expertise. Large language models offer a natural-language alternative, yet their tendency to hallucinate raises concerns about result reliability. We present SANE (Schema-Aware Natural-language Evaluation), a novel paradigm for domain-specific text-to-SQL evaluation: schema-grounded, automatically generated benchmarks tied to real and specific experimental structure.

Methods

We evaluate a custom LLM research assistant that queries a PostgreSQL database of high-throughput drug screening experiments using a 4-bit quantized LlaMA 3.1 model without training or fine-tuning. SANE automatically generates realistic, schema-grounded test queries directly from database contents and experimental structure. The framework systematically derives 572 natural language queries spanning multiple complexity levels including simple retrieval, complex analytical queries, multi-step interactions, and controlled perturbations such as typographical errors and missing context.

Results

The few-shot system achieves 97.2% overall accuracy across all query categories, demonstrating reliable performance without any model training. Simple queries reach 100% accuracy, while complex analytical queries achieve 98.4%. Most failures stem from ambiguous or underspecified inputs, manifesting as overly cautious clarification requests rather than incorrect SQL generation. Only 5 of 16 failures involved slightly incorrect SQL.

Conclusion

These results indicate that few-shot large language models can provide reliable database access in well-defined domains when combined with schema-aware prompting and domain-specific constraints. By eliminating both SQL expertise requirements and the need for model training, this approach significantly lowers barriers to accessing high-throughput biological data for end-users, enabling researchers to directly interrogate experimental results and accelerate data-driven discovery.

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Development of a Wearable Sensor System for Home-Based Assessment of Periodic Limb Movements during Sleep

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Introduction

Restless Legs Syndrome (RLS) is frequently associated with periodic limb movements during sleep (PLMS), which can significantly influence sleep quality. Clinical assessment and treatment follow-up are often performed in a sleep laboratory using polysomnography, which is resource-intensive and does not allow long-term monitoring in everyday life. The aim of this work is to develop a wearable sensor system for objective home-based assessment of PLMS and related sleep parameters.

Methods

The system concept encompasses the development of a wearable sensing approach capable of capturing established disease- and sleep-related parameters, including the periodic limb movement index (PLMI), heart rate, sleep stages and arousals. It further comprises the design of a measurement setup for bilateral lower-limb monitoring and the implementation of signal-processing methods for the analysis of movement and physiological data. A clinical study will be conducted to demonstrate the comparability of the defined sleep parameters with those obtained in the sleep laboratory.

Results

A Shimmer3-based sensing platform was developed to record electrodermal activity (EDA), photoplethysmography (PPG), angular rate, and acceleration. Sensors are placed bilaterally on both feet, enabling the acquisition of movement patterns, sleep position, and periodic limb movements. Based on actigraphy data, it is likely possible to derive a PLMI-like index. EDA is investigated for its potential to provide insight into sleep stages and additional sleep-related parameters. The pulse wave amplitude of the PPG signal will be used to detect arousal and obtain additional information about sleep stages. The ethics application for the planned sleep laboratory validation has been completed.

Conclusion

The developed sensor system is a promising approach for objective and continuous home-based assessment of PLMS. It enables assessments close to everyday life and may support long-term monitoring and therapy evaluation in patients with RLS. The findings provide the basis for further clinical validation and the development of a digital, patient-centered monitoring solution.

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The SafePolyMed Medication Management Center – A patient-centered platform for improving safety in polypharmacy

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Introduction

Polypharmacy is a major contributor to adverse drug events (ADEs), particularly in older and chronically ill patients, due to complex drug–drug interactions (DDIs) and drug–gene interactions (DGIs). Despite advances in pharmacogenomics and digital health, existing medication management tools often lack interoperability, scalability, and meaningful patient involvement. The EU-funded SafePolyMed project addresses this gap by developing a patient-centered, technically interoperable digital platform to improve medication safety and patient empowerment in polypharmacy.

Methods

The SafePolyMed Medication Management Center (MMC) was designed and implemented as a web-based, service-oriented health information system. The MMC follows a modular architecture composed of loosely coupled REST-based services and a browser-based single-page application for patients and healthcare professionals. It integrates curated drug interaction data, pharmacogenomic guideline-based recommendations, patient-reported outcome measures, and secure analytics components. Interoperability is ensured through alignment with established healthcare standards, including ATC, ICD-10, and HL7 FHIR. Data protection and access control are implemented in accordance with GDPR requirements using role-based authorization and consent management.

Results

The first deployed version of the MMC provides functionality for electronic medication plan management, annotation of medications with DDI and actionable DGI information, documentation of pharmacogenomic test results, and structured symptom reporting via patient diaries. A dedicated analytics component enables transparent monitoring of system usage and detected medication-related risks. The architecture supports abstraction of technical complexity for end users while enabling extensibility for future AI-based services, including ADE risk prediction and precision dosing models.

Conclusion

The SafePolyMed MMC demonstrates a feasible and scalable technical approach for integrating pharmacological knowledge, pharmacogenomics, and patient-reported data into a unified medication management platform. Its modular, interoperable design and strong focus on patient empowerment position the MMC as a promising digital solution to improve safety and personalization in polypharmacy management and to support future AI-driven clinical decision support.

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Electroporation-Mediated Membrane Permeability as a Driver of Cardioversion: A Computational Study

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Introduction

Electrical cardioversion terminates cardiac arrhythmias by delivering direct current. Moreover, strong electrical shocks cause transient permeabilization of biological membranes, i.e., reversible electroporation. This mechanism has been suggested as a contributor to cardioversion. This study investigates whether reversible electroporation alone is sufficient to reproduce cardioversion in silico.

Methods

External electric field distributions were calculated for a 2D tissue slab by applying a voltage difference across opposite corners. Local pore densities were assigned proportional to the electric field magnitude. Then electroporation-mediated membrane currents were introduced into a mathematical model of the human atrial cardiomyocyte. This modified cell model was embedded into the tissue model of a 2D tissue slab. The previously computed heterogeneous pore distributions were applied to monodomain simulations where reentrant spiral waves had been initiated. Finally, the effect of varying local pore densities and durations to terminate reentries was assessed.

Results

Increasing the prescribed pore density resulted in a clear transition from unsuccessful cardioversion to wavefront modification and, ultimately, successful reentry termination. For shocks below 450 V, depolarization remained heterogeneous and reentry persisted. In contrast, 500 V shocks yielded complete depolarization and termination of reentry. The voltage threshold for reentry termination was highly sensitive to pore resealing kinetics.

Conclusion

Despite modeling simplifications, these findings demonstrate that transient membrane permeabilization alone can terminate reentrant activity in atrial tissue models, supporting electroporation as a plausible enabling mechanism in shock-induced arrhythmia termination.

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Real-time robotically assisted optical coherence tomography with low-latency surface tracking for large-area skin imaging

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Introduction

Optical coherence tomography (OCT) provides microscopic-resolution, depth-resolved imaging of tissue but is typically restricted to small fields of view and operator-dependent scanning. Robotic OCT systems aim to extend coverage, yet are often limited by low imaging speeds and dependence on external vision systems. In contrast, MHz-rate swept-source OCT enables imaging speeds 2-3 orders of magnitude higher than conventional systems, allowing motion-robust in vivo imaging and large-area coverage. Building on this, we previously introduced large-area robotically assisted OCT (LARA-OCT). However, earlier implementations were constrained by acquisition latency and data-transfer dead times, resulting in discontinuous imaging.

Methods

The LARA-OCT platform, consisting of a seven-degree-of-freedom robotic arm and a self-built OCT system based on a Fourier domain mode-locked (FDML) laser operating at a 3.3 MHz sweep repetition rate, was extended by integration with a real-time acquisition and processing framework. The Lübeck University real-time OCT software (LURO) was interfaced with the robotic control system to enable synchronized data acquisition, real-time image processing and data streaming. Probe distance and two-dimensional orientation information are extracted directly from volumetric OCT data enabling continuous probe-to-surface alignment without additional sensors.

Results

The integration of the robotic platform with the real-time OCT software increases the control loop frequency from a few Hertz to the OCT volume acquisition rate (20-200 Hz). This enables low-latency probe alignment with stable maintenance during motion and large-area mosaic acquisition with minimal dead time, resulting in improvements of approximately 3× in physical area acquisition rate and 3.7× in volume acquisition rate.

Conclusion

Real-time LARA-OCT can enable fast, automatic and surface-curvature independent imaging of large areas. This advancement represents a key step towards clinical deployment, facilitating detection of spatially heterogeneous features beyond localized regions of interest. It further suggests potential for OCT-guided robotic navigation, where high-speed, low-latency depth sensing is essential.

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Automated OCT Probe Positioning System for Contactless and Stable Skin Imaging

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Introduction

Skin burns are common across all age groups, and Optical Coherence Tomography (OCT) is widely used for their diagnosis. However, image quality and repeatability depend on precise and stable probe positioning, as small variations in distance or angle can degrade results. The VivoSight Dx OCT system uses interchangeable standoffs to maintain a fixed probe-to-skin distance during manual operation, but operator-dependent factors such as handling technique and applied pressure can still introduce inconsistencies. In structural OCT imaging, the probe must remain stable for approximately 15 seconds, which is challenging on uneven or anatomically complex surfaces. To address these limitations, this work presents a compact, portable, and contactless automated OCT probe positioning system.

Methods

The proposed system integrates a custom probe holder, a time-of-flight distance sensor, and a motorized linear actuator within a closed-loop control framework. The probe holder was developed using 3D scanning and CAD refinement to ensure secure and accurate mounting of the VivoSight Dx OCT probe. A stepper motor-driven lead screw enables precise axial motion, while the sensor continuously measures the probe-to-skin distance. A control algorithm maintains a predefined target distance, with a tolerance band to reduce sensor noise and prevent oscillations. The system is mounted on a flexible magic arm for clinical adaptability, and all electronic components are housed in a 3D-printed casing to ensure compactness and low weight.

Results

Experiments conducted on human subjects using the hand and forearm demonstrate reliable maintenance of the target probe-to-skin distance (approximately 61–62 mm). The system achieved stable positioning and improved structural OCT image consistency compared to manual operation. High-quality B-scan images were successfully acquired without the use of standoff caps. The tolerance band effectively reduced unnecessary micro-adjustments, ensuring smooth operation during acquisition.

Conclusion

The proposed system enables stable, repeatable, and contactless OCT imaging without the need for standoff caps or complex robotic systems. It reduces operator dependency, improves imaging stability, and enhances clinical usability, while also supporting better sterility and reduced infection risk. Future work will focus on improving sensing alignment and enabling fine user-controlled adjustments to adjust the target distance for anatomical variability.

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Closing the Gap of Model Explanation and True Model Focus

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Introduction

Deep learning models classify electrocardiograms (ECGs) with high accuracy, but their black-box nature hinders clinical adoption. Post-hoc explainable artificial intelligence (xAI) methods aim to address this problem by highlighting decision-relevant ECG regions. However, prior work on xAI methods for ECG classification models showed that different post-hoc methods applied to the same model reveal divergent explanations, raising the question of which faithfully reflects the model's reasoning. Validating these explanations is also challenging, as perturbation-based approaches can introduce domain shifts and artifacts that confound assessments of feature relevance.

Methods

Self-explaining neural networks (SENNs) provide an intrinsically interpretable alternative to post-hoc explanation by learning sample-wise input transformations that are element-wise linked to the ECG and linearly aggregated into classification logits, thereby tying model highlights to the evidence used for prediction. We implemented ECG-SENNsation, a SENN for five-class multi-label classification of 12-lead ECGs using the publicly available PTB-XL dataset. We then evaluated its explanatory focus maps against 12 post-hoc xAI methods using an established stability metric. Pairwise stability differences were quantified by the absolute rank-biserial correlation (r) from the Mann–Whitney U test.

Results

Consistent with previously reported performance from the literature, ECG-SENNsation achieved a macro AUROC of 93.1% on unseen test data. Focus maps demonstrated significantly superior explanation stability compared to all 12 post-hoc xAI methods ($p < 0.0001$). Notably, SENN focus maps outperformed the widely used xAI method Integrated Gradients with large effect size (median stability: 11.15 vs. 34.56, $r=0.878$). Moreover, explanations were in line with clinical knowledge.

Conclusion

We showed that SENNs produce significantly more stable and reliable explanations than post-hoc xAI methods while maintaining comparable classification performance to black-box models. This highlights the potential of intrinsically interpretable model design to improve the trustworthiness of ECG classification. SENNs therefore represent a promising foundation for AI-driven clinical decision support and systematic ECG knowledge discovery.

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CaP-electrodeposition in electrospun PLLA/ZnO nanofiber nonwovens - Bioactive implant coating and scaffold applications

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Introduction

Solid bioactive calcium phosphate (CaP)-based coatings on metallic substrates are established to improve osseointegration of bone implants. Less work is published on highly porous pre-mineralized fiber structures for coatings or scaffolds. In this study, research on electro-chemically mineralized poly-L-lactic acid (PLLA) nanofiber covers is introduced. This work focusses on the feasibility of the manufacture of porous osteoconductive scaffolds with adjustable mineral content.

Methods

Aqueous solutions of calcium nitrate and ammonium diphosphate were used as electrolyte for electrochemical deposition of CaP. The performance of carbon (C), magnesium (Mg) and titanium (Ti) electrode pairs was investigated (voltage: 2 – 20 V). Ti electrodes proved to be advantageous regarding erosion, deposition homogeneity, gas generation, and mineral adhesion, and therefore were covered by electrospun PLLA nonwovens for electrochemical mineralization. Investigations on morphology and chemical composition were performed by scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDX), and optical microscopy.

Results

Recordings of voltage and current revealed a stable operating process. The nanofiber covers were homogenously penetrated by mineral crystals, which enclosed fibers. Chemically reactive electrode materials (e.g. Mg) can be included in the deposited crystals. EDX revealed Mg in deposited crystals when using Mg electrodes. In addition, EDX analysis is suitable for indirect detecting electrode erosion by identifying electrode elements in mineral deposits. Using Ti electrodes, the expected elements with relative Ca/P ratio of 1.2 ± 0.3 were detected.

Conclusion

The degree of mineral fraction can be adjusted by processing time. A voltage of 15 V proved to be the best compromise between deposition rate and process time for the introduced setting with Ti electrodes. A high porosity as well as pre-mineralization is intended, which assumedly allows good cell infiltration and rapid osseointegration of the implant. Further work is intended to involve studies on mineral filling density, other polymer scaffolds, and biological testing.

Keywords: hybrid scaffold, bioresorbable, mineral

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Development of a Ventilated Animal Tissue Free Lung Model for Bronchoscopy

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Introduction

The more you do something, the better you become - this also applies to surgical procedures. Traditional teaching methods are reaching their limits due to limited availability, poor reproducibility, and patient safety concerns. Despite ethical concerns, endoscopy training is still widely practiced on patients worldwide, partly due to a lack of alternative techniques. In contrast, training models provide a controlled environment where theoretical knowledge can be applied in practice. They enable targeted repetition, supporting the development of motor skills and helping beginners improve instrument handling and awareness of tissue structures.

Methods

An artificial bronchial tree was created using additive manufacturing based on a donated dataset and cast in silicone. To simulate ventilation, a Plexiglas tube was designed and sealed in a movable manner using precisely fitted components. To simulate respiratory movement, a linear reciprocating piston was connected to a piston.

Results

Additive manufacturing proved effective for producing the lung. As the lung exhibited comparable peristalsis in a ventilated model, the mould had to be made using a very thin, elastic layer of silicone. For integration into the final model, a mounting plate was designed to securely attach the lung and fit into a Plexiglas cylinder sized according to the required stroke volume. On the opposite side, a sealed yet movable module was connected to a reciprocating piston. The piston motor allows adjustment of speed (0–120/min) and stroke length (3–15 cm), enabling simulation of shallow to deep breathing. The system showed smooth, stable operation with visible periodic ventilation and no detectable vibration.

Conclusion

The results suggest the developed model has potential as a training system for bronchoscopic applications. It realistically simulates physiological pressure and volume changes during breathing and could serve as an optimized platform to train endobronchial valve placement and other ventilation-dependent techniques.

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Mechanical properties of femtosecond laser-patterned micro-implant structures

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Introduction

Laser-induced periodic surface structures (LIPSS) offer great potential for functionalizing metallic implants, such as improving endothelialization within stents. However, ultrafast melting and resolidification can induce microstructural changes, including grain refinement, increased dislocation density, and residual stresses, which may affect mechanical properties. Since stent structures are highly sensitive, this study investigates the influence of LIPSS on the macroscopic mechanical behavior of stainless steel using three-point bending tests, focusing on changes in Young's modulus by comparing structured and unstructured samples within a three-point bending test setup.

Methods

Stainless steel tubes (OD 1.8mm WT 0.125mm) were laser-cut, electro-polished, and structured with LIPSS using a femtosecond laser system. Unstructured samples were used for reference. Three-point bending tests were performed to evaluate elastic behavior and Young's modulus. Surface morphology and dimensions were characterized using SEM, digital microscopy, and microCT. Young's modulus was calculated based on the mechanical and geometrical measurements using Euler-Bernoulli beam theory.

Results

Electron microscopy confirmed smooth unstructured surfaces and periodic LIPSS (850nm) on structured samples. Three-point bending tests showed linear force–displacement behavior, indicating purely elastic deformation. Sample geometry was measured to calculate area moments of inertia. The resulting Young's modulus was 202GPa for structured and 199GPa for unstructured samples, both slightly above nominal values. Overall, LIPSS (height 150nm) did not affect the macroscopic mechanical properties of the stainless steel samples.

Conclusion

This study investigated the influence of LIPSS on the mechanical behavior of micrometer-sized stainless steel structures. The Young's modulus of structured and unstructured samples showed close agreement, confirming unchanged elastic behavior and no impact of the surface modification on the macroscopic mechanical behavior. Thus, the laser-affected zone is sufficiently small compared to the overall cross-section of the investigated structures, indicating that LIPSS represents a mechanically safe functionalization approach. Future studies will address fatigue behavior and long-term performance under physiological conditions.

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A Dynamic In Vitro Periodontal Pocket Model for the Evaluation of Resorbable Drug Delivery Systems

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Introduction

Periodontitis is a prevalent chronic inflammatory disease that leads to loss of tooth supporting tissues. It is caused by a dysbiotic biofilm in periodontal pockets, where pathogens are difficult to eliminate. Resorbable local drug delivery systems (DDS) are clinically relevant for achieving high local drug concentrations while minimizing systemic side effects. However, their development is limited by the lack of physiologically relevant *in vitro* models that replicate key features of the periodontal pocket, such as fluid flow, anaerobic conditions, and multispecies biofilms.

Methods

Within this project, an innovative three-component composite was developed, consisting of the bioresorbable polymer matrix polycaprolactone (PCL), the buffering additive magnesium carbonate ($MgCO_3$), and the antibiotic doxycycline. Monofilament structures were fabricated from this composite using additive manufacturing. Antibiotic release and material degradation were assessed. For biological evaluation, a periodontal multispecies biofilm model was established. In parallel, a dedicated *in vitro* periodontal pocket model was developed to enable biofilm cultivation under anaerobic conditions while simulating physiological fluid flow.

Results

The developed material system enabled controlled drug release over 14 days, with the hydrophobic PCL matrix minimizing initial burst release. $MgCO_3$ stabilized the pH by neutralizing acidic degradation products, thereby protecting dental hard tissues. Testing within the dynamic bioreactor system demonstrated that the DDS effectively eradicated the periodontal multispecies biofilm. The use of the flow-based *in vitro* model revealed robust antibacterial efficacy under conditions that more closely resemble the *in vivo* situation, highlighting the limitations of static testing approaches.

Conclusion

We developed a resorbable drug delivery system with tailored release kinetics for local periodontal therapy, eliminating the need for surgical removal. The developed dynamic *in vitro* periodontal pocket model enables evaluation under physiologically relevant conditions, including fluid flow, anaerobiosis, and complex biofilms, thereby improving the predictive value of preclinical testing and supporting the development of optimized local therapies.

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OCT-Based Characterization of Cardiac Microstructures with Histological Correlation in Ex Vivo Heart Tissue

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Introduction

Early detection of pathological tissue changes improves diagnostic accuracy and patient outcomes. Within the OptoCarDi project, an imaging system with a fiber-based probe is developed to enable optical coherence tomography (OCT) as a high-resolution imaging modality for intracardiac imaging. This work focuses on experimental studies of heart tissue and the correlation of OCT images with histology to better understand OCT image characteristics of cardiac structures in prior to measurements with the catheter probe.

Methods

Ten fresh animal hearts were dissected at the University Hospital Jena. From each heart, 20–30 tissue samples were collected from various atrial and ventricular regions. Investigated features included free-running Purkinje fibers, the endocardial layer (endothelium, connective tissue, myocardium), and chordae tendineae. A subset of samples (> 2cm × 2 cm) was examined by OCT and subsequently fixed in formaldehyde, while other samples were embedded in 1 cm^3 agarose cubes to establish a spatial reference between OCT and cryosectioning. The samples were examined using the Telesto OCT system (Thorlabs, 2 mm imaging depth with 5.5 µm axial resolution in air) to obtain 2.5 mm^3 3D scans of cardiac structures. 30 agarose-embedded samples were frozen and processed to obtain histological sections for direct visual comparison with OCT data.

Results

OCT enabled visualization of cardiac microstructures, including Purkinje fibers and endocardial layers. OCT B-scans showed promising agreement with corresponding histological sections, particularly in agarose-embedded samples with defined spatial referencing. Differences between fresh and fixed tissue highlighted changes in optical contrast and morphology. Based on these data, a preliminary OCT atlas of cardiac microstructures is currently being developed.

Conclusion

OCT enables differentiation of key cardiac microstructures, with histological correlation confirming its validity for structural characterization. The resulting OCT atlas improves understanding of intracardiac morphology and supports further development of catheter-based OCT system within the OptoCarDi project.

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Rectangular Magnetic Pulse Generator for Magnetic Nanoparticle Displacement

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Introduction

Magnetic nanoparticles (MNPs) are widely used in biomedical applications such as magnetic drug targeting and magnetomotive ultrasound (MMUS), where magnetic fields displace MNP inclusions within tissue to enable imaging of their distribution and investigation of mechanical tissue properties. MNPs are attracted by magnetic field gradients, generating localized body forces that drive tissue displacement. Existing pulsed systems have predominantly employed sinusoidal or Gaussian waveforms, limiting achievable impulse characteristics.

Methods

A capacitor-discharge pulse generator was developed using a 6300 µF capacitor charged up to 200 V and discharged through a 4-turn coil via a SiC MOSFET switch, achieving rectangular pulse waveforms. Pulses were characterized across varying amplitudes using a 10 mΩ shunt resistor and oscilloscope. Finite element simulations in COMSOL Multiphysics 6.3 modelled the magnetic-to-mechanical coupling in a viscoelastic tissue phantom (20 × 40 × 40 mm) with a 6 mm spherical MNP inclusion ($\mu_r = 5.5$).

Results

The pulse generator produced magnetic pulses as short as 1 µs with rise and fall times below 200 ns, maintaining a rectangular characteristic across all tested durations. Peak field strength scaled linearly with supply voltage, reaching an estimated 100 mT at 200 V. FEM simulations demonstrated axial displacements of up to 65 µm in response to a 100 mT, 500 µs rectangular pulse, exceeding minimum thresholds reported in previous pulsed MMUS work. For pulse durations above 500 µs, simulated displacements were sufficient to induce shear wave propagation throughout the phantom volume, with micrometer-scale displacements observable across the entire tissue phantom.

Conclusion

A rectangular magnetic pulse generator meeting MMUS requirements has been developed and numerically validated. Simulation results confirm sufficient tissue displacements for MMUS and shear wave elastography. Future work will explore pulsed applications including experimental validation of magneto-acoustic imaging and shear wave elastography, leveraging the generator's variable pulse length and short rise times.

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Development and Validation of a Reaction Chamber for Controlled Molecular Imprinting

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Introduction

Molecularly imprinted polymers (MIPs) are artificial polymer matrices that can be tailored to recognize specific target molecules. Owing to this selective binding capacity, they are promising materials for sensor systems, biomedical diagnostics, and point-of-care applications. Despite their potential, photoinitiated MIP synthesis requires carefully controlled reaction conditions, as UV exposure, reactive chemicals, and insufficient sealing can compromise polymer formation and reproducibility. This work focuses on the development of a dedicated reaction chamber for reliable UV-assisted MIP preparation.

Methods

A compact reaction chamber was designed to combine chemical stability, UV accessibility, and airtight closure. Polytetrafluoroethylene was selected as the main chamber material, while an ethylene tetrafluoroethylene window enabled UV irradiation of the reaction mixture. A perfluoroelastomer sealing component was integrated to minimize leakage and environmental exchange. The system was tested for resistance against synthesis reagents, transmission of 365 nm UV light, and hermetic performance. Internal environmental changes were monitored using a BME280 sensor. MIP formation was evaluated through polymerization experiments, followed by surface analysis using scanning electron microscopy.

Results

The chamber materials remained stable during exposure to the applied reagents. The UV window showed high transparency at 365 nm, allowing about 90% of the incident radiation to reach the reaction area. Sealing experiments demonstrated a largely stable internal atmosphere with only minor variations. During application testing, the chamber supported successful polymer formation. SEM images showed clear morphological differences between samples, and cortisol-imprinted polymers displayed a porous surface structure consistent with molecular imprinting. The design also reduced direct reagent-related damage and improved experimental control.

Conclusion

The developed chamber provides a suitable environment for UV-induced MIP synthesis. Its combination of chemical resistance, UV permeability, and hermetic sealing supports reproducible polymerization and offers a practical basis for future MIP-based sensing and diagnostic technologies.

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Impact of Head-Mounted 3D Visualization on Precision and Ergonomic Load in Experimental Surgical Tasks

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Introduction

Surgery often requires static postures, leading to increased ergonomic strain. Head-mounted three-dimensional visualization (HMD) of a camera feed directed onto the surgical field may overcome these limitations by decoupling visualization from fixed viewing axes. This study investigated the effect of HMD on motor performance, spatial precision, and perceived ergonomic load.

Methods

A custom-developed software pipeline streamed a camera signal (VISERA ELITE II, 30° rigid laparoscope, Olympus Hamburg, 1920 × 1080 pixels, interlaced mode) in real time to a Valve Index HMD (Steam, Bellevue Washington, 1440 × 1600 pixels per eye). The visualization setup was checked for correct image transmission and stereoscopic presentation. A comparison with fixed projection systems was not performed. Ten participants with varying levels of surgical experience (0–20 years) and no prior training performed two laparoscopic tasks (needle-threading and running-suture) in a randomized cross-over design (with vs. without HMD). Procedure time, error rates, collision frequency, and spatial deviation (x- and y-axis) were recorded. Subjective ergonomics, visual disturbance, and dizziness were assessed using visual analogue scales. The Wilcoxon signed-rank test was used for paired samples.

Results

HMD significantly increased procedure times (needle-threading: 75.5 s vs. 387.5 s; running-suture: 131.0 s vs. 290.0 s; $p < 0.001$). HMD was associated with higher error rates, including increased misthreading (6.5 vs. 20.0) and failed stitches (1.0 vs. 4.5; $p < 0.001$).
No significant difference was observed for x-axis deviation ($p = 0.403$), whereas y-axis deviation increased significantly (0.114 mm vs. 0.208 mm; $p < 0.001$).
Visual disturbance was more pronounced, whereas dizziness remained low. Subjective ergonomic ratings were lower during needle-threading ($p = 0.028$) with no significant difference in the running-suture.

Conclusion

HMD reduced efficiency and impaired spatial precision compared with direct vision. Further improvements in image quality, latency, and camera control are required before clinical application.

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Deep Learning Microsleep Classification

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Introduction

Deep neural networks, particularly CNNs, have made significant progress and are increasingly being applied to EEG data. However, due to limited datasets in biosignal analysis, their application remains challenging. The aim of this work is to use CWT and CNN to detect microsleep events (MS) in EEG data using a large dataset.

Methods

The dataset comprises five studies involving 84 participants and over 128 recorded nights in a driving simulator. The recordings include multi-channel EEG signals collected under realistic conditions and cover varying degrees of fatigue. The large number of measurements ensures high data variability. EEG segments were transformed into time-frequency images using CWT and used as input for seven CNN architectures, including ResNet, EfficientNet, and DenseNet, for the classification of microsleep (MS) and sustained attention (SA).

Results

The time-frequency images of the EEG segments generated using CWT resulted in high classification performance across all CNN architectures, with validation accuracies ranging from 94.7% to 96.8%. This enabled a reliable distinction between microsleep (MS) and sustained attention (SA). DenseNet121 performed 1.9% to 2.1% worse than the best models. Furthermore, the sensitivity of all CNNs was 3.5% to 7.1% lower than their specificity.

Conclusion

CNNs demonstrate high performance in classifying CWT-based EEG images even with smaller datasets ($N \approx 4.2 \cdot 10^4$). All models examined converged stably without signs of overfitting and achieved validation accuracies of up to 96.8%. Classical SVM approaches deliver comparable results but require significantly more complex, multi-step preprocessing steps that must be optimized empirically.

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Unlocking Oxycardiorespirograms to Identify Preterm Breathing Patterns: An Exploratory Baseline Classification Study

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Introduction

Detecting central apneas and assessing cardiorespiratory stability are crucial in preterm neonates. Although polysomnography remains the diagnostic gold standard, its routine use is limited. Multi-channel oxycardiorespirograms (OCRG) offer a non-invasive alternative, capturing respiratory patterns, heart rate variability, and oxygen saturation; however, their automated analysis remains underdeveloped. This study explored whether baseline machine-learning approaches can differentiate term-like and preterm breathing patterns as markers of respiratory maturation.

Methods

We retrospectively analyzed 75 OCRG recordings (January 2021–June 2025) from 75 infants with corrected age <52 weeks. A nasal flow-based preprocessing pipeline was developed. As a baseline, we employed both a one-nearest-neighbour classifier using Dynamic Time Warping (DTW) and a random forest classifier to differentiate term-like and preterm breathing patterns. Model performance was evaluated using stratified group 5-fold cross-validation with subject-wise splitting.

Results

The one-nearest-neighbour model achieved a mean accuracy of 0.641, precision of 0.656, recall of 0.641, and an F1-score of 0.648. The random forest model showed a mean accuracy of 0.751, precision of 0.643, recall of 0.751, and an F1-score of 0.665. Classification performance varied by group: term-like breathing patterns were identified with ~75% (one-nearest-neighbour) and ~97.6% (random forest) accuracy, while preterm patterns were identified with lower accuracy (~30% and 2.6%, respectively).

Conclusion/ Future Aspects

While 1-NN showed a differentiation between term and preterm patterns, the random forest correctly identified only ~2.6 % of preterm patterns. The limited detection of preterm patterns highlights the impact of class imbalance, small sample size, and heterogeneity of preterm respiratory physiology. With the need for a more representative dataset, future work will focus on building a more balanced dataset based on selected apnea-linked bradycardial events, and integration of additional physiological monitoring channels to improve robust detection of clinically relevant respiratory instability.

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Designing a High-Throughput Platform for Contraction Analysis in Cardiac Macrotissues

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Introduction

Cardiovascular diseases remain the leading cause of mortality worldwide, while drug development is limited by insufficiently predictive in vitro models. Engineered human myocardium enables functional assessment of cardiac tissue but current high-throughput systems are restricted to auxotonic measurements and cannot capture preload-dependent isometric forces of contraction. This study presents a novel platform enabling intra-plate iFOC measurements under physiologically relevant conditions.

Methods

A new analysis platform compatible with a 48-well cultivation system was developed by removing geometric constraints of the original platform while retaining essential features for tissue handling and cultivation. A contact-based force-sensing tool was used to apply controlled preload and measure iFOC without removing tissues. Engineered human myocardium tissues were transferred after formation and experimentally evaluated in both systems.

Results

The cultivation platform limits preload due to geometric constraints needed for tissue formation, preventing tissues from reaching maximum iFOC. The new analysis platform enabled a significantly extended preload range, allowing full characterization of the preload–force relationship. Experimental validation demonstrated improved measurement capability and suitability for physiologically relevant contractility assessment.

Conclusion

The proposed platform enables non-destructive, high-throughput iFOC measurements with adjustable preload and overcomes key limitations of existing systems. It establishes a scalable basis for automated cardiac tissue analysis and may improve the predictive power of engineered heart models in drug discovery. Future work will address automation, reproducibility and long-term validation.

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Biohybrid Lung Development: Stable Endothelialization of Multilayer Hollow Fiber Membranes under Defined Flow Conditions

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Introduction

Chronic lung diseases remain a major global health burden, and donor organ shortages limit lung transplantation as the only curative option for end-stage patients. Biohybrid lung, based on extracorporeal membrane oxygenation technology and endothelialization of blood-contacting surfaces, aim to improve hemocompatibility and enable long-term respiratory support. A key challenge is the establishment of stable endothelial layers within clinically relevant oxygenator architectures under relevant flow conditions.

Methods

Clinically relevant multilayer hollow fiber membrane (HFM) constructs (3–5 layers) were assembled and seeded with human endothelial cells (ECs). Endothelial confluence was assessed by Calcein staining and ZBTB46 expression under static conditions (24h vs. 48h). Single-layer HFM systems were exposed to continuous and pulsatile flow at flow rates of 15–60 mL/min. Endothelial phenotype was analyzed by RT-PCR, focusing on extracellular matrix markers, coagulation-associated and shear stress–responsive genes. Impact of seeding density (13–29 million ECs) and assembly conditions, including spacer integration and perfusion-assisted seeding, was evaluated.

Results

Confluent endothelial monolayers were achieved across all HFM layers, independent of culture duration, seeding density, or assembly conditions. Under dynamic flow conditions, no differences were observed in extracellular matrix markers (collagen, laminin) or thrombomodulin expression compared to static culture. Tissue factor expression was increased under flow, independent of flow mode. HMOX1 expression was slightly reduced at higher flow rates (60 vs. 15 mL/min), while KLF2 expression was higher under static conditions. Variations in seeding density did not affect endothelial marker expression (e.g. collagen IV, E-selectin, tissue factor).

Conclusion

These results demonstrate two key aspects for biohybrid lung development: (i) the feasibility of scalable endothelialization of multilayer HFM architectures, and (ii) the mechanical robustness of endothelial monolayers under physiologically relevant flow conditions. Together, these findings support the development of endothelialized oxygenator systems with improved hemocompatibility and their potential for extended application in respiratory support.

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Glioblastoma-Associated Epilepsy: An Exploratory Radiomic Analysis of MRI-Derived Morphological and Spatial Tumor Features

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Introduction

Epilepsy is a frequent complication in glioblastoma patients, contributing to morbidity and diminished quality of life, and may reflect underlying tumor biology. It remains difficult to predict using clinical parameters or visual MRI assessment alone. Although MRI data is routinely acquired, its value for anatomically informed assessment of epilepsy-related tumor characteristics remains underexplored. We investigated a retrospective glioblastoma cohort to determine if MRI-derived morphological and spatial tumor radiomic features can predict epilepsy.

Methods

We analyzed a retrospective cohort of 205 glioblastoma patients with multimodal MRI data (T1, T1CE, T2, FLAIR). Images were preprocessed and registered to the SRI24 reference space. Tumor segmentations were generated with top-ranked algorithms from the MICCAI BraTS challenge via BraTS Orchestrator. We extracted morphological and atlas-based spatial features describing anatomical localization. Associations with epilepsy were assessed via exploratory univariate analyses with false discovery rate (multiple-testing) correction.

Results

Exploratory univariate analyses revealed associations between several MRI-derived morphological and spatial markers and epilepsy occurrence. Enhancing tissue surface area ($\rho = -0.2999$, $p = 1.024\times10^{-5}$) was the only feature that remained significant after multiple testing corrections. Further associations were observed for enhancing tissue volume ($\rho = -0.2482$, $p = 2.899\times10^{-4}$) and the fraction of whole-tumor located in the left lateral orbitofrontal gyrus ($\rho = -0.2352$, $p = 6.065 \times 10^{-4}$).

Conclusion

MRI-derived morphological and spatial tumor features, particularly anatomical localization descriptors, are associated with epilepsy occurrence in glioblastoma and demonstrate the feasibility of an imaging-based, anatomically informed analytical framework. These hypothesis-generating findings provide a foundation for future multivariate studies integrating radiomic, clinical, and longitudinal data toward a more comprehensive characterization of tumor-associated epilepsy and its prognostic implications.

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Dynamic fluid phantoms for impedance plethysmography – a proof-of-concept study

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Introduction

Impedance plethysmography (IPG) is a non-invasive sensing technique to assess variations in fluid volumes based on changes in bioelectrical impedance. While physical impedance phantoms are quite common for other methods such as electrical impedance tomography, they are rare for IPG. In fact, IPG investigations require a dynamic system with conductive blood and tissue simulants. Such a dynamic fluid phantom might provide well-defined test scenarios toward more sophisticated analysis methods.

Methods

In this proof of concept study, we implemented two separate impedance phantoms made of gelatin and silicone to assess their suitability for dynamic fluid phantoms in IPG. Our concept for the aquagel phantom involved a full-body structure in which the fluid flows through the body via a narrow channel. For the silicone phantom, we manufactured a conductive tube, which acted as a elastic fluid channel inside of a body filled with tissue simulant solution. We integrated both phantoms into a fluid circulation system with a pulse wave generator, a multi-frequency impedance analyzer, and sensors to assess pressure and volume flow.

Results

For both phantoms, we were able to obtain time-varying impedance signals, which qualitatively correspond to the recorded fluid dynamics in terms of an impedance decrease when more of the conductive blood simulant (pulse wave) passes through the phantom made of less conductive tissue simulant. The recorded base impedances (42 – 55 Ω) and impedance variations (0.15 – 0.4 Ω) were in a value range in accordance with typical IPG signals.

Conclusion

While the aquagel phantom showed mechanical limitations, the silicone phantom appears promising for further research. We understand this study as first step toward a more comprehensive dynamic fluid phantom, which might consider different and more sophisticated operating conditions and the integration with complementary sensor types (e.g., optical sensors) into a multi-modal phantom.

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Discriminability of spatial frequency-reduced EEG microstate patterns

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Introduction

Microstate EEG analysis investigates short-term quasi-stable brain states, usually using four to seven characteristic patterns. The microstate time sequence characteristics are used for medical research on novel biomarkers for neurological or psychological diagnostics. Unfortunately, pre-processing steps are highly study-specific, including spatial filtering to reduce noise and high spatial frequency activity of the EEG topography.
In this work, we propose Spatial Harmonic Analysis (SPHARA) as a new, efficient, and objective approach for EEG preprocessing and identification of microstates by their spatial frequency components. Our aim is to determine the required spatial components for an adequate and efficient representation of EEG microstates.

Methods

We examined canonical EEG microstate templates from 24 independent studies using 58 to 65 electrodes and comprising four to seven patterns. Their spatial frequency characteristics were analysed by transforming the microstate patterns to the SPHARA domain. Regarding the distribution of the signal energy over the spatial frequencies, four levels of reduction (basis function subsets) were investigated: 5, 10, 15, and 20. The reduced pattern sets were evaluated i) by their self-similarity using the within correlation of original and reduced patterns, and ii) by the discriminability of the microstates, using their pairwise between-state correlation.

Results

The reduction of spatial wavelengths to between 100 and 300 mm (5–20 basis functions) results in a reduction of 1 to 5 % of the pattern's overall signal energy. The within correlation depends on the microstate type and the reduction level. Correlations range from 0.967 to 0.997. The between-state correlation of 15 and 20 basis functions shows no considerable difference to the original setup.

Conclusion

Microstate patterns could be represented by reduced spatial frequencies without loss of information. The low-dimensional representations do not limit the discriminability between the microstate patterns and enables more efficient feature spaces.

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Objective Voice Assessment and Real-time Acoustic Feedback for Therapeutic Training

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Introduction

Human speech arises from coordinated neural, respiratory, and articulatory processes and conveys both linguistic and functional information, making it well suited for objective assessment and therapeutic intervention. In clinical contexts, speech is often evaluated subjectively, which can limit reproducibility and consistent monitoring of progress. This highlights the need for objective, quantifiable analysis that supports reliable assessment and continuous monitoring in therapy.

Methods

We developed a system that combines objective voice assessment with real-time acoustic feedback to support therapeutic speech and voice training in patients with Parkinson's disease as well as other speech impairments. Key acoustic parameters, including pitch, amplitude, jitter, shimmer, and speech activity, are captured to provide reproducible assessment. Real-time feedback is delivered through intuitive visual or auditory cues, enabling users to perceive and adjust aspects of voice production such as articulation, prosody, and phonation. The system is designed for both clinical use and independent practice, allowing continuous, self-directed training.

Results

The system enables interactive voice training across multiple acoustic parameters through exercises tailored to individual users, supporting progressive improvement. In addition to its training function, it provides acoustic insights that help distinguish perceptual deficits from physical limitations. The interface facilitates goal-oriented, patient-specific exercises and encourages active, self-directed practice in both clinical and home settings. Initial pilot evaluations assessed system functionality and user interaction with the real-time feedback, with preliminary observations indicating that users were able to engage with the feedback and adjust aspects of their voice production during training.

Conclusion

As a therapist-independent support tool, the system provides personalized guidance beyond clinical sessions, promotes motivated practice, and supports ongoing skill development. It could complement conventional therapy by extending training into home-based settings, thereby enabling more accessible and continuous rehabilitation. This integrated approach may enhance the efficiency, consistency, and reach of speech and voice therapy.

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Opportunities of Collaborative Robots in the Rehabilitation of Upper Extremities

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Introduction

Stroke is one of the most common and most life-altering diseases worldwide. However, due to technical and economical restrictions, therapy times are often limited, obstructing the rehabilitation chances for patients. In fact, therapy is subject to prioritization. While lower extremities usually receive more therapy and have more technical rehabilitation systems available, upper extremities are treated less frequently, and lack flexible, accepted, and economically viable rehabilitation devices.

Methods

We analyze opportunities of collaborative robots to be used as highly flexible upper extremity rehabilitation devices. We organized a workshop with practitioners from robotics and neurorehabilitation, in which we created a shortlist for potential use-cases and discussed them in depth, including observations of therapy sessions. Based on the workshop's results, we drive requirements on the implementation of collaborative robots as rehabilitation devices in neurorehabilitation.

Results

We observe that upper extremity rehabilitation is an underresearched application and that collaborative robots are a viable platform thereof. They offer an improved flexibility compared to market-available systems, are well suited for adoption in neurorehabilitation due to the internal safety and sensory systems, and may lower financial burden for clinics to adopt rehabilitation robots. However, the requirements on rehabilitation systems are high and their implementation complex. Thus, the identified requirements also indicate open research questions, like shared control in ternary systems, that need to be solved to achieve holistic and flexible rehabilitation with collaborative robots.

Conclusion

We conducated a requirements analysis together with practitioners on collaborative robots to be used as upper extremity rehabilitation device in neurorehabilitation. We list a comprehensive overview of the requirements and indicate research gaps in the paper.

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Magnetomotive Tissue Displacement Simulation Pipeline for Ultrasound Imaging

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Introduction

Magnetic Drug Targeting (MDT) employs magnetic nanoparticles (MNPs) for localized cancer therapy, but real-time imaging of their spatial distribution remains a major challenge. Magnetomotive ultrasound (MMUS) offers a promising solution by detecting tissue displacements induced by externally applied magnetic fields. However, the interpretation of MMUS signals is complicated by the interplay between magnetic forces, tissue mechanics, and ultrasound signal formation.

Methods

In this work, we present a comprehensive simulation pipeline for MMUS imaging that models the complete signal chain from magnetic excitation to ultrasound-based displacement estimation. The framework integrates finite element modeling of magneto-mechanical interactions, ultrasound radiofrequency (RF) data simulation, beamforming, and displacement estimation using a global ultrasound elastography approach (2D-GLUE).

Results

Simulation results demonstrate magnetically induced displacements on the order of micrometers, with peak values around 8 µm and characteristic shear wave propagation following pulsed excitation. The reconstructed displacement fields closely match the simulated ground truth, confirming the validity of the pipeline, although minor artifacts arise from ultrasound imaging and estimation processes.

Conclusion

The presented framework enables systematic investigation of MMUS imaging and provides a foundation for developing improved reconstruction methods. It shows that measured displacements do not directly correspond to MNP distributions due to mechanical coupling effects, demonstrating the need for advanced inverse and simulation approaches.

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Smart SWIR wavelength selection for remote heart rate measurements

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Introduction

Remote Photoplethysmography (rPPG) is a vital technology for ambient assisted living, enabling non-invasive monitoring of vital signs for the elderly and reducing the need for manual caregiver checks. This study aims to increase the robustness of heart rate measurements by expanding the spectral range into the infrared and implementing an algorithm that automatically selects the wavelength with the optimal signal-to-noise ratio (SNR).

Methods

The experimental setup utilized a Lucid Vision Atlas SWIR camera (Sony IMX990 InGaAs sensor) synchronized with an LED array emitting ten wavelengths across the visible, near-infrared (NIR), and short-wave-infrared (SWIR) spectra. Multispectral video was captured at 50 frames per second. Cardiac signals were extracted from intensity fluctuations caused by blood pulsation. Blind Source Separation (BSS) techniques, specifically PCA, were employed to decompose the signals and identify the component with the highest SNR. Findings were validated against an ECG reference.

Results

The multispectral approach outperformed methods using a fixed wavelength. While the strongest SNR was typically found in the green and red visible light spectrums, environmental factors such as ambient light and reflections frequently degraded these channels. In such instances, the system successfully identified and switched to more stable NIR or SWIR wavelengths. This automatic detection significantly increased measurement robustness and decreased the frequency of signal failures.

Conclusion

Flexible, automatic wavelength selection significantly improves the reliability of SWIR-based rPPG. These results justify the integration of multispectral imaging in ambient assisted living environments for more dependable continuous health monitoring.

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Temporal interference transcranial electrical stimulation (TI-tES) – technology and application in clinical research

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Introduction

Temporal interference transcranial electrical stimulation (TI-tES) uses two high-frequency stimulation currents; the difference in their frequencies (Δf) is thought to modulate activity in deep brain regions without directly stimulating them with high frequencies. This technology places certain demands on the stimulation setup in terms of galvanic isolation and linearity.
We introduce and evaluate a stimulation setup that covers the entire chain from the current sources to the electrodes as the application interface, and we assess its feasibility for neurophysiological modulation in a pilot functional magnetic resonance imaging (fMRI) study.

Methods

We built on recent hardware designs, realizing parallel current-sources designed for transcranial (±4 mA) and peripheral (±40 mA) stimulation, providing low 1/f noise over a bandwidth up to 5 kHz and rise times of a few microseconds for pulses with a bandwidth up to 200 kHz. The current sources were evaluated for TI-tES performance on a resistor network. Assessments using a physical phantom with different stimulation electrode materials (conductive silicone, Ag/AgCl-coated, and sintered Ag/AgCl) enabled evaluation of signal quality and artifact generation under various stimulation conditions. The feasibility of our stimulation setup to modulate neurophysiological activity in the hippocampus was evaluated in a first-in-human fMRI study.

Results

The introduced current sources demonstrated a well-suited technical performance based on an accuracy of 99.25% in linearity and low intermodulation artifacts below 0.01%. However, the extent of intermodulation artifacts depended on the stimulation electrode material in a recording setup with Ag/AgCl electrodes. Coated Ag/AgCl provided the lowest intermodulation artifacts of 0.8% in the phantom assessment. Correlates of neurophysiological activity were modulated in the left hippocampus as the target area in a first-in-human fMRI study.

Conclusion

Our stimulation setup provides an integrated TI-tES framework combining innovative current sources (low-noise, galvanically isolated, synchronized) with a well-suited stimulation electrode for reliable non-invasive deep brain stimulation paradigms. Phantom-based assessments underscore the importance of electrode material consideration in determining signal fidelity and artifact profiles, guiding translational steps to clinical studies.

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Preliminary results of dry EEG validation using Acoustic Evoked Potentials in Healthy Volunteers

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Introduction

Approximately 5,000 cochlear implants (CIs) are implanted annually in Germany. Optimal therapeutic outcomes require meticulously tuned, individualized CI settings. This adjustment is manual, subjective, labor-intensive, and costly. Further challenges arise particularly for patient groups with reduced compliance. We aim to develop a novel system for objective, individualized CI parameter determination using multichannel electroencephalography (EEG) with dry electrodes. Here, we compare dry EEG against gel-based EEG using acoustic-evoked potentials (AEPs) recorded from healthy subjects to validate the novel dry electrode technology and inform subsequent channel-selection strategies.

Methods

Multichannel EEG was recorded from six normal-hearing volunteers in two sessions, using dry and gel-based EEG caps with 64 channels. Unilateral stimulation was applied via insert earphones. Auditory threshold (T-level) and comfortable hearing level (C-level) were determined for each individual and session. Stimuli consisted of 1 kHz sinusoidal tone bursts at four intensity levels: (i) 3 dB below T-level, (ii) T-level, (iii) midway between T-level and C-level, and (iv) C-level in pseudo-randomized order.
Data was filtered (1–30 Hz band-pass, 50 Hz notch) and subsequent manual bad channel and bad trial rejection. AEP and Global Field Power (GFP) were calculated by averaging corresponding trials per subject.

Results

Channel reliability and preparation time of the gel-based and dry EEG system are comparable to prior validations. As expected, sub-threshold auditory stimulation does not elicit measurable AEPs. Threshold-level stimuli rarely elicit AEPs while above-threshold stimulus intensity successfully induces AEPs in both dry and gel-based caps with comparable results in all metrics (latency, SNR, GFP and topography).

Conclusion

The results show promising outcome and replicate prior validation studies of dry electrodes for differing applications and focus, highlighting the applicability of dry EEG for AEP recordings. Our preliminary findings support the feasibility assumption of using AEPs for automated CI parameter selection in future closed loop CI fitting protocols.

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Description of a haptic user interface for remote palpation

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Introduction

Precise detection of tumor boundaries critically influences outcome quality of tumor excision surgery. While stiffness is a suitable indicator for discrimination between healthy and diseased tissue, this tool is available to surgeons only to a limited extent during minimally invasive surgery or robotically assisted surgery. Haptic feedback can be a valuable addition to the current use of visual cues and reduced haptic sensations, and provides the opportunity to display measured tissue stiffness directly.

Methods

We propose a method to provide stiffness information for remote palpation using a device with a series elastic actuator and describe an implementation in detail. The device's pose is tracked to palpate a virtual object in the form of a stiffness point cloud, acquired from automated force and indentation depth measurements. Two tracking methods, one based on a sensorized, passive kinematic chain, and one based on ArUco markers and a webcam, are described.

Preliminary Results

In preliminary tests, the device and tracking showed promise regarding their suitability for stiffness display of data collected from a soft silicone tissue phantom with a stiffer inclusion. The two tracking methods are compared to a CNC machine as reference, with mean euclidean distances of [1.54±0.92, 12.17±5.73] mm between reference and the marker and kinematic chain methods, respectively. The haptic device is able to display force errors <10% in a range of 1 to 6 N.

Conclusion

The technical evaluation and optimization of the complete implementation remain in progress. A user study is planned to quantify the method's suitability for inclusion boundary detection.

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Teaching Systematic Innovation in Biomedical Engineering: Integration of TRIZ into Medical Engineering Education

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Introduction

Medical engineering involves rapid technological progress and patient-specific solutions, requiring both technical expertise and systematic problem-solving skills. Traditional analytical models like the V-model structure problem-solving but require creativity, which can be challenging for students. This paper investigates whether TRIZ can enhance creativity and innovation in medical engineering education.

Methods

TRIZ (Theory of Inventive Problem Solving) is a structured methodology for developing innovative technical solutions by identifying and resolving contradictions. Developed by Genrich Altschuller through the analysis of 1.5 million patents, it offers 40 inventive principles and tools like the Contradiction Matrix. TRIZ complements methods like VDI 2221 by supporting early development phases. At the University of Stuttgart, TRIZ is integrated into student projects. Some students apply it in final theses, present it to peers, and create their own materials; in one project —combining two vital-sign measurement prototypes—it is explicitly required..

Results

Students formulated the problem as an if–then condition and identified a contradiction between improved ease of operation and increased volume. Using the contradiction matrix, they derived four inventive principles and selected asymmetry as the most promising. This led to ideas such as asymmetrical sensor placement, rotating the measured object, and asymmetrical housing design, including timing adjustments. Overall, twelve solution variants were generated. Feedback was positive, and teachers observed a more structured approach.

Conclusion

TRIZ reduces dependence on individual creativity, experience, or chance by providing a structured framework for problem solving and reuse of inventive patterns. It helps generate innovative solutions even for seemingly unrelated problems. However, it can be complex and time-consuming due to its extensive toolbox. In contrast, VDI-based methods guide the process but focus more on how to reach a solution than on generating solution ideas. Therefore, TRIZ is a valuable complement in engineering education, especially for fostering creativity and innovation in students.

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A comparison of different magnetometers for magnetorelaxometry of magnetic nanoparticles

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Introduction

The magnetization dynamics of magnetic nanoparticles (MNP) can be characterized through the use of magnetorelaxometry (MRX). A pulsed DC magnetic field aligns the magnetic moments of the MNP, after which a sensitive magnetometer is used to measure the relaxation of the net magnetic moment, as described by Brownian and Néel relaxation. Utilizing a multi-sensor and multi-excitation configuration, MRX can be translated into an imaging modality.

Methods

The objective of this study is to compare different commercially available magnetometers for MRX. We investigate superconducting quantum interference device magnetometers (low-Tc SQUID), optically pumped magnetometers (OMG and PPM from Twinleaf, QZFM from QuSpin), fluxgate magnetometers (FL100 from Stefan Mayer Instruments and DRV425 from Texas Instruments), magnetoinductive sensors (RM3100 from PNI Sensor), and magnetoresistive sensors (AMR2501 and TMR8501 from Multidimension Technology). These sensors exhibit a range of different characteristics beside technology, including varying standoff distances, bandwidths, different noise levels and dead times. The magnetometers are examined for two exemplary MNP samples: one exhibiting fast relaxing (~1 ms time constant) and the other one slowly relaxing (~1 s time constant). The samples are implemented as liquid resp. gypsum-immobilized sample of Perimag (micromod Partikeltechnologie). The excitation field employed in all experiments is consistent, with a maximum flux density of 5 mT magnetizing the MNP. We derived mathematic models of the sensor responses in order to predict signal-to-noise ratios based on sensor and setup parameters (bandwidth, sampling rate, dead time, noise spectrum, sensing area/volume, sensor standoff).

Results

A quantitative metric for the assessment of MRX setups with different boundary conditions was developed. For large sensor-to-target distances (e.g. > 5 cm), SQUID or OPM are recommended. Nevertheless, in specific scenarios involving small distances and short relaxation times, alternative magnetometers demonstrated superior performance in comparison to SQUID and OPM.

Conclusion

The systematic comparison of MRX setups resulted in an easy-to-use metric for selecting the optimal sensor for specific MRX characterization and imaging setups.

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An Open-Source Simulation Model of a Medical Oxygen Concentrator

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Introduction

Medical oxygen is essential for modern healthcare, yet access remains limited in many regions worldwide. Portable oxygen concentrators based on pressure swing adsorption (PSA) offer a decentralized solution but contribute significantly to the energy demand of healthcare facilities. A detailed understanding of their dynamic process behavior is required to improve efficiency. However, existing models often neglect relevant transport effects or system interactions. This work develops a system-level dynamic model of a PSA-based oxygen concentrator, validated against experimental data from a commercial device.

Methods

A dynamic model of a PSA-based oxygen concentrator is developed using a one-dimensional isothermal formulation. The model describes mass transfer, adsorption kinetics based on a linear driving force approach, and pressure drop using the Ergun equation within the adsorption columns. A compressor model and mass balances for the connected volumes are included to represent the complete system. The equations are discretized using a finite volume method and solved numerically in MATLAB.

Results

The simulation results show that the model accurately reproduces the dynamic behavior of the oxygen concentrator, including the propagation of concentration fronts over the PSA cycle within the adsorption columns. The temporal evolution of the oxygen mole fraction in the product gas tank is reproduced in close agreement with the experimental data. The largest deviations occur during the initial transient phase, while the cyclic steady-state behavior is accurately captured.

Conclusion

A dynamic model of a PSA-based medical oxygen concentrator has been developed and validated against experimental data. The model provides a consistent system-level description of the coupled process dynamics and captures the key characteristics of the PSA operation. It can be used to systematically analyze operating conditions and to assess and improve the energy efficiency of oxygen concentrators. Future work will focus on extending the model by incorporating additional gas components and more detailed component descriptions.

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Towards a Pseudo-Labeling Workflow for Celltype-Classification from Explanted Brain Slice Recordings

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Introduction

Neurodegenerative diseases can lead to sensory and motor impairments in humans. Brain-computer interfaces can partially restore these functions. Epilepsy poses a major societal challenge due to the unpredictability of seizures, limiting patients' autonomy, safety, and social participation while placing a significant burden on healthcare systems . This paper presents a machine learning-based workflow to derive pseudo-labels for identifying pyramidal cells and interneurons from spike waveforms in extracellular micro electrode array (MEA) recordings. We determine the quality performance and assess online feasibility through data curation.

Methods

We used brain slice recordings from the Koch Group. It contains extracellular recordings from the human neocortex. We use the Open Source Python framework denspp.offline for deploying different end-to-end signal processors. Applying common pre-processing, we permutated different feature extraction methods (PCA, t-SNE, UMAP). Up to three features are used for clustering with GMM and k-Means. The quality performance is determined with mean pairwise Pearson correlation, inter- and intra-cluster distance by the Silhouette Score and Calinski-Harabasz Index.

Results

Among classical pipelines, t-SNE + k-Means achieved the highest within-cluster similarity (0.806→0.856), followed by UMAP + GMM (0.806→0.854). Cleaning increased similarity consistently by ≈0.04–0.06 (e.g., PCA + k-Means: 0.744→0.801; t-SNE + GMM: 0.782→0.841). Template matching yields the highest within-cluster similarity (0.85–0.87) but weak separation (CH: 1.6k–2.7k, silhouette: 0.20–0.27). OSort shows a clear similarity–separation trade-off. Strict attains the best separation (silhouette 0.478, CH 5.25k) with high similarity (0.838); majority yields the highest similarity (0.869) but weak separation (silhouette 0.134, CH 1.23k); all lies in between (similarity 0.827, silhouette 0.185, CH 2.08k).

Conclusion

We compared different pipelines in order to evaluate a configuration to deploy a real-time–capable classifier for brain slice recordings. Moreover, the evaluation shows that different feature-extraction and clustering approaches in combination with a data curation provide complementary strengths, supporting the robustness of the overall pseudo-labeling strategy.

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An Interdisciplinary Approach to Integrate Sustainable Development into Teaching for Biomedical Engineering

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Introduction

Engineering sciences, in particular biomedical engineering, can provide important technological solutions that contribute to the United Nations' Sustainable Development Goals (SDG). However, sustainability is often only marginally addressed in engineering curricula and rarely in an interdisciplinary context. The recently launched project Sustainable Health Technologies at Ulm University addresses this gap by systematically integrating sustainability into undergraduate and postgraduate teaching. Our four-year project is funded by the Carl-Zeiss-Stiftung and aims to establish sustainability as a recurring theme in engineering education and to promote responsible technological development by combining ecological, social, and interdisciplinary perspectives.

Methods

Implementation will be carried out through several complementary approaches:

- Development of an interdisciplinary SDG module series (fundamentals and application).
- Creation of a case study pool as an open educational resource to facilitate the integration of sustainability topics into existing courses by lecturers from different disciplines.
- Implementation of specific measures in the Bachelor's program *Biomedical Engineering*, including sustainability-related student projects and the new Biomedical Engineering Master's specialization *Sustainable Health Technologies*.

The entire project will be continuously monitored to evaluate its impact on students and teachers using both quantitative and qualitative metrics.

Initial implementation

As a first step, we conceived an interdisciplinary and interactive SDG lecture module in which experts from various fields, such as engineering sciences, medicine, economics, and psychology, give short lectures outlining sustainability-related challenges in their respective domains to students from different study programs.
Students then work in interdisciplinary groups on a concrete project and are required to obtain the necessary expertise by actively consulting and questioning these experts.

Outlook

The first cycle of the new SDG module and the new specialization will start in the winter semester 2026/27. At the same time, as part of a doctoral thesis, we will assess the implementation and outcomes of the program and provide recommendations for future improvements.

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Surface Electromyography based Detection of Neck and Shoulder Muscle Fatigue using Maximal Overlap DWT and Entropy Features

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Introduction

Prolonged use of computers and handheld devices is a major contributor to neck and shoulder musculoskeletal disorders, often leading to muscle fatigue. Muscle fatigue causes reduced force capacity and altered neuromuscular activity, assessed using surface electromyography (sEMG). However, its nonlinear and nonstationary nature complicates analysis.This study aims to detect and analyze the neck and shoulder muscle fatigue conditions using sEMG signals combined with multiscale signal processing and computational learning models.

Methods

The sEMG signals were acquired from the Sternocleidomastoid (SCM), Splenius Capitis (SPC), and Trapezius (TPZ) muscles of fifty healthy volunteers (29 males & 21 females) during routine laptop work to induce neck muscle fatigue under controlled conditions. The experimental protocol is designed for twenty minutes and sEMG signals are recorded for same duration from respective muscles. Discomfort levels were monitored using the Borg CR-10 scale to identify fatigue onset. The recorded signals were preprocessed and decomposed using the Maximal Overlap Discrete Wavelet Transform (MODWT) with a Daubechies (db4) mother wavelet. Shannon Entropy (SE) and Permutation Entropy (PE) were extracted from the resulting sub-bands to capture signal irregularity and temporal complexity. These features were then used for classification using Support Vector Machine (SVM) and Convolutional Neural Network (CNN) models.

Results

The seven level MODWT decomposition is applied to the preporcessed sEGM signals from SCM, SPC and TPZ. The decpmposition of SCM reveals distinct multiscale characteristics across detailed coefficients (D1–D7) and approximation coefficients (A7), confirming the nonstationary nature of sEMG signals. Higher-frequency bands show lower variations, while mid-frequency components (D4–D6) exhibit pronounced activity. The SE and PE features are extraced from the detail and approximation coefficients and found to be distinct in both conditions across all muscles ($p<0.05$). The distribution of entropy features demonstrated that clear discrimination between non-fatigue and fatigue conditions, particularly in the mid-frequency bands (D4–D6), indicating increased irregularity and altered temporal dynamics during fatigue. The CNN achieved a higher classification accuracy of 89% compared to 87.50% obtained using the SVM. These results confirm the effectiveness of entropy-based features in capturing fatigue-related changes in sEMG signals.

Conclusion

The proposed MODWT based entropy analysis, combined with computational learning models such as SVM amd CNN, provides a reliable framework for detecting and monitoring neck and shoulder muscle fatigue conditions. These findings highlight the potential of this approach for developing the continuous fatigue monitoring and fatigue assessment systems in ergonomics and rehabilitation applications.

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Modelling the hydrolytic degradation of polymeric implants accelerated by magnetic nanoparticle heating

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Introduction

Bioresorbable scaffolds made of degradable polymers such as poly(lactic-co-glycolic) acid (PLGA) are envisioned to support tissue regeneration and disintegrate once no longer needed. However, the device's degradation rate cannot be adjusted once implanted, preventing personalized treatment. Embedding magnetic nanoparticles (MNP) into the scaffold enables control over the degradation rate in vivo via local heating using an alternating magnetic field. To assess the effect of MNP heating on the degradation, a spatially resolved, mechanistic model which can capture steep internal temperature gradients is required.

Methods

Following recent approaches, the degradation process is described by a system of coupled differential equations, which model autocatalytic hydrolysis and diffusion of soluble oligomers. MNP clusters are incorporated as heat sources in varying shapes and distributions throughout the scaffold. The temperature dependence of reaction rate and diffusion coefficients is modelled via the Arrhenius equation. The model is numerically solved using the finite element method in the commercial software COMSOL Multiphysics.

Results

The polymer's degradation is accelerated by MNP heating. This is enhanced by the autocatalytic effect: When the MNP clusters generate heat at the scaffold center, acidic oligomers are produced by hydrolysis faster than they can diffuse out of the polymer. They catalyse further reaction, locally decreasing the average molecular weight. Device mass loss is initially delayed, and drops once advanced degradation is reached, allowing for the trapped oligomers to diffuse out. The impact of autocatalysis on the degradation rate depends on the density of the MNP distribution and the diffusion distance from the heat spots to the polymer surface.

Conclusion

Degradable polymeric materials containing MNP provide a way to design temporary and drug eluting implants with dynamically tailorable response to therapeutical needs. Numerical simulations demonstrate to be capable of predicting the behavior of the complex interactions between MNP heating and hydrolytic degradation.

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Influence of Pulse Shape on Respiratory Response in Non-Invasive Phrenic Nerve Stimulation

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Introduction

Mechanical ventilation is a life-saving therapy widely used in intensive care. Inactivity of the diaphragm during ventilation leads to rapid muscle atrophy, complicating the weaning process. Electrical phrenic nerve stimulation has shown potential to mitigate respiratory muscle degeneration. While optimal stimulation waveforms have been explored in digital twins, their transferability to humans remains unclear. Based on these findings, we hypothesize that asymmetric biphasic pulses improve stimulation efficiency compared to symmetric pulses.

Methods

Eleven healthy volunteers provided written informed consent and received bilateral non-invasive phrenic nerve stimulation at the neck. Stimulation (1.5 s, 30 Hz) was synchronized with the onset of inhalation using a 1 × 1 cm cathode and a 10 × 4 cm anode frame. The superior edge of the anode was aligned with the level of the cricoid cartilage, with its vertical midline positioned over the sternocleidomastoid muscle. Symmetric biphasic pulses (150 µs per phase) were compared to asymmetric biphasic pulses (150 µs first phase, 150 µs interphase delay, 1500 µs second phase at one-tenth amplitude). Stimulation amplitudes relative to the individual threshold (80%, 100%, 120%) were applied in randomized order. Inhalation volumes were measured via spirometry and normalized to the median volume of spontaneous breathing.

Results

Symmetric pulses increased median inhalation volumes to 115.6%, 123.6%, and 128.1% for 80%, 100%, and 120% amplitudes, respectively. Asymmetric pulses resulted in 121.2%, 124.7%, and 133.6%. Although asymmetric pulses consistently resulted in higher volumes, statistical significance was observed only at 80% amplitude ($p<0.01$, Wilcoxon signed-rank test).

Conclusion

Asymmetric biphasic pulses show a quantitative advantage over symmetric pulses in non-invasive phrenic nerve stimulation. The significant effect at lower amplitudes suggests improved efficiency in neural recruitment or indicates limited statistical power at higher amplitudes. Future studies should include larger study groups and patient populations to validate clinical applicability.

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Developent and Validation of a Test Setup for the Assessment of Large-Diameter Tubular Vascular Graft Compliance

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Introduction

Cardiovascular diseases are increasingly prevalent and can cause multiple forms of vessel degeneration. Commonly used vascular grafts, however, do not match the native vessels' compliance and can therefore negatively influence hemodynamics. Without precise measurement methods, differences in compliance of large-diameter tubular prostheses remain difficult to compare and quantify. This study presents a dedicated modular *in vitro* test setup designed to quantify the compliance of large-diameter tubular vascular prostheses in accordance with ISO 7198.

Methods

This stand-alone test setup consists of a reservoir, a pulsatile pneumatic pump and a compliance chamber, as well as three-dimensionally printed prosthesis holders allowing for the analysis of various implants. Pressure, graft diameter, fluid temperature, implant elongation and flow are continually monitored. Sensor-based measurements are visualized on a touchscreen. To validate the test setup, the dynamic radial compliance of novel electrospun prosthesis prototypes and porcine aortas was evaluated.

Results

The setup enables precise adjustment of systolic and diastolic pressure levels relevant for fluid-dynamic assessment (measured ranges 90/50, 120/80, and 150/110 mmHg). Pressure stability can be maintained within ±0.75 mmHg. Temperature can be held at 37°C. Graft diameters are measured with a precision of ±0.01 mm. With these controlled conditions, the measurement setup fulfills the requirements specified in DIN EN ISO 7198 for vascular graft testing. Dynamic radial compliance of the prosthesis prototypes (n=8) was measured at 1.85±1.7 %/100 mmHg, 1.68±1.8 %/100 mmHg, and 1.85±1.7 %/100 mmHg, for physiological pressures of 90/50 mmHg, 120/80 mmHg, and 150/110 mmHg, respectively. Corresponding values for porcine aortas (n=5) were markedly higher (16.6±2.5 %/100 mmHg, 10.4±3.28 %/100 mmHg, and 6.3±2.26 %/100mmHg).

Conclusion

The presented test setup enables precise simulation of physiological pressure ranges and high-resolution measurement of mechanical and fluid dynamic parameters. The system therefore provides a practical platform for standardized *in vitro* compliance testing of vascular implants.

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Neurostimulation treatment for epilepsy: from the established to the unknown

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Introduction

Neurostimulation treatment established as a safe and effective therapeutic option for people with drug-resistant epilepsy. In most cases, it achieves a good clinical response with responder rates of up to 75%. However, the underlying pathophysiological mechanisms are not yet fully understood, and treatment management is still based on subjective criteria.

Methods

The talk provides an overview of the neurostimulation procedures approved to date and their concepts. It also summarizes the current state of knowledge on biomarkers in the context of neurostimulation for epilepsy and provides an outlook on systems still in development..

Results

There are currently three approved neurostimulation procedures available in Europe: vagus nerve stimulation (VNS), deep brain stimulation, and focal cortex stimulation. These differ significantly in terms of stimulation application, i.e., focal stimulation versus remote stimulation. Their use is safe and effective and can achieve a seizure frequency reduction of up to 75%. Meta-analyses and multicenter studies have enabled the identification of initial clinical predictors for a good response. In addition, scientific analyses of electrophysiological revealed that later responders and non-responders can already be differentiated perioperatively. Non-invasive systems such as transcranial direct current stimulation and transcutaneous auricular VNS are currently undergoing clinical testing.

Conclusion

Current neurostimulation methods already allow for individualized application. Growing clinical and scientific evidence enables more objective and optimized therapy management. Non-invasive neurostimulation systems are currently undergoing clinical testing and would greatly benefit therapy application, especially for vulnerable patient groups.

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Platform4Health.Ruhr: A Project for Improving Healthcare Access in the Ruhr Region with an interactive Navigation and Information Platform

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Introduction

Navigating the German healthcare system and accessing health information is becoming increasingly complex due to growing healthcare demands for prevention, health promotion, and health care services. Tools are needed to enable people to navigate structures and services despite differences in vulnerability, resources, and capabilities. The project Platform4Health.Ruhr consists of aa step-wise approach for the design and implementation of a platform that enables people with diverse needs to independently and autonomously access information on health topics and navigate the healthcare system, either digitally or locally in their urban community.

Methods

In this work, we propose the project Platform4Healthh.Ruhr, which uses a hybrid methodology of requirements engineering and agile development to develop an innovative platform.

Results

The presented project aims to develop a platform for personalized responses to queries related to prevention, health promotion, health care and to regionally contextualized services and gives citizens in the Ruhr area.
The project consists of 4 main phases:

1. Requirement Analysis,
2. Design of User Interface and Content Creationn
3. Implementation of interactive Platform
4. Evaluation

Conclusion

The project started in Fall 2025 and develops an advanced digital health platform for the Ruhr region that provides digital health information in a variety of formats, taking into account individual needs and being tailored to the needs and requirements of various potential user groups.

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Zeta potential and endothelialization of implant materials

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Introduction

The long-term performance of implants is governed by biocompatibility, which is strongly influenced by surface properties such as wettability, charge, and topography. These parameters regulate protein adsorption and cell adhesion at the material-tissue interface, thereby controlling tissue integration and immune responses. Polymer-based implants are widely used due to their tunable properties and surface modification potential. The zeta potential, reflecting surface charge in aqueous media, is a key determinant of protein corona formation and subsequent cell interactions. This study investigates how zeta potential of biomaterials influences cell-polymer interactions.

Methods

Polymer films of thermoplastic polyurethane, polycarbonate urethane, poly(L-lactide), poly(L-lactide-co-caprolactone), and poly(L-lactide-co-glycolide) were fabricated via gel casting and characterized by scanning electron microscopy. The zeta potential was measured using the streaming potential method. Cytotoxicity of material extracts was assessed according to ISO 10993 using a resazurin-based assay. Morphology of endothelial cells on the polymer surfaces was analyzed by fluorescence microscopy.

Results

SEM revealed distinct differences in polymer film topography, ranging from smooth (PLGA, TPU) to textured or heterogeneous structures (PLLA, P(LLA-co-CL), PCU), while ePTFE exhibited a fibrous structure. All materials showed negative zeta potentials, which became less negative after serum treatment (except TPU). No cytotoxicity was detected. Endothelial cells adhered well to PLLA, PLGA, TPU, and PCU, but poorly to P(LLA-co-CL) and especially ePTFE. Serum treatment had little effect except on ePTFE. Overall, zeta potential changes did not correlate with endothelial adhesion or morphology.

Conclusion

Untreated aliphatic polyesters, polyurethanes, and ePTFE showed distinct negative zeta potentials, but these differences largely disappeared after serum incubation, indicating masking by adsorbed biomolecules. Accordingly, surface charge had only minor effects on endothelialization, suggesting that protein adsorption dominates cell response. Thus, zeta potential alone is insufficient to predict endothelialization, and additional surface parameters and biological conditioning must be considered.

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LifeStream SLEEP: A Cloud-Native Platform for Gender-Aware Sleep Medicine

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Introduction

We present LifeStream SLEEP, a cloud-native platform engineered for medical, pharmaceutical, and life-science applications that require secure, scalable, end-to-end data pipelines. The framework provides device-agnostic sensor integration via SDKs and standard APIs (e.g., for wearable biosensors or radio-frequency radar and EEG systems) and harmonizes incoming data (acquisition, de-identification, encryption) into uniform models. User interfaces follow established UI/UX patterns for biomedical signals (e.g., EEG, ECG, vital signs), reducing development overhead. Data and algorithms are managed in a compliant, enterprise environment for reproducible training and deployment. All components use containerized microservices for elastic scalability, and versioned data pipelines facilitate future AI/ML training.

Methods

In a BMBF funded project on gender-specific obstructive sleep apnea (OSA), LifeStream will be customized for inclusive monitoring and analysis. OSA manifests differently by sex, and women often exhibit hypopneas and arousals that standard tests miss. Our system communicates with contactless RF radar and skin-friendly EEG sensors build by Fraunhofer IDMT for unobtrusive, long-term sleep monitoring. LifeStream's analytics pipelines ingest these multimodal signals, enabling AI models to detect apneas. The user interface of the platform visualizes complex sensor and vital data in a way that is understandable to primary care physicians and sleep medicine specialists, thereby supporting communication among physicians, patients, and specialists. Additional, an intelligent chat-assistant („INSIGHT“) interprets visualizations into clear, human-readable insights for clinicians and patients.

Results

Our user interface and co-pilot will be specifically designed for the target group through co-creation workshops with end users, with a focus on gender-specific differences. The interface will be continuously optimized based on user feedback.

Conclusion

By bridging AI prototyping and production in a secure, gender-aware platform, LifeStream accelerates biomedical innovation, ultimately improving early, tailored diagnosis and treatment for all patients.

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Feasibility Study on Automated Classification of Colposcopy Imaging for Cervical Cancer

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Introduction

Cervical cancer remains the fourth most common malignancy among women worldwide, with over 660,000 new cases annually. Colposcopy is crucial for determining appropriate treatment, which relies on accurately classifying the cervical Transformation Zone (TZ) into Types 1, 2, and 3, as well as grading lesions as minor or major according to the 2012 Rio Classification. However, the procedure remains highly subjective and prone to error. As AI-based classification systems can support robustness and existing approaches lack standardization for multi-site clinical translation, we present a deep learning prototype for the automated classification of cervical TZ types from 2D colposcopy images.

Methods

We utilize the publicly available Intel & MobileODT Cervical Cancer Screening dataset containing colposcopy images collected globally from low-resource or underserved regions and labeled by expert gynecologists into three TZ classes. Our image classification pipeline was implemented using the in-house standardized AUCMEDI framework, employing a ConvNeXt with transfer learning based on ImageNet. The methodology includes extensive online image augmentation, adapted resizing and intensity normalization, class-weighted focal loss to address class imbalance, and ensemble learning through 3-fold bagging (mean-aggregation). Data is split at patient level with stratified cross-validation to prevent data leakage.

Results

Initial experiments on the benchmark demonstrate promising classification performance with F1-scores of $0.70_{\pm 0.05}$, $0.68_{\pm 0.06}$, and $0.70_{\pm 0.07}$ for Type 1, 2, and 3, respectively, competitive with prior published benchmarks on this dataset. As expected, differentiating between Types 2 and 3 remains highly challenging due to the inherent ambiguity caused by an obscured squamocolumnar junction. Qualitative evaluation is currently in progress on a retrospectively curated in-house colposcopy dataset at the University Hospital Augsburg.

Conclusion

This work presents a proof of concept for an AI-assisted cervical TZ classification system. Future work focuses on retrospectively clinical validation and the integration of explainable AI methods to support clinical trust and adoption.

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Accuracy of Stereo Endoscope Calibrations for Forward and Oblique Optics

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Introduction

Accurate geometric calibration is a prerequisite for metric 3D reconstruction from stereo endoscopes, but practical deployment is complicated by non-standard optics such as angled views, strong lens distortion, and clinically realistic image artifacts including specularities and low texture. In addition, internal device-specific image processing may affect the repeatability of the effective camera geometry.

Methods

We evaluated two calibration methods for a stereo endoscope with interchangeable 0º and 30º viewing directions: (i) a planar-target-based calibration using an AprilGrid-style fiducial pattern and (ii) a reconstruction-based calibration approach that optimizes geometric consistency from stereo correspondences. To assess repeatability, data were acquired in three independent recording sessions per optical configuration with device resets in between. Calibration quality was quantified by measuring known distances on two reference objects and by analyzing distortion magnitude maps.

Results

Both calibration methods produced visually plausible rectification. Quantitative evaluation, however, showed that metric accuracy strongly depended on image location. For the teeth prosthesis, with landmarks near the image center, measurement errors remained low (MAE: 0.2491-0.4308 mm). In contrast, the metallic specimen, which also included peripheral measurements, showed substantially larger errors (MAE: 1.7329-2.7981 mm). Distortion analysis further revealed a more anisotropic and off-center pattern for the oblique optics as well as noticeable changes across repeated acquisitions, indicating limited repeatability of the effective intrinsic geometry.

Conclusion

The results show that visual rectification quality alone is not sufficient to assess calibration performance in stereo endoscopy. Reliable intraoperative 3D measurement requires quantitative validation of both accuracy and stability, especially for oblique optics and for measurements outside the central low-distortion image region.

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Self-Supervised State-Aware Modeling for Robust Analysis of Noisy Ballistocardiographic Signals from Bed-Integrated Sensors

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Introduction

Bed-integrated force sensors enable unobtrusive acquisition of ballistocardiographic (BCG) signals for contactless monitoring of vital parameters. In practice, however, these signals are strongly affected by motion artifacts, posture-dependent morphology changes, and non-stationary sensor coupling. Conventional signal processing often requires heuristic tuning and lacks robustness, while supervised learning approaches depend on labeled datasets that are rarely available. This work proposes a state-aware framework that combines self-supervised representation learning and probabilistic modeling to separate artifact-dominated from physiologically plausible signal segments and to support robust heart-rate and respiration-related analysis.

Methods

BCG signals acquired from a bed-integrated force sensor system at a sampling rate of 100 Hz were analyzed. The dataset comprises recordings from seven subjects under controlled posture variations and includes cardiac and respiratory components as well as motion artifacts. Signals were segmented into 30 s windows to account for non-stationary behavior. Manual annotations of respiration cycles and motion artifacts were available, and photoplethysmography (PPG) served as reference for heart rate.

The proposed method follows a two-stage strategy. First, latent signal representations are learned using self-supervised masked time-series reconstruction. Second, a Hidden Markov Model (HMM) with Gaussian emissions is fitted in the latent space to model recurring signal states and their temporal transitions.

Results

The proposed framework provides a structured basis for modeling non-stationary BCG signals under varying noise conditions. In particular, the combination of self-supervised latent representations and HMM-based state modeling is designed to distinguish artifact-contaminated segments from physiologically plausible signal patterns and thereby support more stable downstream estimation of heart rate and respiration-related signal content.

Conclusion

The presented framework combines self-supervised learning and probabilistic state modeling for robust and interpretable analysis of noisy BCG signals, particularly in data-limited and artifact-prone scenarios. Future work will focus on quantitative evaluation and validation on extended datasets, including larger bed-based BCG databases with synchronized cardiovascular reference signals.

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Towards assessing the degradation of magnetic nanoparticle loaded biodegradable implants in a theranostic platform

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Introduction

Biodegradable drug carriers and implants for controlled drug release and targeted therapy are already in clinical use. However, once deployed in vivo, their degradation behaviour and associated structural changes, and thus their therapeutic performance, remain difficult to assess and control. Incorporating magnetic nanoparticles (MNP) into biodegradable implants establishes a powerful theranostic platform for simultaneous non-invasive monitoring and controlled degradation. MNP act as tracers for Magnetic Particle Imaging (MPI), enabling sensitive, real-time tracking, while also functioning as nanoactuators that generate localized heat under an alternating magnetic field (AMF) at higher frequencies. This dual functionality facilitates accelerated degradation and on-demand drug release, creating a feedback-controlled system for precise, image-guided therapy.

Methods

MNP-loaded implant materials were investigated in regard to their degradation behaviour stimulated by magnetic hyperthermia (MH). MPI and MH were performed using a Bruker BioSpin MPI 25/20 FF system in combination with a hyperthermia inlay module. Sequential MPI measurements monitored signal changes associated with ongoing degradation processes. The resulting signal characteristics were evaluated in order to assess their relation to degradation dynamics.

Results

Results indicate that the MPI signal depends on the physical state of the embedded MNP within implant material. Degradation processes influence both signal amplitude and spatial distribution, likely mediated by alterations in the MNP microenvironment. These findings demonstrate the sensitivity of MPI to structural transformations within the carrier system.

Conclusion

MPI reveals strong potential as a powerful non-invasive modality for real-time monitoring of biodegradable implants degradation in theranostic applications. Its ability to directly detect MNP allows sensitive tracking of degradation, while, in combination with MH controlled actuation of drug release is enabled. These findings are key for the development of MPI and MH towards a platform technology for image-guided therapies.

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AI-Based Identification of Pedicle Screw-Rod Systems from Radiological Images

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Introduction

Spinal screw-rod systems are orthopedic implants used to stabilize the spine, typically consisting of pedicle screws connected by longitudinal rods to restore alignment and ensure mechanical stability. Their use has increased significantly in recent decades. Identification of implanted systems is often challenging, particularly in cases of incomplete documentation, and can delay preoperative planning and surgical procedures. This study aims to develop and evaluate an AI-based approach for preoperative identification of screw-rod systems from radiological imaging data.

Methods

An AI-based classification algorithm was implemented using a compact Residual Network (ResNet-18) trained on annotated CT datasets. Data from 66 patients were included, comprising multiple volumetric CT series acquired during routine clinical imaging. All volumes were converted to Hounsfield units and normalized to a common intensity representation. A threshold-based pipeline was applied for screw localization. To reduce inter-scan variability, images were spatially normalized according to field of view (FOV), and screw-head-centered regions of interest were extracted for segmentation and classification. Incorporating multiple axial scans under varying imaging conditions per patient resulted in 1,081 labeled screw instances.

Results

For validation, previously unseen scans from 20 additional patients were used, yielding a test set of 166 screws. The algorithm identified screws from four manufacturers, reflecting the implant systems available at the collaborating clinical center and not the full diversity of commercially available systems. The model operates in a closed-set classification setting without mechanisms for detecting unseen implant classes. Overall accuracy was 96.43%, with sensitivity ranging from 93.9% to 100%. Inference required under 20 seconds on low-performance hardware.

Conclusion

The proposed application enables reliable and time-efficient identification of screw-rod systems. Limitations arise from the restricted number of implant systems represented. Further studies with larger and more diverse datasets are required to improve generalizability and clinical applicability.

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Deep brain stimulation in movement disorders – technological advance and progress in healthcare

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Introduction

Deep brain stimulation (DBS) is an established therapy for movement disorders, including Parkinson's disease with resistant tremor or dopaminergic fluctuations uncontrolled with oral dopamine replacement therapy. Unprecedented technological progress with DBS has been made in recent years, and this begins to transform health-care models, patient access, and personalization of DBS therapy.

Methods

Major therapeutic inventions have been made in recent years. 1) As catalyzed by the COVID pandemic, a fully re-motely accessible DBS system has been released (Abbott); 2) Sensing technology of pathological beta band activity recorded from the DBS electrodes allows for continuous monitoring of the PD motor state in ecological settings. Only recently, adaptive stimulation has been released allowing DBS to adjust in real-time to the momentary therapeutic requirements of a patient (Medtronic); 3) Using advanced probabilistic modelling of current spread of DBS pulses based on the biophysical properties of axon models, DBS programming can now be steered in anatomical space using Illumina Software (Boston Scientific).

Results

1) Remote DBS has improved DBS care by resulting in faster meaningful clinical improvement after primary implantation, easier patient access to therapy experts, and effective trouble shooting in case of therapy complications allowing to monitor and optimize therapy remotely in a patients naturalistic setting at home; 2) Adaptive stimulation has recently been shown to be safe and feasible, and is about improve the clinical outcomes of patients, in particular in case they experience residual dopaminergic fluctuations with continuous DBS; 3) Anatomic modelling of DBS programming is helpful to steer stimulation to the expected sweet spot, thereby lowering patient and physician burden with recurrent reprogramming sessions. Further, it helps to circumvent stimulation to sour spots, thereby preventing stimulation-related side effects and allowing for addressing individual characteristics in patient anatomy, effects, and side effects.

Conclusion

Technological progress transformed the therapeutic landscape of patients with DBS therapy, allowing for better access, higher personalization and more effective reprogramming sessions.

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Platform for dynamic adjustment of MNP concentration for magnetic particle imaging performance characterization

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Introduction

For characterization of the sensitivity of a magnetic particle imaging (MPI) device, magnetic nanoparticles (MNP) are typically measured over a range of concentrations in a serial dilution. Here, we introduce a novel platform that enables dynamic adjustment of MNP concentration in a dispersion through a microfluidic control system. Mimicking concentration changes in the circulatory system, the platform can be used for performance evaluation of MPI by combination with 3D-printed resolution phantoms.

Methods

The dilution control platform is composed of a microfluidic flow controller (Fluigent) that delivers defined flow rates of MNP suspension and diluent to a microfluidic mixing chip (baffle mixer, microfluidic ChipShop), which is subsequently connected to a 3D-printed measurement phantom. This enables precise setting and continuous tuning of both concentration and flow rate of MNPs. Time-controlled concentration protocols with 3D-printed custom flow phantoms were used for performance evaluation of a commercial MPI device (Bruker Biospin). Developed phantoms comprise spiral and V-shaped patterns for resolution studies, anatomical vessel geometries and structures for spill-over investigation using static MNP as reference.

Results

The setup was validated using time-resolved magnetic particle spectroscopy (MPS) (Bruker Biospin) with a flow cell insert that enables direct measurement of the resulting dilution in flow. We established that dilutions between 1:10 and 1:1000 (MNP:ddH_20) can be reproducibly set (Reproducibility standard deviation for 1:1000 ~15%, for 1:200-1:10 <5%) and adjusted at a flow rate of 1 mL/min and demonstrated imaging of various 3D-printed phantoms. We successfully determined the detection limit of the used MPI scanner with a Synomag MNP system (Synomag-D COOH, 50nm) and performed spatial and temporal resolution investigations.

Conclusion

The developed dilution control platform has been validated using time-resolved flow MPS. MPI measurements of several phantoms have been successfully carried out. In future work, the setup will be used for inter-scanner comparisons to further advance the harmonization of MPI.

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Three-dimensional Geometry of Polyimide-based Ciruits for Active Stent Application

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Introduction

The development of stent technology led to Active Stents describing stents equipped with electrical components and sensors. This improvement realizes real-time monitoring of physiological parameters and effects on the stent at the implantation site. Existing prototypes serve either miniaturization or functionality but lack in longevity testing and adequate energy and data transmission. Polyimide (PI)-based chip-in-foil technology offers a new integration approach for equipping stents with electrical circuits. An ultra conformable circuit design could overcome both continuous cyclic load and strong compression during implantation. Therefore, PI-based thin film structures were fabricated and post-processed in three dimensions by annealing for an additional geometrical degree of freedom.

Methods

PI-based samples are fabricated by spin coating a double layer of the precursor on a silicon carrier wafer, resulting in 10 µm thick PI. Further structuring is conducted with a nanosecond laser to produce 1.5 x 30 mm² stripes. Additional simplified electrical circuits are fabricated by sputter depositing platinum layer of 300 nm in-between both PI layers. Post-processing the samples is performed by using a metal mold and annealing at 321 °C to reshape the geometry into the third dimension. Reproducibility of the geometry is characterized optically and additionally DC resistance measurements are conducted.

Results

The fabricated PI-stripes resulted in horseshoe geometries with a diameter shape accuracy of 99% with respect to the metal molds. Longevity testing of the circuits was conducted by bending the samples with 220,000 cycles. The resistance resulted in 6% difference before and after mechanical load.

Conclusion

It was possible to create structures for an Active Stent application by taking advantage of the conformability of PI to get first insights on mechanically bearable loads with respect to cyclic stress. Further analysis and improvement of the processes and characterization is necessary, especially with emphasis on integrating the circuit into a stent.

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Characterizing Bladder Filling Physiology with Long-Axial-FOV Dynamic PET/CT

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Introduction

During dynamic PET imaging, the urinary bladder accumulates tracer excreted by the kidneys, causing expansion that displaces adjacent organs. Since CT is typically acquired after PET, the bladder is often delineated at its largest volume, creating positional inconsistencies for neighboring organs. We therefore track bladder expansion and evaluate its frame-by-frame shape.

Methods

In 23 patients, bladder masks from automated multi-organ segmentation frameworks (TotalSegmentator and MOOSE) were used to define an approximate bladder region as initialization for a custom region-growing algorithm. Starting from the final PET frame, the algorithm propagated the mask backward through the dynamic PET frames using voxel intensity normalization, distribution-based correction, and region growing to capture temporal changes.

Results

The result of the algorithm is a collection of segmentation masks for each PET frame, starting from the last PET frame and ending whenever the bladder is no longer visible in PET. It failed in 2/23 cases because of anomalous uptake near the bladder. In the remaining 21 patients, the volume growth over time followed a linear pattern (coefficient of determination $R^2 = 0.94[0.88,0.97]$), while the fractional anisotropy (a shape quantifier) showed a decreasing trend, i.e., the bladder became closer to a sphere as it filled (Spearman correlation $\rho = -0.86[-0.96,-0.61]$). To assess the accuracy of existing state-of-the-art models, we calculated Dice–Sørensen coefficients (DSC) using the masks generated by our method as reference segmentations, resulting in 0.40 ± 0.37 for TS and 0.70 ± 0.26 for MOOSE.

Conclusion

We developed and evaluated a custom algorithm for urinary bladder segmentation in dynamic FDG PET imaging. Unlike existing state-of-the-art segmentation models, which demonstrated limited accuracy for bladder delineation, our method successfully traces the bladder over multiple PET frames. This approach enables reliable tracking of bladder expansion, allowing the reduction of potential misalignment of adjacent organ masks.

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Multimodal Classification of Parotid Tumors - A Proof of Concept

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Introduction

Preoperative differentiation between benign and malignant parotid tumors is challenging, but can influence treatment and outcome. We investigated how artificial intelligence can support this process by multimodal classification.

Methods

Clinical tabular data and ultrasound images from 658 patients (507 benign, 151 malignant) were used, and a dedicated preprocessing pipeline addressed common issues in real-world clinical data. After preprocessing, 594 patients remained (449 benign, 145 malignant). We evaluated unimodal and multimodal approaches for binary parotid tumor classification. XGBClassifier was used for tabular classification and ResNet-18 for image classification. To combine the unimodal classifiers, we injected the results of image classifier aggregated by patient in the table data and trained a new tabular classifier.

Results

The tabular classifier achieved good performance, with an accuracy of 0.88 and a weighted F1-score of 0.88. Malignant tumors were detected with a recall of 0.80 and precision of 0.75, while benign tumors showed a recall of 0.91. The image-level classifier showed moderate performance, with an accuracy of 0.73 and a weighted F1-score of 0.74. Patient-level aggregation of image-level predictions slightly improved performance, reaching an accuracy of 0.75. The combined model achieved the best overall balance, maintaining an accuracy of 0.88 while increasing the weighted F1-score to 0.89. Malignant recall improved to 0.93, although malignant precision decreased to 0.70, indicating increased sensitivity at the cost of more false-positive malignant predictions.

Conclusion

Injecting image classifier knowledge into the tabular model improved sensitivity for malignant tumors, increasing malignant recall from 0.80 to 0.93. Aggregated image-derived features contributed substantial predictive value, accounting for 35.87% of the normalized gain. These findings suggest that clinically relevant information can be extracted even from imperfect retrospective imaging when combined with clinical variables. Our results support the feasibility of multimodal parotid tumor classification and motivate future validation on larger cohorts and higher-quality imaging data, as well as optimizing fusion strategy.

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Development of an FPGA-Based Low-Field Pulsed NMR System with AI-Driven Data Processing for Point-of-Care Applications

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Introduction

Nuclear magnetic resonance (NMR) spectroscopy is a powerful and widely used technique for studying the physical, chemical, and biological properties of molecules. High-field NMR spectrometers provide excellent spectral resolution but are typically bulky and expensive and are therefore not suitable for mobile applications. Low-field NMR offers a cost-effective alternative suitable for point-of-care applications, though at the expense of spectral resolution. The aim of the project is to design a low cost, FPGA-based low-field NMR device that uses artificial intelligence for spectral analysis of blood.

Methods

The system utilizes a Red Pitaya STEM 125-14 platform and comprises four components: a probe and magnet assembly, analog excitation and receiving chains, an FPGA-based digital processing chain, and a convolutional neural network (CNN) for compound identification. RF pulses were generated via a Direct Digital Synthesis (DDS) module to be fed into the probe with a 5 W power amplifier. The receiving chain consisted of two cascaded low-noise amplifiers intended to amplify weak return signals from the probe. Quadrature detection was implemented on the FPGA to extract the in-phase and quadrature components. The CNN was trained on simulated NMR spectra of twelve compounds across multiple frequency ranges.

Results

The excitation chain successfully produced 21 MHz pulses, with the amplifier delivering approximately 94 V peak-to-peak to the probe. The receiving chain amplified signals as low as 115 µV while preserving signal integrity. Testing the quadrature detection chain confirmed the expected 90° phase relationship between I and Q components, with data rate reduced from 125 MS/s to 0.976 MS/s. The CNN achieved accurate compound classification on 21.29 MHz spectra, demonstrating the feasibility of AI-assisted spectral analysis at low field strengths.

Conclusion

These results demonstrate the feasibility of a low-cost FPGA-based NMR console enhanced with AI-driven spectral analysis. Future work will focus on testing real FID signals and expanded training data before deployment in complex biological applications such as haemoglobin analysis.

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From Material Processing to Clinical Performance: Quantifying PLLA Degradation in Resorbable Implants

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Introduction

Temporary bioresorbable implants are a promising approach to maintain fallopian tube patency during the postoperative healing phase, where permanent metallic stents are unsuitable due to migration risk and chronic foreign-body reactions. Poly(L-lactide) (PLLA) is widely used in resorbable devices, yet its degradation behavior is highly sensitive to processing history, geometry, crystallinity, and environmental conditions. Reported degradation rates vary substantially across the literature, complicating the design of implants that require predictable short-term mechanical stability followed by controlled resorption. To address this variability, a harmonized, data-driven assessment of PLLA degradation is required.

Methods

A systematic review of ten peer-reviewed publications (2018–2025) yielded 128 datasets covering diverse PLLA grades, form factors, and degradation environments. All data were harmonized by normalizing molecular weight, converting timepoints to weeks, and standardizing residual mass. A multilevel mixed-effects meta-regression model with residual mass (%) as the outcome was applied. Fixed-effect moderators included form factor, manufacturing method, degradation medium, pH, temperature, and time, while Publication_ID and nested study_ID were modelled as random intercepts.

Results

Residual mass followed a distinctly non-linear trajectory with accelerated mass loss in later degradation phases. Elevated temperatures and alkaline media increased degradation rates, whereas physiological conditions (37 °C, PBS) showed highly consistent behaviour across studies. Form factor was a major determinant: films and fibres exhibited substantially higher residual mass than 3D-printed structures, while braided and laser-cut geometries showed no independent effect after adjustment. PLA grade did not significantly influence degradation. Moderate residual heterogeneity indicated unmeasured influences such as crystallinity, porosity, or processing history.

Conclusion

This harmonized meta-analysis identifies time-dependent hydrolysis, geometry, and medium as the primary drivers of PLLA degradation. The results provide a quantitative basis for designing temporary bioresorbable stents with predictable functional lifetimes. Future modelling should incorporate detailed morphological descriptors to further reduce study-level variability and improve translational applicability.

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Participatory Requirements Analysis for a Data-Driven Depression Aftercare App – Insights from the INSITU Project and Implications for an Iterative Application Design

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Introduction

The post-discharge period following inpatient treatment for depression is characterised by high relapse risk and long waiting times for outpatient specialist care. The BMFTR-funded INSITU project is developing a data-driven, multimodal system for individualised therapy management, using a standard tablet to capture audio, video, and touch-based inputs. A voice dialogue system (voicebot with optional avatar) guides patients through daily self-assessments; clinicians access longitudinal data via a web-based dashboard. This contribution presents findings of a participatory requirements analysis invoking patients and healthcare professionals.

Methods

As a first step of the user-centred development process, a participatory requirements analysis was conducted with two target groups: patients (N = 15) and healthcare professionals (N = 29). Separate anonymous online questionnaires (SoSci Survey) combined closed-ended items and open free-text fields, administered at Bezirksklinikum Augsburg, University of Augsburg, Germany. The study was classified as non-advisory by the Ethics Committee of LMU Munich (Project No. 25-0664-KB).

Results

Both groups prioritised ease of use, mood and activity tracking, data privacy, and crisis management features. Patients additionally emphasised concrete support during deterioration (personal safety plans: 73.3%), daily routine structuring (80%), and mindfulness/self-care content (93.3%). Healthcare professionals highlighted warning systems for crisis symptoms (69%), psychoeducation (mentioned 7 times in open responses), standardised questionnaires (PHQ-9), and diary functions. The avatar concept was rejected by approximately 80% of patients (“creepy”), indicating that it must be fully optional and configurable. Gamification was endorsed by 60% of patients when kept lightweight. A majority of professionals (62.1%) rated reimbursability as an essential prerequisite for adoption.

Conclusion

The findings inform INSITU system design and may inform other similar applications. They directly guide the development of the MVP. Initial results from a planned usability and acceptability evaluation of the MVP in July 2026 will be presented at BMT 2026.

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SSVEP-Based Answer Selection Using a Low-Cost 8-Channel EEG System

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Introduction

The main contribution of this study is the evaluation of classification accuracy and user experience in a simplified and cost-efficient BCI setup. We investigated the feasibility of an SSVEP-based answer selection system using a low-cost 8-channel EEG headset. To reduce system complexity, only three occipital channels (PO7, Oz, and PO8) are used for signal analysis. A quiz-based experimental paradigm is employed in which users select between two answer options by focusing on flickering visual stimuli. The findings of this research will form the basis for the development of an online version of the game. The game is intended to serve as an inclusion tool for people with physical impairments. These impairments include disabilities, accidents or temporary incapacities, as well as age-related physical decline. It is hoped that this will improve quality of life through increased autonomy, as well as the promotion and stimulation of cognitive abilities.

Methods

An experiment was conducted to record and process the SSVEP whilst viewing flickering rectangles. The experiment is designed as a quiz in which questions with answer options A or B are answered based on the observation of the rectangles. The recorded EEG signals are analyzed using canonical correlation analysis (CCA) to determine the selected answer.

Results

The experiment was conducted twice: once with the frequency pair 10 Hz and 17 Hz, and once with 6 Hz and 17 Hz. Trial 1 recorded an average accuracy of 82% and trial 2 recorded 89%. Both average accuracy rates are very good results for an EEG system using only three channels. Almost all subjects were able to achieve a high accuracy rate without having to undergo extensive training beforehand or have the signal processing adapted to each individual subject. Of course, the individual accuracy rate depends heavily on the subject's concentration

Conclusion

Despite relying on only three occipital electrodes, the system achieved high classification accuracies, showing that reliable BCI performance can be obtained with minimal hardware complexity and without extensive user training. In addition, the comparison of different stimulation frequency pairs indicated that both classification accuracy and user comfort are influenced by the chosen frequencies.

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AI in Sleep Research: Do foundation models solve all problems?

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Introduction

Big Medical Data and new AI model architectures have led to the development of "foundation models", i.e. models, that have been trained typically unsupervised on broad data and can be applied to several specific tasks, so called "downstream tasks". Currently, more and more medical models are published, encompassing biosignal sleep data.

Methods

This contribution discusses advances and possible shortcomings of foundation models in contrast to task-specific models with focus on applications in comorbid and wearable settings. Current foundation models in biosignal analysis are included and – where applicable – compared to performance of AI models specifcally trained for the respective task relevant for sleep medicine and research.

Results

The performance of foundation models in biosignal analysis is currently still not comparable with supervised task-specific deep learning models in terms of model performance, but allows for fast piloting of new hypotheses. For example a currently published foundation model on sleep recordings by Thapa et al. (DOI: 10.1038/s41591-025-04133-4) showed interesting prediction performance for several disorders, but for sleep staging it is outperformed by task-specific state-of-the-art methods.

Conclusions

For foundation models, the general rule as for all signal analysis methods stands: It opens excellent new opportunities in questions, that have not been (intensively) explored yet, but for specific, and well defined tasks, specific and established models should be considered if it comes to transfer in clinical practice.

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Standardized Transducer Placement Representation for Improved Reviewability of Ultrasound Examinations

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Introduction

Demographic change makes autonomous and semi-autonomous solutions in healthcare increasingly important. In ultrasound imaging, such systems can help reduce the strong operator dependency of conventional freehand examinations by enabling more reproducible scans along predefined transducer paths. Decoupling image acquisition from image assessment, however, means that professionals who interpret the images retrospectively often lack spatial context about where on the patient each image was recorded. This spatial context can be reintroduced in a standardized way within the assessment view.

Methods

We present a method for the visualization of ultrasound data in a spatial context. We perform synchronized recordings of transducer paths and patient surface geometry, using an RGB-D camera. The patient's body surface is densely detected, with correspondences to a standardized body model. The acquired transducer positions and orientations are mapped onto a standardized body visualization.

Results

The process was tested in an exemplary setup for the screening of kidneys, but can be applied to examination types that are performed anywhere on the body surface. The resulting visualization allows for ultrasound image assessment with a provided transducer pose context, relative to the body model.

Conclusion

The proposed approach preserves the spatial context of the recorded data and provides a consistent anatomical reference for retrospective diagnostic assessment. This forms a basis for future automated and robotic ultrasound workflows, where the examination itself can be robotized and the decoupled diagnostic assessment is performed by trained medical staff. It is also a valuable addition to the documentation for current ultrasound images for retrospective re-evaluation.

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Development of a High-Speed Swept-Source OCT System for Synchronized Benchtop and Mobile Intracardiac OCT Imaging

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Introduction

Optical coherence tomography (OCT) provides high-resolution imaging of biological tissue and is widely used in intravascular applications. However, future intracardiac OCT imaging poses additional challenges due to cardiac motion, large imaging volumes, and the need for robust synchronization. Within the OptoCarDi project, a high-speed OCT platform is being developed for future catheter-based intracardiac imaging.

Methods

A swept-source OCT system based on a Fourier Domain Mode Locked (FDML) laser operating at 1310 nm and MHz A-scan rates was implemented. The setup employs a fiber-based Michelson interferometer with balanced detection and high-speed data acquisition. Synchronization of laser sweep, acquisition, and scanning was achieved using laser-derived trigger and clock signals combined with numerical k-space resampling. A piezoelectric fiber scanner enables spiral scanning with a circular field of view in the millimeter range. ECG-gated acquisition was integrated to reduce motion artifacts in dynamic cardiac environments. Custom software provides synchronized acquisition, GPU-based processing, and real-time visualization. In addition to the benchtop system, a compact mobile platform was developed, and a catheter probe with a diameter below 3 mm was developed.

Results

The system achieved a sensitivity exceeding 90 dB at MHz A-scan rates. Axial resolution was below 10 µm in air and below 8 µm in tissue, while lateral resolution was below 20 µm. A roll-off greater than 2 mm at −3 dB was observed. Stable synchronization enabled reproducible spiral scanning and artifact-reduced imaging of biological samples. The achieved imaging performance is within the range reported for state-of-the-art intravascular OCT systems while providing MHz-rate acquisition and synchronization strategies specifically targeting future intracardiac applications.

Conclusion

The presented system combines high-speed OCT, ECG-gated synchronization, spiral scanning, and mobile implementation in a single platform. These developments provide a foundation for robust future intracardiac OCT imaging and catheter-based cardiovascular diagnostics.

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Noise Conditioned Bayesian Optimization Strategy Selection for Self-Driving Labs

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Introduction

Self-driving labs have become a widespread paradigm for automating research and development processes across disciplines such as biology, chemistry, and pharmaceutical research. Such systems combine robotics and software to optimize target metrics in an automated loop, aiming to find high-quality solutions in few iterations. Noise inherent in sensors and robotic actuation not only affects the speed at which the optimal result is found, but also which optimization strategies perform best.

Methods

We present a simulation-based methodology to analyze self-driving lab loops and to select the optimal acquisition function and hyperparameters for Bayesian optimization by incorporating known uncertainty in realistic simulated system behavior. Plausible system responses are generated using Gaussian Process priors parameterized by domain knowledge. We demonstrate our approach by comparing five candidate acquisition functions and hyperparameter combinations. The evaluation is performed on response functions with two levels of smoothness and under varying levels of actuation and sensor noise.

Results

The results show that optimizer performance strongly depends on both noise characteristics and system smoothness. In noisy environments, exploratory strategies outperform others, while in low-noise settings, more exploitative strategies are preferable. Additionally, sensor and actuation noise affect performance differently depending on the underlying system behavior.

Conclusion

The proposed framework works without pre-collected data. It enables researchers to select an optimal BO strategy and to estimate the experimental budget required to reach a target performance. Our results demonstrate that incorporating noise characteristics into optimizer selection can significantly reduce the number of required experiments.

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Chances and challenges of magnetomyography with optically pumped magnetometers

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Introduction

Magnetomyography measures the magnetic field that is generated by electrical currents during muscle contractions. The resulting magnetic fields can be recorded with optically pumped magnetometers (OPMs). New generations of commercially available OPMs enable the measurement of muscle signals with all three vector components and with small sized sensor heads (e.g. 1,24 cm x 1,66 cm x 2,44 cm for Qu-Spin Gen 3 sensors) in highly shielded environments (e.g. magnetically shielded rooms or table top magnetic shields).

Methods

Commercially available optically pumped magnetometers (Qu-Spin QZFM Gen.3) were used to assess their use, limitations and possibilities in magnetomyography of skeletal muscles. The OPMs utilize Rubidium atoms in heated vapor cells that are excited by a laser. An excited collective spin state becomes sensitive (regarding absorption of light) to external magnetic fields and enables the detection of pT-range magnetic field strengths in shielded environments. Magnetomyographic signals of the abductor digiti minimi (small finger muscle) were observed. Additionally, the ability to utilize the sensors on smooth muscle cells was investigated in preclinical test setups at frequencies below 1 Hz.

Results

The measurements on the small finger muscle allowed a detailed mapping of the magnetic field of a skeletal muscle. Stimulated muscle activity was recorded with six sensors simultaneously. A three dimensional vector analysis revealed signal evolution over time and at various positions. An estimation of the position of the innervation zone of the muscle (i.e. the nerve-muscle attachment point) was possible.

Preclinical tests of smooth muscle activity showed that the utilized OPMs are in principle able to record magnetic field at low frequencies in a shielded environment. While signal to noise ratio becomes more pronounced in this frequency range, the utilization of a gradiometric setup can help to reduce noise.
Sensor limitations regarding clinical applications like sensor stability, cross axis leakage, the necessity for a magnetic shield etc, were observed.

Conclusion

While the field of magnetomyography with OPMs is quite young, the results from the measurements with skeletal muscles show the potential of this new technology in understanding muscle signal propagation and evolution as a first step towards understanding pathological muscle activities. Preclinical tests in tabletop magnetic shields show the feasibility of measuring low frequency muscle signals (i.e. smooth muscles).

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Evaluating Plug-and-Play Applicability of Magnetometer-Free IMU-based Joint Kinematics Estimation

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Introduction

Magnetometer-free joint kinematics estimation using Inertial Measurement Units (IMUs) is vital for clinical motion tracking to avoid magnetic disturbances. However, true clinical utility depends on "plug-and-play" (PnP) functionality, allowing systems to operate without specialized expert knowledge. Traditional estimators, such as Multiplicative Extended Kalman Filters (MEKF) and Maximum A Posteriori (MAP) approaches, depend on domain-specific hyperparameters, which limits their autonomy. This study evaluates these methods against a parameter-free Recurrent Neural Network (RNN).

Methods

The algorithms were evaluated using two datasets: IRM-8, featuring high-precision robotic movements, and DIODEM, which utilizes 3D-printed kinematic chains with foam padding to simulate soft-tissue-like movement (STM). Three methods (MEKF, MAP, and an RNN trained solely on simulated data) were tested across diverse experimental scenarios. Evaluations focused on out-of-the-box performance, hyperparameter sensitivity via grid searches, and robustness against motion artifacts.

Results

While MEKF and MAP performed well in their original domains, they failed to generalize to the DIODEM dataset using default parameters. Grid searches showed that optimal parameters for traditional methods shift significantly between hardware domains and joint types. Under STM, their accuracy degraded further. In contrast, the RNN maintained robust performance across all datasets without subject-specific tuning. Even with STM, the RNN achieved errors between 10° and 15°, outperforming typical visual expert inspections.

Conclusion

Traditional MAP and MEKF algorithms are sensitive to hyperparameter tuning, with optimal settings shifting depending on movement and artifacts. The RNN-based approach offers true PnP functionality by achieving comparable or superior performance without requiring subject-specific tuning. It overcomes the primary barrier to system-level PnP autonomy by eliminating expert-led recalibration during domain transitions. Consequently, data-driven models present a scalable solution for unsupervised clinical motion tracking where expert calibration is impractical.

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Low-Power Plasma Activation of Industrial Materials: Comparative Characterization of Gas and Substrate Effects on Surface Free Energy and Stability

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Introduction

Plasma-based surface treatments are widely used methods to specifically tailor material properties for biomedical applications, including improved wettability, biocompatibility, and adhesion without causing structural damage. This study investigates the effectiveness of a custom-built low-power plasma system for the activation of various industrial materials, with a focus on stability and process flexibility.

Methods

A parallel-plate plasma system with micrometer-scale adjustable electrode spacing was developed to enable stable plasma generation at reduced power levels (mW range). Both DC and AC excitation were applied using different process gases (compressed air, nitrogen, and argon). Six materials (epoxy resin, gold, rubber, copper, silicon wafer, and PTFE) were treated under controlled conditions. Surface characterization was performed using contact angle measurements to determine surface free energy (SFE) and atomic force microscopy (AFM) to assess morphological changes. Additionally, time-dependent measurements were conducted on gold and silicon wafer samples to evaluate the stability of surface activation.

Results

Plasma treatment resulted in a significant increase in SFE for all investigated materials, with the most pronounced effects observed for initially low-energy surfaces such as copper and gold. High-energy materials like silicon wafer and epoxy resin showed smaller relative changes. The influence of gas type and excitation mode varied depending on the material. AFM analysis confirmed that surface morphology remained largely unchanged, demonstrating non-destructive processing. Time-dependent measurements revealed stable SFE values over at least 60 minutes, indicating durable surface functionalization.

Conclusion

The results demonstrate that low-power plasma activation is an effective and gentle method for enhancing surface properties of industrial materials that are time-stable. After activation, all samples except PTFE reached similar SFE values, suggesting that the maximum achievable SFE likely reflects the limits of the low-power plasma system.

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Electrochemical Characterisation of New Textile Stimulation Electrodes and Their Application

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Introduction

Functional electrical stimulation (FES) is a therapeutic method used to restore lost or damaged neurological functions. While transcutaneous stimulation typically uses self-adhesive hydrogel or rubber electrodes, textile electrodes are increasing in popularity thanks to their ease of application.
We present a new textile electrode based on conductive silicone yarn and analyse its electrochemical characteristics. We evaluate their usability in transcutaneous FES by integration in a fully textile applicator.

Methods

The electrochemical characterisation included electrochemical impedance spectroscopy, open circuit potential, and electrochemical noise measurements. All measurements were performed in contact with a 0.9% sodium chloride solution. Impedance spectroscopy was conducted over 24 hours across a frequency range from 0.1 Hz to 1 MHz. Open-circuit potential measurements were recorded over 12 hours. Electrochemical noise was analysed in the time domain over one hour, and the power spectral density was calculated for a frequency range from 0 to 500 Hz. In addition, the textile electrodes were integrated into a knitted sleeve and their applicability and usability were evaluated.

Results

The developed electrodes showed median impedances of 19.6 kΩ at 0.1 Hz and decreased to 98 Ω at 1 MHz, which are comparable to or lower than previously reported textile stimulation electrodes. The noise characteristics and potential stability were comparable to those of conventional electrodes. The knitted sleeve was well tolerated, but showed limitations in practicability due to hygienic considerations.

Conclusion

In addition to their electrochemical performance, the presented electrodes combine the skin compatibility of rubber electrodes with the high wearing comfort of textile electrodes. These properties make them a promising, reusable, and user-friendly alternative for stimulation applications.
Future work will focus on investigations of different use cases for the new textile electrodes with the textile applicator, e.g. in home stimulation.

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Hydration management system for sports and health care applications – Test bench development and field study in endurance athletes

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Introduction

Adequate fluid intake is essential for all individuals, particularly in sports and healthcare settings. The development of an intelligent hydration management system to give individual drinking recommendations could provide significant support. As an intermediate step, aim of the current work is the development of a test bench allowing automated testing of sensor systems for drinking volume determination. In addition, a field study with runners was conducted to analyze drinking behavior and its influence on physiological parameters under conditions of physical exertion.

Materials and Methods

The idea of the automated test bench is to generate defined pressure profiles, corresponding to the complex behavior of human tube-based drinking. The setup consists of a fluid circuit representing the drinking process in a tube and a pneumatic circuit mimicking the pressure conditions in the mouth.
The field study comprised of three consecutive training days with 22 endurance runners. Data were collected using a multi-part questionnaire that included both numerical data and self-assessments using rating scales, combining objective measures with subjective perceptions.

Results and discussion

An automated test bench allowing the simulation of human tube-based drinking was developed. Drinking volume is determined by measuring the water content in water and waste reservoirs using digital precision scales. Pressure profiles were generated by using an array of vacuum reservoirs and dedicated time-controlling of fast-switching valves.
In the field study, no significant association was found between thirst perception and urine color as a marker of hydration status.

Conclusion

The test bench enables the simulation of human tube-based drinking and thereby the automated testing of sensor systems for drinking volume determination.
As subjective markers such as thirst perception and fatigue appear to be unreliable indicators of actual hydration status, intelligent hydration management systems could provide valuable decision support by estimating individual hydration requirements in sports and healthcare applications.

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A Scalable and Efficient Hardware Accelerator for Realtime EMG-based Gesture Recognition using Deep Learning

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Introduction

Reliable hand gesture recognition based on surface electromyography (sEMG) is a cornerstone for intuitive prosthetic control. While deep learning models like convolutional neural networks (CNNs) offer high classification accuracy, their deployment on wearable devices is often hindered by strict power constraints and the requirement for real-time responsiveness. This study evaluates the OpenEye hardware accelerator, a scalable FPGA-based architecture designed to bridge the gap between complex neural network topologies and embedded resource limitations.

Methods

We deployed a multi-scale 1D-CNN with spatial-temporal attention on the OpenEye accelerator, utilizing the Ninapro DB2 benchmark dataset for evaluation. The architecture was tested across various hardware configurations, varying the number of processing element (PE) clusters and array dimensions. To optimize efficiency, post-training quantization (PTQ) was applied to convert the model to INT8 precision. Hardware performance was characterized on a Xilinx ZU19EG FPGA at 200 MHz, focusing on the trade-offs between kernel complexity, window size (256 vs. 512 samples), and inference throughput.

Results

The multi-scale CNN achieved a classification accuracy of up to 89.3% (median 90.2%). The hardware evaluation demonstrated near-linear scaling of resources and performance. Even for the most complex configurations, OpenEye achieved an inference latency of 5.3 ms, which is significantly below the 125 ms threshold for perceived lag in prosthetic control. Furthermore, the INT8 quantization incurred a negligible accuracy penalty of less than 0.1%, confirming the robustness of the quantized model for clinical applications.

Conclusion

OpenEye provides a highly efficient and modular platform for real-time EMG classification. Its sub-millisecond latency and predictable scaling enable the integration of sophisticated AI models into energy-constrained prosthetic limbs. These findings facilitate the development of next-generation wearables that offer amputees more intuitive, robust, and responsive limb replacement.

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Enhanced cross-talk in an osteoblast/osteoclast co-culture model on hybrid hydrogels containing bioactive glass nanoparticles

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Introduction

Biopolymeric hydrogels are an interesting alternative for bone regeneration, particularly as a base material for nanocomposites with inorganic fillers. However, comprehensive studies on co-cultured bone cells and the underlying crosstalk mechanisms remain limited in this context. Here, the effects of bioactive glass nanoparticles (BGN) on the physicochemical properties of gelatin (GelMA)- and hyaluronan (HAMA)-based hydrogels and on osteogenic differentiation of human bone marrow stromal cells (hBMSC) were analyzed. Further, crosstalk mechanisms in an osteoblast(OB)/osteoclast(OC) co-culture model were assessed.

Methods

Freeze-dried cylindrical hydrogels were prepared in silicon molds. A composite hydrogel composed of 5% GelMA/3% HAMA±4% w/v BGN was prepared and gamma-irradiated. Co-culture experiments were conducted for 35 days, without Dexamethasone and standard supplements for osteoclastogenesis (M-CSF+RANKL). Samples were analyzed every 7 days with corresponding hBMSC monoculture as control. The effects were evaluated through biochemical assays for cell proliferation, osteogenic/osteoclastogenic differentiation, and real-time quantitative PCR.

Results

BGN did not alter the pore size of freeze-dried hydrogel, but reduced the elastic modulus by 50%. GelMA/HAMA/BGN composites increased cell proliferation and alkaline phosphatase (ALP) activities peaking after 14 days. Furthermore, osteoclast differentiation was initiated in both hydrogel variants, specifically in GelMA/HAMA/BGN, supported by elevated TRAP5B activities and *M-CSF / RANKL* gene expression within 7 days. An active crosstalk mechanism for the osteoclast to reinitiate osteogenic differentiation is also shown after 35 days, supported by recurring *Runx2* and elevated *Sphingosine kinase*, but reduced *Semaphorin 4D* gene expression.

Conclusion

GelMA/HAMA/BGN composites are a favorable base for multi-component bone substitute material due to enhanced hBMSC proliferation, earlier osteogenic differentiation, and support for active osteoblast/osteoclast cross-talk. These are valuable insights in a physiologically relevant co-culture model. Future studies should include additional osteogenic measures, such as electrical stimulation, to elucidate further physiologically relevant effects on cellular cross-talk to optimize biomaterials for bone-related medical devices.

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AF Screening Methods During Sleep Using Unobtrusive Measurement Technology

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Introduction

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia, rising steeply with age and carrying substantial risk of stroke, heart failure, and dementia. Under AF, irregular ventricular filling causes beat-to-beat stroke volume variation, manifesting as pulse interval irregularity and reduced pulse amplitude across photoplethysmography (PPG), ballistocardiography (BCG), capacitive electrocardiography (cECG), remote PPG (rPPG), and contactless radar – enabling unobtrusive multimodal detection. Current ESC guidelines acknowledge insufficient evidence for integrating these technologies into screening practice, and passive monitoring during rest or sleep remains absent from care pathways, particularly in geriatric populations where wearable self-screening uptake is lowest.

Methods

A targeted literature review was conducted across PubMed and IEEE Xplore. Technologies evaluated included PPG wearables, BCG bed sensors, cECG, rPPG, and radar, assessed using RR interval and pulse amplitude variability criteria. Additionally, we present findings from HypAFib, a prospective study at RWTH Aachen on multimodal unobtrusive sensor fusion for AF detection in geriatric patients.

Results

PPG-based smartwatches demonstrate pooled sensitivity of 95%, specificity of 97%, and AUC of 0.97 across 26 studies (n=17,349), though signal quality degrades with skin pigmentation in diverse older populations. BCG bed sensors achieve an AUC of 0.97 on an independent test set, though a recent randomised trial found a 48.5% false alarm rate in deployment. Contactless radar achieves sensitivity of 84.4% and specificity of 99.5%. Shared limitations include motion artefacts and ectopic beat interference; modality-specific constraints further affect applicability in real-world settings. Relative RR metrics such as pRR3.25% outperform conventional pRR50. In HypAFib, hierarchical fusion of cECG, BCG, and reflective rPPG in 30 geriatric patients over 30 minutes achieved F1=0.90 and AUC=0.94.

Conclusion

Passive, compliance-free monitoring approaches show particular promise for geriatric populations where self-screening compliance is lowest. Clinical translation requires modality-specific refinement and validation in multimorbid populations, as initiated by the HypAFib study.

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Characterization of Time-Dependent Dissolution of Hydrophilic PTCA Catheter Coating Particles Using Dynamic Image Analysis

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Introduction

Hydrophilic polymer coatings are widely used in percutaneous transluminal coronary angioplasty (PTCA) catheter systems to improve lubricity and trackability. However, coating-derived particles released during device use represent a relevant aspect of device safety evaluation. While standards such as USP <788> address particulate analysis, advanced imaging techniques like dynamic image analysis are not yet fully considered in catheter-specific standards. In addition, the time-dependent behavior of hydrophilic particles may influence their detectability and risk assessment.

Methods

Particles were generated using a simulated use model based on ASTM F2394-07(2022) during application of two commercially available PTCA catheter systems. The resulting particle suspensions were analyzed using dynamic image analysis (FlowCam). Measurements were performed at three defined time points after particle generation (t_1 = 0 h, t_2 = 4 h, t_3 = 24 h). Particle size distributions and concentrations were evaluated in size classes between 10 and 500 µm.

Results

For both catheter systems, the highest particle counts were observed immediately after particle generation, with the majority of particles in the 10–25 µm size range. Over time, a pronounced decrease in particle counts was observed, particularly in the size range of 10–100 µm. After 24 h, particle counts were reduced by more than 50 % for both devices. A substantial fraction of this reduction (approximately 30–45 %) occurred within the first 4 h, whereas the subsequent decrease between 4 h and 24 h was less pronounced. Larger particles (100–500 µm) showed only minor changes over time.

Conclusion

The results demonstrate a clear time-dependent dissolution of hydrophilic coating-derived particles, leading to reduced particle persistence in aqueous environments. While this behavior may mitigate long-term particle-related risks, acute effects immediately after particle release remain relevant. Furthermore, the findings highlight that particle analysis is highly dependent on the timing of measurement, emphasizing the need for immediate or standardized post-generation analysis to ensure reliable and comparable results.

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Real-time classification of patient-ventilator interaction using surface electromyography

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Introduction

Patient–ventilator asynchronies (PVA) are common during mechanical ventilation and are associated with discomfort, prolonged stay in the intensive care unit (ICU), and increased mortality. Respiratory surface electromyography (sEMG) enables continuous, non-invasive monitoring of patient effort. For automatic assessment of PVA in the ICU, robust, real-time segmentation and classification algorithms are required.

Methods

In this article, we adapt two previously published offline algorithms for inspiratory onset and offset detection in respiratory sEMG into real-time capable implementations and evaluate their performance for detecting different forms of PVA.

Results

Both proposed real-time algorithms achieve high detection performance with median sensitivity and positive predictive value (PPV) above 0.9. For PVA classification, offline and real-time algorithms yield similar results with median PPV above 0.8 for most types of PVA.

Conclusion

Our results demonstrate the potential of respiratory sEMG in the ICU for non-invasive, automatic and real-time monitoring of PVA.

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Dry EEG for the Detection of Delirium Endotypes: Towards Scalable Neurophysiological Biomarkers of Acute Brain Network Disorders

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Introduction

Delirium is a common acute neurocognitive syndrome characterized by disturbances in attention, cognition, and arousal. It frequently occurs in critically ill patients and is associated with increased mortality, long-term cognitive decline, and progression to dementia. Current diagnostic approaches are largely phenotype-based and rely on clinical observation, which incompletely captures the underlying neurobiological processes and contributes to misdiagnosis and heterogeneous treatment strategies. Electrophysiological characterization using electroencephalography (EEG) offers a direct window into neuronal network function and enables a more mechanistic understanding of delirium as an acute brain network disorder.

Methods

Both visual and quantitative EEG analyses have demonstrated robust correlations between electrophysiological alterations and delirium severity, including spectral slowing and disrupted functional connectivity. Importantly, these features appear to be consistent across different etiologies of delirium, supporting the concept of a common neurophysiological pathway. Reduced electrode montages and simplified acquisition protocols have further shown promising results, suggesting feasibility for routine clinical monitoring.

Results

In this context, dry electrode EEG systems emerge as a key enabling technology for rapid, scalable, and user-friendly data acquisition in clinical environments. Recent studies indicate equivalence between dry and conventional gel-based EEG in estimating event-related potentials and connectivity measures, highlighting their potential for large-scale deployment in delirium research and bedside monitoring.

Conclusion

The integration of dry EEG with advanced qEEG analytics paves the way for objective, large-scale neurophysiological biomarkers that may improve early detection, stratification, and treatment targeting in delirium. Ultimately, linking electrophysiological endotypes with underlying pathophysiological mechanisms may facilitate a transition towards biomarker-driven precision medicine in acute brain disorders.

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Development of a Controlled Pneumatically Actuated Lung Phantom for Surgical Simulation Support and Collapse Modeling

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Introduction

Temporary lung collapse occurs in thoracic surgery to access intrathoracic structures during artificial pneumothorax. During single-lung ventilation, one lung remains ventilated while the contralateral lung is isolated by a double-lumen tube and collapses through airway outflow. Lung expansion and collapse depend on alveolar pressure (P_{alv}) and intrapleural pressure (P_{pl}), while transpulmonary pressure (P_{tp}) determines lung stability. Pleural pressurization initiates collapse, whereas airway outflow influences the evolution of P_{tp} and lung deflation. However, most lung phantoms focus on anatomical realism or ventilation mechanics and never address pressure-driven lung collapse. Moreover, lung phantom platforms may provide reproducible measurements for surgical simulation and support surgical planning and intraoperative guidance.

Methods

A pneumatically actuated lung phantom was developed to study pressure-driven lung collapse. The system consisted of a compliant balloon inside a rigid transparent chamber. Airway and pleural pathways were implemented using pneumatic pumps and sensors. P_{alv} and P_{pl} were measured and P_{tp} was calculated. The phantom represented the collapsing right lung, while the left lung remained ventilated. Two collapse configurations were tested under identical P_{pl}: passive outflow with the airway pump switched off and active outflow with additional airway suction applied through the airway pump. Each configuration was repeated 20 times with inflation followed by collapse.

Results

Collapse occurred as P_{tp} decreased toward or below zero. During inflation, P_{alv} plateaued while P_{pl} decreased, producing positive P_{tp}. During collapse, increasing P_{pl} reduced P_{tp} and passive outflow led to gradual collapse as P_{tp} approached zero. Active outflow produced more negative P_{tp} and faster deflation.

Conclusion

The proposed pneumatically actuated lung phantom enables controlled and repeatable investigation of pressure-driven lung collapse. By independently combining pleural pressurization with passive or active airway outflow, the system reproduces distinct lung collapse behaviors, providing a reproducible platform for studying collapse dynamics and supporting surgical simulation and planning.

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Brain oscillation-synchronized stimulation to enhance motor recovery in early subacute stroke: a randomized controlled exploratory trial comparing personalized, non-personalized and sham repetitive transcranial magnetic stimulation (BOSS-STROKE)

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Introduction

Stroke is the most frequent cause of permanent disability worldwide. Repetitive transcranial magnetic stimulation (rTMS) is a non-invasive form of therapeutic brain stimulation that has shown moderate effect sizes in improving paretic arm and hand function in stroke patients, indicating a strong medical need for more effective interventions. Personalized rTMS – synchronized to specific brain states via real-time EEG analysis – has demonstrated superior neuromodulatory effects in preparatory studies, but its clinical benefit in stroke rehabilitation has not yet been established.

Methods

BOSS-STROKE is an ongoing multicenter, randomized controlled, double-blind, three-arm parallel-group exploratory trial. Subacute stroke patients are randomized to receive either (1) personalized rTMS synchronized to the negative peak of the ongoing sensorimotor μ-oscillation, (2) conventional non-personalized rTMS, or (3) sham stimulation. The primary outcome is paretic arm and hand function. Personalized rTMS applies TMS pulses at individually optimized time points to maximize long-term potentiation of motor networks affected by the stroke lesion.

Results

The trial is currently in the recruitment phase. Preparatory work has consistently shown that μ-oscillation-synchronized rTMS induces more reliable and larger neuromodulatory effects compared to standard rTMS, providing a strong mechanistic rationale for the intervention. Clinical outcome data are expected to be available in 2026. Results will be presented at the conference.

Conclusion

BOSS-STROKE is the first trial to investigate whether personalized, brain state-dependent rTMS translates into a meaningful clinical benefit for stroke patients. If the hypothesis is confirmed, this approach has the potential to significantly improve motor rehabilitation outcomes and quality of life for stroke patients in Germany and beyond.

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Leveraging Intraoperative Blood Pressure Analytics for Future Post-operative Renal Risk Predictions

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Introduction

Often associated with intraoperative hemodynamic instability phases, acute Kidney Injury (AKI) remains a significant postoperative complication. High-fidelity arterial pressure waveforms can provide a detailed view of physiological stress contributing to this. Our goal is to assess the scientific validity of a large-scale data integration pipeline designed to collect high-resolution hemodynamic data, which, when combined with longitudinal postoperative clinical history, will form the basis for machine learning models to predict AKI risk.

Methods

The main challenge is the heterogeneity and fragmentation of intraoperative data. We focus on building a Python and R framework to sync multi-modal datasets, including high-frequency HDF5 sensor data and surgical event logs. A key obstacle is non-contiguity: patient data often come from multiple HDF5 files with asynchronous start times and different sampling rates. Our pipeline uses a timestamp-based "Data Broker" architecture indexing files with Unix timestamps, enabling reconstruction of surgical timelines. We are also enhancing the integration of surgical phase metadata to provide context for hemodynamic changes.

Results

Early segmentation was performed on a small subset of data from cardiac surgery patients. While the current segmentation process is "phase-agnostic" and treats surgeries as a single continuous event, the results for non-Heart-Lung Machine (HLM) phases are highly promising in terms of data quality and feature extraction (e.g., trends related to Area Under the Curve for specific features in the signal). At this stage, no direct correlation with postoperative outcomes has been observed; instead, the focus remains on extracting robust physiological parameters. The derived metrics, alongside comprehensive postoperative medical history, are intended to inform future predictive machine learning models.

Conclusion

Our findings show that high-resolution pressure data can be curated and indexed despite fragmentation. Future work will include phase-specific segmentation, isolating the HLM and cross-clamp periods, to address non-pulsatile flow and provide clean, labeled data for early AKI detection models.

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A Low-Cost Vibrotactile Wearable to Support Sensory-Impaired Patients in Virtual Environments

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Introduction

Sensory-impaired individuals, particularly those with hearing loss or visual impairment, often lack directional cues for spatial orientation, rehabilitation, and safety training. Tactile body-referenced stimulation can substitute these cues by translating environmental or virtual events into localized vibrations. However, equipping many patients with commercial haptic vests remains costly. This work presents the HapticVest, a low-cost wearable delivering directional vibrotactile feedback on the upper body. It shows that readily available components enable a significantly more cost-effective solution. The system includes a Unity-based Virtual Reality (VR) application for further development and optimisation of latency, spatial resolution, and directional accuracy.

Methods

The HapticVest uses an off-the-shelf heating vest retrofitted with eight Eccentric Rotating Mass (ERM) vibration motors across front, back, and side regions. An ESP32 microcontroller receives motor intensities via Bluetooth from the VR application. A direction mapping algorithm converts 3D collision vectors from the VR scene into motor activation patterns, enabling spatial feedback.

Results

The feasibility of the system was demonstrated using a specially developed VR application. Challenges addressed include wireless real-time communication, directional mapping of virtual events to physical motor positions, and automatic safety deactivation on connection loss. All eight motors are independently controllable with adjustable intensity and synchronized with in-game events. Material costs remain below 100 euro, about 80% less than a comparable commercial vest (bHaptics TactSuit Pro, approximately 500 euro).

Conclusion

Its low cost and documented hardware make the HapticVest a step toward providing assistive vibrotactile systems to many sensory-impaired patients. Potential applications include rehabilitation, exposure therapy, and spatial orientation training. Planned future work includes latency measurements, user evaluation with sensory-impaired participants, and refinement of direction mapping.

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atSSD: A Smartphone-Based Audiotactile Sensory Substitution Device for Hearing-Impaired Individuals

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Introduction

Hearing loss affects approximately 430 million people worldwide, projected to reach 700 million by 2050. Cochlear implants utilize only 22 electrodes compared to 3,500 inner hair cells and remain inaccessible due to costs exceeding USD 20,000. Sensory substitution devices convey auditory information through an intact sense. This paper presents the atSSD (audiotactile sensory substitution device), a smartphone and ESP32-based wearable that converts environmental sound and speech into vibrotactile patterns. A spectral pathway maps frequency bands to a motor matrix. A semantic pathway translates recognized words into sign-language-derived patterns.

Methods

The wearable uses an ESP32-S3 microcontroller with a 3×3 ERM motor matrix on the upper back, connected to an iOS smartphone via Bluetooth. Latency was measured internally via timestamps across 48 sessions and externally via 240 Hz video recording. Energy consumption was recorded using an INA219 sensor. Speech recognition accuracy was evaluated under three noise conditions (35, 50, and 80 dB). A pilot study (n = 12) assessed vibrotactile sound localization using repeated measures ANOVA.

Results

The spectral pathway achieved 62 ms latency. The semantic pathway measured 144.4 ± 54.7 ms internally and 276 ± 58 ms externally. Estimated battery life reached 15.7 hours with 2.3% energy overhead from semantic processing. Speech recognition accuracy was 98% in quiet, 94% in office, and 87% in loud conditions across 125 patterns. The pilot study showed significant improvement in localization accuracy ($p = 0.022$, large effect).

Conclusion

The atSSD demonstrates feasible smartphone-based audiotactile sensory substitution at material costs of 80–210 EUR. The dual-pathway architecture combining spectral and semantic vibrotactile feedback is unique among existing systems. Current limitations include iOS-only implementation and evaluation with normally hearing participants.

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3D-printed static and dynamic phantoms for harmonization of Magnetic Particle Imaging

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Introduction

Phantoms are mandatory to evaluate the performance of medical diagnostic modalities like magnetic resonance imaging or computed tomography. Standardized phantom structures and operating procedures are essential to check the performance of devices and methods and ensure imaging quality and reliability. In the emerging and promising field of magnetic particle imaging, standardized phantoms and operating procedures are lacking. To close this gap, we developed static phantoms to facilitate cross-platform comparisons of existing MPI devices mimicking defined anatomical structures.

Methods

An adjustable static phantom consisting of plates with fillable structures was designed and 3D printed. The plates were filled with structures containing magnetic nanoparticles (MNPs) using a 3D printing technique or embedding them into polymer matrix. The magnetic behavior of these structures was investigated using Magnetic Particle Spectroscopy (MPS) (pureDevices) and MPI (Bruker Biospin). To evaluate the final MPI image, the geometry of all structures was analyzed by scanning them with a Revopoint 3D scanner. The point cloud from the scan was compared with one obtained by Poisson-disc sampling of the STL file. Based on MRI datasets from humans, a hollow vessel structure was segmented and 3D printed.

Results

An adjustable, stackable phantom was developed and geometrically analyzed. Difference images were created, and parameters such as distance distribution, Hausdorff distance and Chamfer distance were evaluated. The first phantom plate is intended for MPI resolution assessment with molds of 18 mm^3 volume, spaced from 0.5 to 3.5 mm in 0.5 mm steps. Additional plates with a defined complex helix structure were created and analyzed. The vessel structure was combined with a micro mixing control pump to simulate continuous nanoparticle flow in anatomic structures.

Conclusion

The phantoms, together with the presented geometry analysis method, will facilitate future inter-scanner comparisons and support the development of standardized operating procedures.

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Evaluation of a High-Frequency Stimulation Platform for Retinal Experiments

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Introduction

Cell-type-selective activation of retinal ganglion cells (RGCs) is a key challenge for epiretinal prostheses. High-frequency stimulation has enabled preferential activation of functional RGC types. Existing commercial and custom non-application-specific integrated circuit stimulators often restrict temporal resolution (≈ 16µs) and lack output logging capability.

Methods

This paper presents and evaluates an open-hardware stimulation platform that overcomes these limitations, generates arbitrary current waveforms and provides dedicated outputs for the simultaneous logging of stimulation current and electrode voltage.

Results

Electrical characterization demonstrated accurate static behavior across channels and sinusoidal waveform generation up to 10 kHz with a 2.5 µs practical temporal resolution (0.8 µs theoretical limit). Successful integration with a commercial micro-electrode array setup was demonstrated with accurate stimulus delivery.

Conclusion

The platform provides a basis for future impedance-aware, adaptive, and closed-loop stimulation strategies targeting RGC-selectivity.

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Electrical Impedance Myography: A Novel Concept in Biosignal-supported Rehabilitation

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Introduction

Age-related decline in muscle mass and function, such as sarcopenia, poses major challenges for rehabilitation and geriatric care. Conventional assessments often rely on subjective evaluation or isolated strength measurements, limiting their ability to capture neuromuscular dynamics. Surface electromyography (sEMG) is widely used to detect muscle activation but has limited reliability for estimating muscle force. Electrical Impedance Myography (EIM) provides complementary information by measuring contraction-related changes in muscle bioimpedance. Combining sEMG and EIM may therefore improve the interpretability of muscle activity assessment.

Methods

A wearable multi-frequency measurement system was developed to simultaneously acquire EIM and EMG signals from skeletal muscles using a shared electrode configuration. Preliminary experiments were conducted during functional movements and controlled leg-extension exercises to investigate relationships between muscle activation, impedance changes, and mechanical force. EIM signal interpretation is based on established bioimpedance principles and model-based analysis of muscle tissue properties.

Results

The developed system enabled synchronized acquisition of electrical activation and impedance-based tissue responses during muscle contraction. Technical validation showed impedance measurement errors below 5% in the combined EIM-sEMG configuration. In controlled leg-extension experiments with a 7 kg load, EIM revealed contraction-dependent impedance changes of up to approximately 3 Ω at low excitation frequencies. Furthermore, frequency-dependent EIM differences between 10 and 50 kHz were observed, while these differences were not distinguishable from sEMG amplitude alone. These findings demonstrate that EIM provides additional quantitative information on contraction- and load-related tissue responses beyond conventional sEMG.

Conclusion

Wearable EIM technology combined with conventional biosignals represents a promising direction for biosignal-supported rehabilitation. The integration of EMG and EIM enables more comprehensive monitoring of muscle function by jointly capturing neural activation and tissue-level responses. Multimodal sensing concepts may support the development of intelligent rehabilitation systems capable of objective therapy monitoring, adaptive assistance, and improved assessment of neuromuscular function.

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Prediction of heart failure based on multimodal data from MIMIC-IV

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Introduction

Heart failure (HF) affects over 64 million people worldwide and remains a leading cause of cardiovascular mortality. Early identification of patients at risk is essential for timely treatment and to support hospital and primary care physicians. This study compares XGBoost and the Transformer-based model bidirectional Cross-Attention on multimodal clinical data to assess whether deep learning (DL) approaches outperform classical machine learning (ML) in early HF prediction.

Methods

We identified HF and non-HF patients from the MIMIC-IV database using ICD-9/10 codes, supplemented by clinical evidence from laboratory results, medications, radiology-, and discharge notes. Furthermore, we defined a 48-hour prediction window prior to the first clinical evidence of HF. Structured features were engineered from rolling-window statistics and clinical thresholds. Both XGBoost and Transformer models were trained on multimodal data and compared through an ablation study. Finally, we developed a clinical decision-support dashboard using a small set of demographic, laboratory, and medication features to deliver a 48-hour HF risk estimate, aiding clinician diagnosis.

Results

Multimodal models outperformed single-modality models across both architectures. The multimodal XGBoost model achieved the highest performance (F1 0.8773, PR-AUC 0.9437), while the multimodal Transformer achieved slightly lower performance (F1 0.8635, PR-AUC 0.9209). Structured data contributed most to XGBoost (PR-AUC of 0.9369), whereas clinical notes were better captured by the Transformer (PR-AUC of 0.8220).

Conclusion

Explainable dashboards further enhance transparency and usability by delivering quantitative 48-hour risk estimates from minimal features. This demonstrates, in this setting, that traditional ML can outperform DL models such as Transformers on tabular-dominated, multimodal clinical prediction tasks while preserving interpretability, underscoring decision-support systems' potential to aid timely diagnosis.

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Few-Shot Personalized Stress Detection from ECG via Self-Supervised Learning

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Introduction

Physiological stress detection using wearable sensors is challenging due to inter-individual variability and limited availability of labeled data for personalization. Traditional supervised approaches often fail to generalize across users without extensive subject-specific calibration and memory overhead. Self-supervised learning (SSL) has recently emerged as a promising paradigm for leveraging large amounts of unlabeled physiological data to learn transferable representations. However, its effectiveness in enabling rapid few-shot personalization for ECG-based stress detection remains insufficiently explored. This study investigates whether SSL-based models can facilitate faster adaptation to individual users compared to conventional supervised and classical machine learning approaches.

Methods

We compare four approaches: a support vector classifier (SVC), a supervised convolutional neural network (SCNN), and two SSL-based CNN models pretrained via contrastive learning. All models are pretrained on the WESAD dataset and adapted to a target dataset (ADR) using transfer learning. Personalization is performed using a k-shot learning framework (k = 0-7 samples per class) using leave-one-subject-out validation strategy. Model performance is assessed using accuracy and F1-score, with repeated experiments.

Results

During pretraining, SVC achieved the highest accuracy (0.814), while SSL-based models demonstrated competitive performance. Upon transfer learning on target dataset, SSL-CNN outperformed other approaches (accuracy 0.644). In few-shot personalization, SSL-CNN showed rapid adaptation, achieving substantial performance gains with as few as 1-3 samples, whereas SVC improved slowly. At higher k, both models converged to similar performance.

Conclusion

Compared to classical and supervised approaches, SSL facilitates faster adaptation with minimal labeled samples, making it well-suited for real-world wearable applications where rapid personalization and limited annotation are critical.

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The effects of stimulation parameters on perception in phase-modulated interference stimulation

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Introduction

Tactile perception systems are essential for environmental interaction, especially in virtual reality and robotics. Mechanical interfaces are often complex, heavy, and costly. Electrotactile stimulation provides a lighter, more affordable, and efficient alternative, but most methods use a single electrode pair, limiting depth control and precision. We present a phase-modulated interference technique with two electrode pairs, enabling targeted activation of tactile receptors at different depths and flexible stimulation pattern generation.

Methods

Voltage signals were generated using a National Instruments PCI-6723 card and converted to current using STMISOLA stimulators (BIOPAC). Four electrodes (10 mm, 30 mm apart, square layout) were attached to the forearm. Three experiments were performed: (1) Perception and pain thresholds were measured by staircase method, varying pulse width (0.75–3.5 ms) at 20 Hz (N = 21); (2) Perceived intensity was compared for test stimuli (1–6 pulses/burst) and standard stimuli (2 or 5 pulses) at 40 Hz, 1.5 ms (N = 12); (3) Regular and variable burst patterns (1:3, 1:5, 3:5) were compared using subjective ratings (N = 12).

Results

Perception can occur without pain, with perception thresholds significantly lower than pain thresholds, establishing a comfortable stimulation window ($F = 75.996$, $p < .001$, $\eta p^2 = 0.792$). Pulse width variation had no significant effect, though precision testing showed marginally lower pain thresholds. Increasing the number of pulses per burst led to significantly higher perceived intensity ($p < .001$), with potential saturation at higher counts. Stimulation pattern (regular vs. variable) did not significantly affect subjective ratings of intensity, regularity, naturalness, or pleasantness.

Conclusion

Phase-modulated interference stimulation enables flexible electrotactile burst patterns without altering perception thresholds. Pulse number effectively modulates subjective intensity, demonstrating this method's potential for adaptive tactile interfaces in virtual reality and robotic applications.

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Physiological Parameter Estimation from Reduced-Wavelength Hyperspectral Data: A Model-Based Study

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Introduction

Hyperspectral imaging (HSI) enables non-invasive assessment of tissue physiology by measuring reflectance spectra across hundreds of wavelength bands. From these measurements, physiological parameters such as tissue oxygen saturation (StO_2), near-infrared perfusion index (NIR), tissue haemoglobin index (THI), and tissue water index (TWI) can be derived. However, hyperspectral acquisition requires complex hardware and produces high-dimensional spectral data. This study investigates whether accurate estimation of physiological parameters is possible using a reduced subset of informative wavelengths, enabling simplified multispectral imaging systems.

Methods

Experiments were conducted using the HeiPorSPECTRAL dataset, consisting of hyperspectral cubes acquired in the 500–995 nm wavelength range. Region-of-interest (ROI) level spectra from 5758 samples across 11 subjects were used for regression analysis. Informative wavelengths were identified through feature relevance analysis and cross-validation stability, resulting in a reduced configuration of 20 spectral bands. Several regression models were evaluated, including Ridge regression, Support Vector Regression, Partial Least Squares, XGBoost, multilayer perceptron (MLP), and one-dimensional convolutional neural networks. All experiments were performed using strict subject-disjoint cross-validation.

Results

The multilayer perceptron achieved the most consistent overall performance across physiological indices. Mean absolute errors of 0.0607 for StO_2, 0.0269 for NIR, 0.0437 for TWI, and 0.0313 for THI were obtained using the reduced spectral subset. Although dimensionality was reduced by 80% compared with the full hyperspectral input, predictive performance remained stable across indices. The selected wavelengths corresponded to physiologically relevant absorption regions associated with haemoglobin, oxygenation, and water content. Pixel-wise reconstruction experiments further demonstrated that models trained on ROI-level spectra generalize to spatial prediction across full hyperspectral images.

Conclusion

The results indicate that physiological parameters derived from hyperspectral imaging can be reliably estimated using a compact subset of wavelengths. Task-specific reduced-band configurations therefore offer a promising pathway toward simplified multispectral imaging systems that preserve clinically relevant physiological information while reducing acquisition complexity.

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Magnetomyography: A Historical Perspective and Modern Challenges

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Introduction

Miniaturized quantum sensing advances have reignited interest in magnetomyography (MMG) — the magnetic counterpart of electromyography (EMG) — a comparably to magnetoencephalography (MEG) or magnetocardiography (MCG) rather unexplored research area in biomagnetism. Early studies (1970–1990) utilizing superconducting quantum interference devices (SQUID) established the basic science of MMG and its potential for non-redundant information on the neuromuscular signal, but the area lay dormant until miniaturized optically pumped magnetometers (OPM) emerged. Despite the renewed interest in MMG, no comprehensive review has yet connected pre-OPM research with contemporary studies, offering a complete overview of nearly all MMG work from its inception to the present and outlining the future challenges that remain.

Methods

A systematic review of all publications from 1972 to the present was conducted. Sensing technologies, muscle measurements, and analyzed metrics were systematically assessed and compared with electromyography. Database searches, including PubMed, IEEE Xplore, and Google Scholar, were performed using keywords related to magnetomyography, magnetic fields, and skeletal muscle recordings.

Results

Of the 75 publications identified, early SQUID-based studies (1972-1990) demonstrated the feasibility of recording magnetic fields from skeletal muscles and revealed signal characteristics distinct from those of surface EMG. Following a dormant period, OPM-based MMG research has emerged since 2017, with increasing focus on clinical applications including neuromuscular disorder assessment, muscle fatigue monitoring, and motor unit characterization. A comparative analysis shows that MMG might hold complementary information to EMG, with advantages including contactless recording and reduced tissue-volume conduction effects.

Conclusion

This comprehensive review bridges five decades of MMG research, connecting foundational SQUID-era discoveries with contemporary OPM-based investigations. The synthesis reveals both the progress made and the persistent challenges that must be addressed—including magnetic shielding requirements, signal interpretation frameworks, and validation against established methods. These findings provide the foundation for the symposium discussions on realizing MMG's clinical potential.

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Novel EEG Technologies for Point-of-Care Diagnostics: Flower Dry Electrodes and Rapid-Application Sponge-Based Systems

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Introduction

Emergency and point-of-care EEG diagnostics are of great clinical importance, but traditional systems require experienced personnel and lengthy setup times. Two emerging technologies address this gap: novel "Flower" dry electrodes featuring a distinct flower-like shape with angled pins, and wet active electrode sponge-based EEG (sp-EEG) systems that can be applied rapidly by inexperienced personnel. Here, we evaluate both approaches for clinical applicability and signal quality.

Methods

For Flower electrodes, a proof-of-concept study was conducted with three patients diagnosed with epilepsy and delirium. For sp-EEG, a case-control, single-blind, non-randomized study enrolled 18 individuals with epileptiform discharges and 11 healthy controls. The setup time was recorded until adequate impedances were achieved. The resulting EEGs were assessed for pathological patterns and signal-to-noise ratio by a blinded neurologist.

Results

Flower electrodes yielded high-quality recordings, enabling reliable identification of generalized spike-wave complexes and intermittent delta activity, with SNR comparable to that in previous EEG studies. Sp-EEG demonstrated significantly faster setup (4.8 min vs. 13.3 min, $p < 0.001$), with all physiological and pathological graphoelements identifiable. Blinded raters could not distinguish sp-EEG from routine EEG by visual inspection alone.

Conclusion

Both Flower dry electrodes and sponge-based EEG systems represent viable alternatives to conventional EEG for point-of-care and emergency applications. Flower electrodes offer patient-centered, gel-free technology without compromising diagnostic quality. Together, these approaches address critical barriers to EEG availability and may significantly improve patient care in resource-limited settings.

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The effect of different flicker stimulation frequencies on retinal vascular regulation

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Introduction

Dynamic vessel analysis (DVA) enables non-invasive assessment of retinal microvascular function by measuring vessel diameter changes in response to flicker light stimulation. Since retinal microvascular dysfunction can be associated with systemic and ocular diseases, DVA may provide valuable insights into vascular health and neurovascular coupling. Our aim was to systematically investigate the influence of different flicker stimulation frequencies on retinal arterial and venous dilation under standardized experimental conditions.

Methods

We studied 12 subjects (7 female, 5 male; mean age 26.2 ± 4.1 years). Retinal vessel responses were measured in a superior artery and vein using a mydriatic fundus camera-based system. Flicker stimulation was applied at five frequencies (1.875 Hz, 3.75 Hz, 7.5 Hz, 15 Hz and 30 Hz) in randomized order. Each measurement consisted of a 60 s baseline followed by two cycles of flicker stimulation (60 s) and recovery (120 s). Arterial and venous flicker-induced dilation (aFID, vFID) were quantified. Depending on data distribution, repeated-measures ANOVA or Friedman tests were used, followed by post-hoc comparisons with correction for multiple testing.

Results

Retinal vascular responses showed a clear dependence on stimulation frequency. Low frequencies induced minor dilation, while responses increased toward the mid-frequency range. At higher frequencies, this increase no longer continued, with responses either stabilizing or showing a slight decline. Venous vessels consistently exhibited greater dilation amplitudes than arteries. Statistical analysis confirmed significant frequency-dependent differences, particularly between low (≤ 3.75 Hz) and higher frequencies (≥ 7.5 Hz).

Conclusion

These findings demonstrate that flicker frequency is a key determinant of retinal vascular response characteristics in DVA. The observed pattern may indicate frequency-dependent retinal processing, with reduced responses at very low and high frequencies potentially reflecting limited neural activation or processing constraints. The results highlight the importance of considering stimulation frequency when comparing experimental studies and interpreting functional vascular measurements.

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Comorbid insomnia and sleep apnea detection: How can we leverage existing datasets to boost AI implementation in wearables?

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Introduction

The scientific community can now benefit from available datasets that provide multimodal, multicentric data acquired from healthy individuals and patients with sleep-related conditions. This is crucial for developing data-hungry algorithms, such as machine learning (ML). However, several factors may hinder the successful use of these multifaceted datasets for AI-based applications. Potential biases may arise from variations in acquisition protocols and device configurations, missing data, and mismatches. When data scarcity is an issue, these repositories are invaluable sources of knowledge that require careful adaptation and analysis. In sleep medicine, wearable sensors offer a promising alternative for more natural, continuous sleep assessment. This study aims to highlight the challenges and opportunities of deploying these datasets to implement robust ML algorithms for sleep staging in patients with two comorbid sleep disorders.

Methods

We collected electroencephalogram (EEG) signals from polysomnography (PSG) recordings of patients with sleep apnea or insomnia from available datasets. After suitable preprocessing, the EEG signals were used as input for different ML models to classify sleep stages. We evaluated the influence of data-driven features, demographics, and disorder severity on classification accuracy. ML strategies were compared by varying model training (e.g., fine-tuning and training from scratch) and model input (e.g., changing the number and configuration of EEG channels).

Results

We accurately analyzed classification errors and identified potential patterns by leveraging EEG channel configurations most comparable to those of the wearable devices. This can serve as a baseline strategy for improving generalization of ML models and tackling data heterogeneity by harnessing publicly available EEG data when sensor-specific data is unavailable.

Conclusion

A thorough examination of existing datasets may unveil distinct patterns associated with comorbid sleep conditions detectable via wearable sensors. Future work will encompass a detailed experimental framework to optimize the development of AI-based wearables and provide useful guidelines in this direction.

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A Study on Segmentation Architectures for Thyroid Scintigram Delineation

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Introduction

Automated segmentation of thyroid structures in scintigraphic imaging is critical for functional assessment and diagnosis of thyroid disorders, yet remains challenging due to low spatial resolution, high photon noise, diffuse boundaries, and strong class imbalance. This study presents a systematic and controlled comparison of four prominent deep learning architectures – U-Net, U-Net++, TransUNet, and Swin-UNet –for thyroid segmentation.

Methods

All models were trained and evaluated on a public tyroid scan dataset (189 training, 23 validation, 23 evaluation studies) under identical conditions to ensure fair comparison. Performance was assessed using a comprehensive set of metrics, including Dice coefficient, Intersection over Union (IoU), sensitivity, specificity, and 95th-percentile Hausdorff distance (HD95). Additionally, computational efficiency was evaluated in terms of parameter count, FLOPs, GPU memory usage, inference latency, and throughput, providing a holistic perspective relevant for clinical deployment.

Results

TransUNet achieved the highest segmentation accuracy (Dice: 0.9178), slightly outperforming U-Net while matching its boundary precision (HD95: 0.82 px). U-Net closely followed (Dice: 0.9133) and demonstrated superior computational efficiency, achieving the lowest latency (3.20 ms/image) and highest throughput (1622.6 images/s), making it particularly suitable for real-time clinical applications. Swin-UNet produced competitive but consistently lower performance, especially in segmenting fine anatomical structures such as thyroid lobes. In contrast, U-Net++ exhibited substancially reduced accuracy (Dice: 0.7756) and high variability, indicating instability in this task.

Conclusion

Overall, the results demonstrate that increased architectural complexity does not necessarily translate into improved performance. While transformer-based and hybrid models provide modest gains through enhanced global context modeling, classical convolutional architectures such as U-Net remain highly robust and efficient. Consequently, U-Net offers the best trade-off between accuracy and computational cost, whereas TransUNet is preferable when maximizing segmentation accuracy is the primary objective.

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Performance of a Gamma Detection Unit with Likelihood-Based Localization Method

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Introduction

In this paper a new gamma detector for use in combination with ultrasound imaging to localize radioactively marked lymph nodes is presented. To help clinicians to identify sentinel lymph nodes in procedures like lymph node biopsy a combination of ultrasound imaging and gamma detector could be helpful. To achieve a useful approach, the gamma unit must localize the radioactive lymph node with a high accuracy. The localisation estimation should be achieved within a few seconds to assure a seamless procedure. To achieve this a likelihood-based localization method was implemented and evaluated.

Methods

The detector consists of six silicon photomultiplier diodes arranged around a rectangle, to fit an ultrasound device in the center. The localization is calculated based on a probability field. The probability field is dependent on the geometric arrangement of the diodes. The measured counts are compared to the probability field, and the most likely position is determined. The system was evaluated with a Co-57 gamma source, which was positioned in a 3 × 3 matrix at three different distances (30, 50, 80 mm). The matrix covers a field of 100 × 60 mm.

Results

The position estimation achieves an Euclidean error of 2.3…46.6 mm depending on the position. For the region of interest, where the ultrasound probe would scan, the Euclidean error is between 2.3…16.5 mm for a measurement duration of 1 s. The likelihood-based localisation has a calculation time of 1.6 s.

Conclusion

The developed detector in combination with the likelihood-based localization is capable of localising of a gamma source. The accuracy is dependent on the position of the grid and further experiments with tighter grid spacing need to be done. An estimation algorithm for estimating the source activity is not yet implemented and the impact on the calculation time and the accuracy need to be investigated.

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Machine-Learning-Enhanced Low-Cost Bionic Fingertip Sensing

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Introduction

Tactile feedback is essential for accurate object manipulation and functional use of prosthetic hands. However, high-resolution tactile sensing systems are often limited by cost, complexity, and integration constraints. Force-sensitive resistors (FSRs) provide a low-cost sensing solution. However, their nonlinear response characteristics and limited spatial resolution constrain accurate force estimation. This study investigates a minimal triangular array of three FSRs combined with machine-learning-based signal fusion to improve force magnitude estimation and spatial localisation.

Methods

A triangular array of three sensors was developed to enable force estimation across seven predefined contact locations. Forces ranging from 0 to 9.8 N were applied using a 3D-printed testing rig, and calibrated voltage outputs from the three FSRs were recorded. A second-order polynomial Lasso regression model was developed to capture linear and non-linear interdependencies between sensor outputs. The model performance was evaluated and compared with a simple force summation baseline.

Results

The regression-based approach achieved a mean absolute error of 3.36% and an R^2 of 0.998 for force magnitude prediction, compared with 23.91% and 0.779 for the force summation baseline. Mean absolute errors across all seven test positions were below 5%. Contact localisation accuracy was 97.1%, with only five misclassified measurements, all occurring at the lowest applied force. The estimated cost of the sensing system was approximately €18 per fingertip, excluding the microcontroller.

Conclusion

The results demonstrate that machine learning can compensate for the inherent limitations of low-cost FSR hardware by capturing the linear and non-linear interdependencies between sensor signals. The proposed approach enables accurate force magnitude and spatial localisation using a minimal three-sensor configuration. The design provides a scalable solution for tactile sensing in bionic and prosthetic hands. Further validation is required under distributed contact conditions and with continuous spatial force mapping.

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Polyzwitterionic hydrogel biosensor for long-term and dynamic EEG

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Introduction

Electroencephalography (EEG) was a technique commonly associated with medical diagnosis, such as epilepsy, and neurology. However, it has become a modality for mobile and outside-the-lab application in real life conditions and self-applied devices. Dry electrodes have led the way in this area, providing simpler application and good signal quality, but concerns about artifact susceptibility, limited wearing comfort, and higher electrode-skin impedance (ESI) have limited their wider implementation. Hydrogel-based sensors are an attractive alternative, retaining a facile application of a solid/dry sensor with good conducitivity given their electrolyte content.

Methods

A biosensor composed of an Ag/AgCl coated polyurethane electrode and a polyacrylamide/alginate/gelatine/AMPS hydrogel was developed. The hydrogel formulation was optimized based on mechanical (compression and adhesion) and long-term electrochemical (intrinsic impedance) characteristics. The optimized formulation was then validated and further improved based on 2-pole 8h ESI measurements performed with electrodes placed 5 cm apart on the forehead of three healthy volunteers. Finally, fabricated biosensors were used in low-density EEG measurements as a proof of concept.

Results

Increased alginate (1.6% wt) and glycerol (15% wt) with reduced crosslinker (MBAA - 0.02% wt) resulted in the hydrogel with lowest long term (24 h) intrinsic impedance of 1733 Ω (at 10 Hz) while retaining desirable mechanical properties. Initial (0h) ESI at 10 Hz for hydrogel and paste-based electrodes (control) resulted in 31 kΩ and 36 kΩ, respectively. Preliminary EEG results showed comparable signal-to-noise ratio to paste-based electrodes.

Conclusion

Presented results support our hydrogel's capability to maintain low impedance over 24h and thus prove the potential for long-term and mobile EEG measurements. Prospectively, observed tunability of mechanical characteristics has the potential of addressing artifact susceptibility and stable contact in hairy scalp areas. Tailored formulations could be used to address these challenges and will be the object of future studies.

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Research Data Integration for AI Development: Process and Learnings

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Introduction

With AI models, the field of healthcare data analytics is advancing rapidly. However, these models often rely on limited public datasets. The organization of clinical studies including the acquisition as well as annotation of clinical data represents a time-consuming challenge, consuming significant efforts before the actual model development can begin. Therefore, we present insights into the current practical process of research data integration for medical AI at a German university hospital.

Methods

Based on multiple clinical AI projects conducted in collaboration with clinical partners, we identified and systematized a recurring ten-step process as a reference framework (order and overlap may vary by project): (0) Stakeholder finding and task definition, (1) ethics committee, (2) data protection compliance, (3) data access and query strategy, (4) data export from clinical systems (5) further data selection and quality control, (6) de-identification and pseudonymization, (7) data transfer to a secure analytics environment, (8) annotation service deployment and process, (9) final data structuring for processing, and (10) model development and application. Each step requires coordinated input from clinical experts and data scientists, covering responsibilities such as patient cohort identification, filtering, annotation, and local clinical infrastructure or workflows.

Results

National efforts like the Medical Informatics Initiative aim to standardize and streamline this process through Medical Data Integration Centers, which extract, harmonize, and provide clinical data upon approval by local Use and Access Committees. Still, such service-based research data integration remains largely unfeasible for complex modalities like high-dimensional clinical data, biosignals, and imaging.

Conclusion

There is a clear need for standardized protocols for research data integration at university hospitals. Particularly for complex clinical data, there is currently no alternative to the presented multi-step reference framework. Establishing robust institutional processes would substantially reduce the overhead required before medical AI development, enabling faster and more reproducible healthcare analytics research.

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Virtual staining of Endoplasmic Reticulum Fluorescence image from Brightfield images using Transformer based GAN

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Introduction

Endoplasmic Reticulum (ER) plays a critical role in cell function and drug response. Fluorescence based cell painting enables detailed visualization of ER morphology and cell response to external perturbations. However, acquiring the fluorescence images for large scale experiments is resource intense and time consuming. In this work, a transformer based Generative Adversarial Network that integrates the convolution operation with the attention mechanism is introduced to predict the fluorescence image from the brightfield images.

Methods

The generator follows an encoder decoder architecture, where the encoder utilizes Swin transformer blocks, enabling the model to capture local and global features. The decoder reconstructs the fluorescence image using transposed convolution layers. The discriminator utilizes a patch-based network that evaluates the structural similarity in the local regions between the predicted and ground truth images.

Results

Quantitative evaluation demonstrates the reconstruction accuracy and structural similarity by achieving PSNR of 33.64, SSIM of 0.92, MSE of 0.000573 and MAE of 0.0114. Further, visual comparison was used to evaluate the morphological consistency in the generated image. Additionally, feature based analysis using Cell Profiler resulted in high correlation between predicted and ground truth images. This indicates the ability of the model to preserve the biological information.

Conclusion

Thus, the proposed approach provides an effective and reliable tool to traditional fluorescence imaging, enabling label free prediction of fluorescence image from brightfield image.

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Temporal Dynamics of Continuous Glucose Monitoring Data: Implications for Automated Meal Detection

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Introduction

Automated meal detection using continuous glucose monitoring (CGM) can reduce the burden of manual meal logging in diabetes management. Most approaches rely on rapid postprandial glucose excursions and are therefore sensitive to signal dynamics. CGM filtering may attenuate or alter glucose signal dynamics and affect automated meal detection. Here, we investigated how differently sampled and filtered CGM data influence performance of two established meal detection algorithms.

Methods

Healthy participants (14 female and 15 male) wore a FreeStyle Libre 3 (Abbott Laboratories, USA) over 14 days under free-living conditions. We analyzed two simultaneously recorded data streams: *auto-logged data* at 5-minute intervals, stored in memory of the device and *device-streamed data* at 1-minute intervals, displayed by the device. After removing artifacts and correcting missing or implausible self-reported meal entries, 8820 hours of data and 2837 reference labels remained. We downsampled device-streamed data to 5-minute intervals and characterized the waveform dynamics using 18 metrics from the time, frequency, and time-frequency domains. We evaluated the detection performance on two heuristic meal detection algorithms based on glucose rate of change (GROC) and glucose acceleration (GA), comparing detection rate and false positives per day.

Results

Device-streamed data showed rapid early postprandial glucose excursions, with higher peak glucose, GROC, and GA values. Auto-logged data, likely due to non-linear filtering, attenuated rapid changes with smoother glucose trajectories and reduced sensitivity to short-term fluctuations.
Device-streamed data resulted in the detection of 30 percentage points more meals, regardless of the algorithm. Compared with device-streamed data, the use of auto-logged data reduced false positives per day by threefold in the GROC-based algorithm and to zero in the GROC- and GA-based algorithm.

Conclusion

CGM signal characteristics substantially influenced meal detection performance, indicating limited robustness. These findings highlight the importance of data accessibility and transparency about signal preprocessing for the development of CGM based meal detection algorithms.

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When Does an AI Update Become a Significant Change? Regulatory Challenges for AI-based Medical Software under the MDR

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Introduction

AI-based medical devices in the European Union are regulated under the Medical Device Regulation (MDR), which relies on clearly defined product states and discrete conformity assessment processes. However, AI systems evolve continuously through updates, resulting in multidimensional performance changes. This creates a structural mismatch with the current regulatory framework, which classifies modifications as significant or non-significant. To address this mismatch, the paper introduces a multidimensional perspective on AI updates.

Methods

A conceptual approach models AI updates as transitions between system states within a multidimensional performance space. System behavior is characterized across dimensions such as accuracy, robustness, and data quality, with accuracy operationalized through metrics such as sensitivity and specificity. The perspective enables structured comparisons before and after updates beyond single-metric and binary evaluation.

Results

The multidimensional perspective demonstrates that AI updates cannot be adequately captured by single-metric or binary assessments. Performance changes occur across multiple dimensions and involve trade-offs, such as improved sensitivity at the expense of specificity. This is particularly relevant in clinical AI applications, especially in medical imaging, where updates may shift diagnostic performance under changing data. The perspective provides a structured basis and supports consistent evaluation within regulatory processes.

Conclusion

AI-based medical devices challenge the assumption of stability underlying current regulatory frameworks such as the MDR. By reframing system updates as multidimensional state transitions, the proposed multidimensional perspective addresses the mismatch between continuous evolution and binary regulatory decision-making. The perspective supports more transparent, evidence-based, and lifecycle-oriented evaluation of AI updates and may contribute to more consistent and future-proof regulatory practices.

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Current Density Distribution in the Lumbar Region under Electrical Stimulation

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Introduction

Electrical stimulation is used for neuromodulation, analgesia, and spinal cord stimulation. Because tissues differ in geometry and conductivity, current propagation is non-uniform. Simplified models may not capture patient-specific lumbar anatomy, tissue interfaces, depth, or shielding by low-conductivity tissues such as fat and bone. This study presents a CT-derived finite-element model to quantify current pathways during surface electrical stimulation. Its contribution is the region-specific assessment of current concentration at electrode–skin interfaces, superficial tissues, and tissue boundaries, and reduced penetration toward deeper spinal structures.

Methods

A CT dataset covering the abdominal–lumbar region was used to reconstruct a model of the T8–S1 region, including skin, fat, muscle, bone, and the spinal cord. After segmentation and preparation, the model was imported into ANSYS Electric for steady-state conduction analysis. Surface source and return electrodes were positioned on the lower back. Tissue-specific frequency-independent isotropic conductivities were assigned using the IT'IS database. The model was solved under quasi-static and resistive assumptions; anisotropic and frequency-dependent behavior were not included. Current-controlled levels of 20, 45, and 70 mA were evaluated.

Results

Simulations showed a heterogeneous current-density distribution governed by tissue geometry, differences in conductivity, and electrode placement. The highest current density occurred near electrode surfaces and superficial tissues, indicating local concentration at electrode–skin interfaces and tissue boundaries. Penetration toward deeper spinal structures was lower than in superficial regions. Increasing current from 20 to 45 and 70 mA increased maximum current density from 44.45 to 100.08 and 155.58 A/m², respectively, while average current density remained below 1 A/m².

Conclusion

This CT-based T8–S1 framework provides a patient-specific approach for identifying current pathways during surface electrical stimulation. Experimental validation is planned using measurements from CT-based 3D-printed tissue phantoms. Findings may support electrode placement, stimulation-intensity selection, and planning for lumbar neuromodulation and spinal cord stimulation.

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Characterisation of Spatial Correlation of High Density Intracortical Neural Recordings

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Introduction

High-density electrophysiology recordings such as Neuropixels provide rich spatio-temporal neural data but impose stringent data-rate constraints. While most compression pipelines predominantly exploit temporal correlations, multichannel recordings exhibit pronounced spatial structure whose contribution to compressibility remains poorly quantified.

Methods

In this work, we present a general analysis of spatial information in electrophysiology data. Using spatial singular value decomposition and rate–distortion analysis, we characterise the low-rank structure of multichannel signals under different preprocessing and masking regimes.

Results

Comparisons with popular temporal, spatial, and spatio-temporal delta encoding reveal that temporal correlations maintain low-rank behaviour, whereas spatial differencing primarily acts as a decorrelating (whitening) operation. There is little difference in results between whole-signal and spike-only analysis, due to spike activity being present in early SVD components and therefore in low-rank reconstructions.

Conclusion

These findings can inform future developments of compression algorithms for neural data.

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Ameca, tell me a story! – A humanoid robot as a storyteller

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Introduction

Social robots designed to engage people – for example, by reading stories aloud – are used to promote language skills and empathy in therapeutic and social support settings. Previous studies have been conducted with young people (aged 8 to 30). In this article, we report on an exploratory study in which a humanoid robot (Ameca) was used as a story reader in care homes to investigate acceptance and the potential for social interaction and cognitive stimulation among people in need of care.

Methods

To achieve this, we developed two counterbalanced types of stories for the humanoid robot: (1) a neutral version, in which the robot 'reads aloud' from a book, and (2) a theatrical version, featuring varied voices, facial expressions, and gestures. The study comprised two phases: an open presentation of the robot, followed by one-to-one sessions where Ameca delivered both stories, after which a structured interview was conducted based on the TS-SF, GAToRS, and Godspeed questionnaires. The Study Board of OFFIS e.V. approved the study (registration number 2024G034).

Results

The study had 34 participants (79.4% women, M = 82.97 years, SD = 7.74 years). Initial findings show that many participants were able to empathise with the stories, and Ameca was consistently perceived as likeable (30 out of 34), particularly due to her deliberate eye contact. It was striking that, on average, the robot was rated more positively after the second story than after the first, regardless of the format of the presentation, suggesting growing familiarity with the robot.

Conclusion

Our results suggest that using the humanoid robot Ameca as a reader has the potential to provide a valuable addition to care homes by encouraging social interaction and therefore, potentially taking some of the strain off staff. In light of the positive feedback, we plan to carry out the study in further care homes.

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A Feasibility Study on Magnetic Localization of Endoscopes Using MEMS Actuators

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Introduction

We present an initial feasibility study on the localization of endoscopes within the gastrointestinal tract using compact micro-electromechanical system (MEMS) transmitters. Each transmitter consists of a MEMS actuator, providing biaxial tilt actuation. On this MEMS actuator, a small magnet is mounted. Resonant tilting of the MEMS actuator in the low kHz regime causes a periodic reorientation of the attached magnet, leading to a characteristic time-varying magnetic field distribution. The resulting signal can be used to determine the position, orientation, and distance of the MEMS actuator relative to the external magnetic field sensors. This approach aims to enable accurate, real-time tracking of endoscopic devices during examinations of the gastrointestinal tract.

Methods

The characterisation process was divided into two main parts: First, measurements were performed using the MEMS actuator at predefined distances and orientations. For this purpose, an experimental setup was used that allows the adjustment of the distance between the sensor and the MEMS actuator, and the angle of the sensor or the actuator. Second, the localization of the actuators was performed using the previously characterized magnetic field signatures as a reference. In this study, magnetic field data recorded by external sensors were used to estimate the spatial parameters of the actuators, including position and orientation.

Results

The experimental results evaluate the influence of the distance and orientation between the sensor and transmitter. The measurements show that a MEMS actuator provides stable and reliable magnetic field signals, which are suitable for a localization at distances up to 30 cm.

Conclusion

This study provides a foundational framework for further research on the precise localization of endoscopes within the gastrointestinal tract. Subsequent work will focus on measurements using an optimized and smaller MEMS actuator to enable real-time tracking of endoscope devices during medical examinations.

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Preliminary FSI-Simulation Study of an Aortic Counter Pulsation Device

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Introduction

According to the German Heart Report 2024, heart failure remains one of the top ten causes of death. A therapeutic gap exists for patients with moderate circulatory support needs: pharmacological therapy alone is often insufficient, whereas ventricular assist devices (VADs) are not appropriate because the expected hemodynamic improvements do not outweigh the associated risks.
Skeletal muscle-based cardiac assist support was investigated in the 1980s and 1990s for patients with moderate to severe heart failure. However, limited progress in muscle stimulation and conditioning protocols, along with the rapid advancement of alternative therapies, resulted in abandoning this research field. Long-term follow-up data indicate that this approach might have been terminated prematurely.

Methods

Based on previous ideas about skeletal muscle-powered cardiac support, a design concept for a contractile chamber was created using the force of the latissimus dorsi to deliver blood into the peripheral circulation in sync with the cardiac cycle, thereby reducing cardiac workload. The feasibility of this design was studied in silico by performing fluid-structure-interaction (FSI) simulations. The mechanical properties of the aorta and chamber material, along with blood flow behavior, were modeled using physiological pressure and muscle-contraction profiles from the literature.

Results

Simulation results show adequate perfusion (pressure 80-90 mmHg, flow velocity 2,9 m/s) of the contractile chamber with the current design. Minor backflow was seen at the distal anastomosis, indicating possible local blood stagnation and a potential risk of thrombus formation.

Conclusion

The proposed design concept seems feasible and provides a solid basis for further development. However, improvements at the proximal valve and distal anastomosis are recommended. Due to modelling limitations, additional validation of the prototype in vitro is planned. For this purpose, a mock-loop circulatory system is applied with an anatomical aortic model to evaluate pressures and flow distribution, especially in the renal and femoral arteries.

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Autoregressive prediction of hemodynamics before TAVR in latent space with pretrained video autoencoders

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Introduction

Transcatheter aortic valve replacement (TAVR) is increasingly applied to intermediate- and low-risk patients, raising the need for better prediction of long-term complications such as aortopathy and thrombosis, as well as efficient, patient-specific hemodynamic assessment. At the same time, recent advances in large video generative models demonstrate that videos can be compressed into low-dimensional latent spaces that preserve key spatiotemporal structure. We hypothesize that pretrained autoencoders can compress cardiovascular blood-flow dynamics and enable prediction of their temporal evolution in latent space.

Methods

We evaluate variational autoencoders (VAEs) from state-of-the-art video models and train an autoregressive 3D U-Net on the latent space to predict systolic flow in a synthetic virtual cohort of 100 TAVR patients. The patients were generated from statistical shape and calcification models, and unsteady systolic flow was simulated by means of computational fluid dynamics (CFD). The resulting velocity fields were voxelized and slice-wise encoded with the VAEs. On the latent space 3D U-Nets were trained to auto-regressively predict future latent time steps, which were decoded back to velocity fields and compared with CFD simulations.

Results

The study demonstrates in a concise manner that large, pretrained video VAEs can be effectively used as surrogate models for complex TAVR hemodynamics. By compressing CFD-based velocity fields into a latent space and performing autoregressive prediction with a 3D U-Net, the mean velocity errors remain below 0.08 m s^{-1}, which is within a range that merits further discussion for clinical applications.

Conclusion

Our results show that pretrained VAEs can compress systolic hemodynamics while preserving relevant flow patterns, thereby enabling forecasting and suggesting a promising route toward computationally efficient surrogates for TAVR hemodynamic assessment.

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Challenges of High Melanin Content on Skin Cancer Diagnosis by Hyperspectral Imaging

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Introduction

Skin cancers are the most common group of cancer and often divided into two main subsets: malignant melanoma (MM) and non-melanoma skin cancers (NMSC). Part of the goal of our research network “Target-H - Innovative Therapies, Smart Diagnostics and Predictive Oxidative Signalling Patterns using the Example of Skin Cancer” is to investigate hyperspectral images of skin lesions to find spectral signatures caused by the presence of skin cancer. While melanin, as a heavy absorber, is also a good indicator for differentiating MM and NMSC, it also presents challenges in investigating other tissue components to differentiate MM from benign melanocytic lesions.

Methods

The effect of melanin is presented on hyperspectral images from in-vivo skin-lesions. These were taken during routine screening at the University Hosptial Rostock using a customized TIVITA Mini Hyperspectral Camera over a wavelength range of 500 to 1000 nm. For examining the analysis methods, spectra from Monte-Carlo simulations are used for their known tissue compositions. These simulations also model the observed effects from the clinical data caused by high melanin concentrations in skin. The influence of melanin is examined on two classical spectral analysis methods, based on absorption-relations at different wavelength regions and linear component fitting.

Results

Melanin heavily impacts remission spectra used in hyperspectral imaging. Due to the high absorbance in melanocytic skin lesions, the intensity detected does not exceed the specular reflectance level in the shortest measured wavelength range in cases of very high melanin concentration. While the examined methods present good approximations for their aims at lower melanin concentrations, high melanin content impacts their precision.

Conclusion

Further research is required to find a general solution to accommodate for the presence of high melanin concentrations in human skin. A combination of methods, which also takes spatial differences from hyperspectral imaging into account, may be beneficial than relying on one alone.

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Show Me the Polyp!
Evaluating the Plausibility of KernelSHAP and Grad-CAM Explanations for Colonoscopy Video Classification

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Introduction

KernelSHAP and Grad-CAM are explainability methods commonly applied to image classification. Both methods aim to improve transparency by identifying image regions that contributed most to a prediction. However, many clinical tasks, such as detecting polyps during colonoscopy, are inherently dynamic. We extended KernelSHAP and Grad-CAM to the task of colonoscopy video classification, assessed the plausibility of their explanations, and evaluated whether the plausibility score alone can reveal model-related faults in video processing.

Methods

We used the EndoFM-LV model, finetuned for binary classification of 16-frame PolypDiag videos, as our pre-trained model. We prepared a 6-frame PolypGen video dataset (PolypGen6) and used it to finetune the pretrained model. For both the pretrained and finetuned models, we generated KernelSHAP and Grad-CAM explanations for polyp class predictions of PolypGen6 samples. Explanations were binarized to extract the model focus approximations. Plausibility was quantified as the intersection-over-union (IoU) between the model focus in polyp-containing frames and their respective segmentation masks.

Results

First, explanation plausibility was low for both explainability methods, although KernelSHAP performed slightly better. IoU scores were generally small and decreased further with higher binarization thresholds. Plausibility varied across frames, but was temporally more consistent for KernelSHAP explanations. Second, explanation plausibility alone could not reveal model faults reliably for both explainability methods.

Conclusion

The plausibility of KernelSHAP and Grad-CAM explanations is clinically insufficient. This motivates future research on improving model focus and evaluating explainability methods better suited to video-based classifiers.

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Single-trial EEG and MEG alpha-band photic driving effects

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Introduction

In recent years, interest in the single-trial analysis of electroencephalography (EEG) and magnetoencephalography (MEG) data has grown, driven by the need for a better understanding of instantaneous brain states and improved signal-to-noise ratios. So-called transient events, or bursts, have been shown to be the building blocks of well-known, established patterns in processed, i.e. averaged, electrophysiological recordings.
To better understand the generation mechanisms and the frequent intra- and interindividual differences that occur during intermittent photic stimulation (IPS), we analyzed the effects of photic driving during individualized IPS in single-trial EEG and MEG in relation to transient events.

Methods

Fifteen healthy volunteers received IPS at eight different stimulation frequencies, depending on their individual alpha peak frequencies (iAPFs). EEG and MEG were recorded simultaneously during the procedure. Transient events were detected during stimulation at and around the iAPF of each volunteer. The events were characterized by their number, frequency, power and time and frequency width.

Results

The main finding was that the number and frequency of events differed significantly across the various stimulation frequencies. The stimulation frequencies $f_{stim} = 0.7 \times iAPF$ and $f_{stim} = 1.3 \times iAPF$ produced notably different results compared to those around $f_{stim} = 0.5 \times iAPF$ and $f_{stim} = 1.0 \times iAPF$. The results presented here extend the conventional (averaging) analysis of photic driving effects and reveal the importance of transient event number and frequency during photic stimulation to describe entrainment and resonance (photic driving) effects.

Conclusion

This study improves our understanding of photic driving effects by contributing a characterization of transient events in single trials with varying stimulation frequencies.

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Optimal Robot Base Alignment for Medical Procedures

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Introduction

Robots are increasingly used in clinical settings. Cart-mounted cobots are typically fixed during procedures, so their reachable workspace is strongly determined by the mounting inclination of the robot base and the tool geometry. While planar base position and tool design have been optimised, base inclination and its interaction with tool angulation remain largely unexplored design variables for medical robots.

Methods

We present a simulation-based framework that evaluates combinations of base inclination and tool angulation using a manipulability-based reachability index. A 7-DoF robot is placed beside a patient bed, modelled as a safety zone excluded from base placement. A local operating space is defined by 15 tool-centre-point poses at one position with varying orientations. Three tool angles (0°, 45°, 90°) and three base inclinations (0°, 45°, 90°) are analysed. For each combination, all feasible, collision-free joint configurations realising the target poses are computed, and Yoshikawa's manipulability is aggregated into a single reachability value.

Results

Across all base inclinations, the straight tool (0°) yields at least twice as many feasible base placements as the 45° and 90° tools and achieves the highest mean normalised reachability. The combination of a 0° tool with a 90° base inclination provides the largest set of valid base positions and the highest average manipulability, whereas changing base inclination for a fixed tool angle alters the number of feasible placements by only about 15–20 %.

Conclusion

Orientation-sensitive tasks favour straight or mildly bent tools with suitable base inclinations, which preserve redundancy for orientation changes and offer more base placement options than strongly bent tools. Purely positional tasks may instead benefit from bent tools and strongly inclined bases. Mounting decisions for medical cobots should therefore reflect the dominant task requirements and practical constraints, and the proposed framework offers quantitative support for selecting base inclination and tool geometry in cart-mounted systems.

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Comparative Vibroacoustic Analysis of Spinal Needle Insertion Actions: Quincke vs. Sprotte

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Introduction: Tactile feedback during needle positioning is often the primary guidance available to clinicians, but it is subjective and dependent on operator experience. Vibroacoustic sensing of tool-material interactions may provide objective information to support needle-based procedures. This study investigated whether friction-induced vibrations captured proximally at the needle hub can distinguish between two common spinal needle designs: Quincke (cutting bevel tip) and Sprotte (non-cutting pencil-point tip).

Methods: Audio signals were recorded at 48 kHz using a miniature microelectromechanical systems (MEMS) microphone mounted at the needle hub during manual insertions into dry foam. A total of 207 recordings (103 Sprotte, 104 Quincke), acquired across two sessions, were divided into four sequential actions, yielding 828 action-level segments of 300 ms each. From every segment, 372 acoustic features were extracted, including Mel-frequency cepstral coefficients (MFCCs), temporal derivatives, Mel-spectrogram statistics, spectral descriptors, and short-time Fourier transform (STFT) magnitude features. Classification was performed using classical machine learning models and convolutional neural networks under a strict recording-level split.

Results: The highest overall needle-type classification performance was achieved by a support vector machine with a radial basis function kernel, reaching 95.2% accuracy on held-out test data and $93.3\% \pm 2.1\%$ in grouped cross-validation. Four-class action recognition achieved 90.5% held-out accuracy. In per-action Quincke-versus-Sprotte analysis, held-out accuracy ranged from 88.1% to 95.2%, indicating that needle-type information remained detectable throughout the insertion-withdrawal cycle.

Conclusion: The findings demonstrate that proximal vibroacoustic sensing can characterize needle-material interaction differences and distinguish Quincke and Sprotte spinal needle designs in a controlled dry-foam environment. These results support acoustic sensing as a complementary feedback modality for needle procedures and motivate further validation in more clinically representative media.

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Rule-Informed Feature Engineering for Interpretable and Transferable Sit-to-Stand Classification

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Introduction

Wearable IMU-based classifiers for post-stroke sit-to-stand (STS) assessment achieve strong in-domain performance but rarely generalise beyond their training dataset. In our previous work, a Random Forest (RF) reached 94.03% accuracy on an STS dataset but collapsed to 23.6% under zero-shot cross-dataset transfer, whereas a rule-based expert model retained 71.3%. This suggests biomechanical grounding confers robustness that generic features do not, yet rule-based models remain rigid as their thresholds cannot be refined by data. We propose rule-informed feature engineering to bridge this gap, expert decision logic into continuous features that data-driven classifiers can optimise.

Methods

We designed 16 biomechanical features derived from an expert rule-based STS classifier, each encoding a biomechanically grounded scalar: range of motion, bilateral asymmetry, extension completeness, knee oscillations, or trunk sway. A Decision Tree (DT) and Random Forest were trained via 5-fold subject-grouped cross-validation on the STS-4Class dataset (330 trials, 11 subjects; four classes: Correct, Fail, Hemiparesis, Step). Generalisation was assessed via zero-shot (direct transfer) and one-shot (per-subject calibration using one reference trial) transfer to CeTI-Locomotion (499 trials, 50 subjects).

Results

The DT independently recovered expert decision boundaries, matching the hip asymmetry threshold within 0.01°. The rule-informed RF achieved 82.33% local accuracy and 87.6% zero-shot cross-dataset accuracy — within 3 percentage points of the rule-based ceiling (71.3%) and far above the generic RF (23.6%). Under one-shot calibration it reached 90.4%, surpassing both the rule-based model and generic RF (60.2%).

Conclusion

Rule-informed feature engineering successfully bridges rule-based and data-driven STS classification. Although local performance remains below generic-feature baselines, the approach recovers expert-aligned decision boundaries and substantially improves cross-dataset generalisation, consistent with biomechanical grounding as the primary driver of transferability in low-data clinical IMU settings. Validation on genuine post-stroke data remains an essential next step.

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Hyperlet Transform-Based Cognitive Load Assessment Using Single Channel fNIRS Signals

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Introduction

Cognitive load assessment using functional near-infrared spectroscopy (fNIRS) has gained increasing attention due to its non-invasive and high spatial resolution nature. However, reliable classification remains challenging due to the non-stationary and nonlinear nature of haemodynamic signals. Conventional time-frequency representation methods often fail to capture subtle amplitude variations from haemodynamic responses due to limited joint time-frequency resolutions.

Methods

This study proposes a Hyperlet Transform (HLT)-based framework for cognitive load estimation using single-channel fNIRS signals. The framework integrates signal preprocessing, HLT-based time-frequency decomposition, multi-domain feature extraction, and optimal feature selection within Leave-One-Subject-Out (LOSO) folds to identify robust biomarkers. The extracted features are applied to five ML clas sifiers namely SVM-RBF, KNN, Naive Bayes, AdaBoost, and RandomForest.

Results

Among the evaluated classifiers, Support Vector Machine with a Radial Basis Function kernel achieved the highest performance, with accuracies of 73.33% for 3-class tasks, 86.67% for Baseline vs Low Cognitive Load, and 90.00% for Baseline vs High Cognitive Load tasks. Further, HLT outperformed conventional time-frequency methods.

Conclusion

The findings emphasize that HLT-derived features effectively capture cognitive workload-related haemodynamic changes and provide strong potential for the development of real-time deployable solutions for next-generation affective computing systems. Future research will focus on multimodal integration, real-time deployment, and validation across larger, more diverse populations.

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ISES - Interactive sleep monitoring system for the early detection of gender-specific sleep disorders

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Introduction

The ISES project consortium (funded by BMFTR) is developing a demonstrator system for interactive sleep monitoring, with a focus on obstructive sleep apnea (OSA) in primary care. The main goal is to explore gender-specific differences in sleep patterns and symptoms, with a prospective objective to improve women's health care, in a field study run by Department für Versorgungsforschung (UOL) and supported by experts for gender-sensitive medicine (OvGU).

Methods

The Fraunhofer IDMT is responsible for the development and evaluation of key sensor systems and analysis methods. Its core contributions are comfortable electrodes for nocturnal EEG and a contactless radar module for detecting breathing, heart rate, and body movement, both of which minimize disruption to sleep and thus enable the recording of nighttime sleep with high ecological validity. In cooperation with Brain Products GmbH, a miniaturized EEG amplifier with an inertial measurement unit (IMU) will be implemented in a manner that allows synchronous data acquisition and processing. The software platform enabling data transfer and visualization will be provided by avisé GmbH. The objective of the project is to gather insights into how suitable such a sensor system is for integration into the general practice care pathway.

Results

In addition to the sensor setup, the IDMT plans to develop and validate methods for the automatic detection and characterization of OSA based on retrospective data. Differences in men and women will be considered and may lead to different models to achieve best results for both groups. Data from the field study will be used to be explored within the machine learning approaches in later stages of the project.

Conclusion

By combining innovative sensor technology with intelligent, gender-specific signal analysis, the vision of ISES is to make a significant contribution to bringing sleep diagnostics out of specialized sleep laboratories and into primary care.

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A multi-organ microphysiological system for radiopharmaceutical biodistribution studies – Technical validation and biological proof with [^{18}F]FDG

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Introduction

Radiopharmaceuticals (RPs) are radiolabeled molecules used in PET imaging and targeted cancer therapy. Preclinical characterization of biodistribution and organ-specific metabolism conventionally relies on animal models, raising ethical and translational concerns. Microphysiological systems (MPS) offer a human-relevant, animal-free alternative. This study presents a multi-organ MPS comprising tumor, liver, and kidney equivalents, validated with [^{18}F]FDG as a well-characterized reference PET tracer.

Methods

A polycarbonate MPS with four interconnected compartments (tumor, liver, kidney, rest-of-body reservoir) was driven by a micropump at 50 bpm. Volume flow distribution was quantified by micro-particle image velocimetry (µPIV). Organ equivalents comprised A431 spheroids (tumor), HepG2 spheroids (liver), and a RPTEC-TERT1/HUVEC-TERT2 co-culture on Transwell inserts (kidney). Static monolayer uptake assays were performed with [^{18}F]FDG (~0.25 MBq/well) with and without competitive glucose blocking (300 mM glucose). Dynamic biodistribution was assessed by phosphor imaging after 10 and 60 minutes of tracer circulation.

Results

µPIV confirmed that the flow distribution matched design values with deviations below 1 percentage point across all compartments. In static assays, all cell types showed specific, GLUT-mediated [^{18}F]FDG uptake: A431 (106.1 ± 5.7 pmol/mg), RPTEC-TERT1 (44.3 ± 3.8 pmol/mg), and HepG2 (32.2 ± 4.8 pmol/mg). Competitive glucose blocking reduced uptake in all cell types, confirming GLUT-mediated transport. Under dynamic conditions, phosphor imaging revealed homogeneous tracer distribution after 10 min and compartment-specific [^{18}F]FDG retention exclusively at organ equivalent positions after 60 min.

Conclusion

The multi-organ MPS demonstrated reliable microfluidic performance and compartment-specific [^{18}F]FDG biodistribution, providing a biological proof-of-concept for a physiologically relevant, animal-free platform for preclinical radiopharmaceutical studies. Future work will focus on quantitative readout methods and evaluation of additional radiopharmaceuticals beyond [^{18}F]FDG.

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A Framework to interactively map Medical Spectral Imaging Research Activities

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Introduction

The rapid growth of scientific literature challenges researchers in staying up to date. Conventional approaches such as systematic reviews or large language model (LLM)-based tools require substantial time, prior knowledge, or paid access and may suffer from limited coverage or reliability. Open interactive maps offer an alternative for visualizing and exploring scientific activities without these constraints. This work presents a framework for the interactive and comprehensible mapping of scientific research activities and demonstrates its application in the field of medical spectral imaging.

Methods

A requirement analysis and front-end design were conducted, followed by an initial evaluation involving six persons from different domains. Open-source technologies for database, back-end, and front-end development were compared. A prototype ("Spectral World Map") was implemented locally. Initial data was retrieved from the Web of Science Core Collection (June 2024), focusing on endoscopic and dermatological spectral imaging publications (2004–2024). Metadata was stored in a MySQL database and geocoded based on author affiliations. The system architecture includes a Python-based back-end (FastAPI), a React-based front-end, and OpenStreetMap services for mapping and geocoding.

Results

The framework enables interactive visualization of global research activities via a web-based map interface. Users can explore institutions, filter publications by predefined categories, and access detailed metadata including DOIs. The system supports database extension through manual entry or import of BibTeX/RIS files. Although current filtering relies on manual clustering, the framework allows flexible adaptation to different research domains. The prototype remains a local demonstration system.

Conclusion

The proposed open-source framework provides an accessible and adaptable solution for mapping scientific activities without reliance on costly LLM-based tools or extensive prior knowledge. Future work includes database expansion, semi-automated text classification, online deployment with user roles, and integration of additional data sources such as funded projects and clinical studies.

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A scenario-driven framework for reproducible in silico testing of physiological closed-loop control systems

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Introduction

Physiological Closed-Loop Control Systems (PCLCS) aim to automate regulation of physiological variables in applications such as mechanical ventilation, anaesthesia delivery, and blood glucose control. PCLCS are safety-critical systems, requiring rigorous testing to ensure patient safety. This work presents a framework to enable reproducible, traceable and extendible in-silico testing of PCLCS.

Methods

The framework provides a pipeline for in silico experiment design, execution, and analysis. For systematic composition of experiments, we decouple control algorithm, system model, and simulation scenario. Simulation scenarios are defined by combining model variants, parameter sets and PCLCS tasks, and encoded in structured, version-controllable formats, enabling traceability and consistent documentation. Parameter sets can be derived from literature or fitted from data to provide patient-specific models (digital patient twins). A dedicated simulation runner automatically assembles and executes experiments based on the scenario definition and invokes analyses of the simulation results.

Results

The framework is demonstrated using a closed-loop mechanical ventilation controller for preterm neonates and a neonatal patient model. Two experiments are conducted: (i) comparison of setpoint tracking with and without spontaneous breathing, and (ii) replication of a previous in-vivo experiment in simulation using a subject-specific digital twin. The results illustrate evaluation across controlled physiological variations, and reproducible execution enabled by version-controlled experiment definitions.

Conclusion

The proposed framework provides a foundation for reproducible and traceable evaluation of PCLCS. By formalizing experiment design and ensuring consistent documentation, it supports rigorous testing workflows in simulation-based validation of PCLCS.

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Fatigue Resistance of Cardiac Lead Insulations - A Novel *in vitro* Test Bench Mimicking Physiological Loading

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Introduction

Cardiac arrhythmias are commonly treated using transvenous pacemakers and implantable cardioverter defibrillators, where intracardiac leads represent a major source of complications. Lead insulation materials, typically silicone or polyurethane, are exposed to complex mechanical and biochemical stresses that may induce degradation mechanisms such as environmental stress cracking (ESC) and metal ion oxidation (MIO).

Methods

Current standards provide limited guidance for fatigue testing under physiologically relevant conditions. This study presents a novel *in vitro* multi-axial test bench designed to evaluate the fatigue resistance of cardiac lead insulation under combined biomechanical and biochemical stresses. Physiological loading conditions were derived from literature data and postmortem measurements on hearts from body donations ($n = 21$), revealing bending radii between 6.5 mm and 30.0 mm. In addition, tensile and torsional loading place significant stress on the lead insulations. These findings informed a superimposed loading regime comprising bending, torsion, and tensile strain in an oxidizing test medium.

Results

The developed system enables synchronized multi-axial loading of up to eight specimens under controlled amplitudes, frequencies, and oxidative conditions. Initial feasibility studies demonstrated progressive surface degradation of specimens with polyurethane 55D insulation, with ESC- and MIO-related defects emerging after 7–10 days of fatigue testing and increasing over time.

Conclusion

The test bench successfully reproduces clinically relevant damage patterns as demonstrated by a comparison of microscopic images. Strong similarities were observed between insulation surfaces of explanted leads from human body donation (> 6 years dwelling time *in vivo*) and samples after 7 days of fatigue testing in the novel multi-axial electrode test bench. Thus, the developed test bench offers a flexible platform for comparative material evaluation and accelerated screening of novel, more biostable, and fatigue-resistant insulation materials.

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Architecture-Driven 3D Membrane Structures for Biohybrid Lungs towards Respiratory Long-Term Support

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Introduction

Long-term application of artificial lungs is limited by blood–material interactions, thrombogenicity, and flow heterogeneities in conventional hollow fiber membrane (HFM) systems, restricting current extracorporeal technologies such as ECMO to short-term support. Our Biohybrid lung concept aims to overcome these limitations by combining optimized flow environments with endothelialized blood-contacting surfaces.

Methods

Three-dimensional membrane architectures based on triply periodic minimal surface (TPMS) designs were analyzed using computational fluid dynamics to assess flow distribution and shear profiles compared to HFM. Multiphysics simulations were performed to evaluate oxygen and carbon dioxide transport as a function of membrane thickness and structural parameters. PDMS-based materials were characterized regarding gas permeability and endothelial compatibility. Endothelialization was assessed by immunostaining and gene expression analysis. CT-based anatomical models were used to simulate perfusion behavior in implant-relevant geometries.

Results

CFD analyses demonstrated more homogeneous perfusion in 3D TPMS structures compared to HFM. While mean flow velocities were comparable (0.030 vs. 0.034 $m \cdot s^{-1}$), peak velocities were reduced (0.062 vs. 0.126 $m \cdot s^{-1}$), indicating decreased flow heterogeneity and fewer regions prone to stagnation. Gas exchange simulations identified membrane thickness and structural dimensions as key determinants, with optimized configurations increasing oxygen transfer by up to 90% while maintaining comparable CO_2 removal. Required membrane surface area was reduced by approximately 44%. PDMS-based membranes showed enhanced oxygen permeability compared to clinical HFM materials. xPDMS supported the formation of a confluent, VE-cadherin–positive endothelial layer with a non-activated phenotype. Endothelialization of complex 3D TPMS structures demonstrated the feasibility of establishing a continuous biological interface. CT-based simulations confirmed homogeneous perfusion in anatomically relevant designs.

Conclusion

Architecture-driven 3D membrane structures enable the integration of improved flow distribution, efficient gas exchange, and biologically functional interfaces. These findings establish a design framework for a biohybrid lung system with enhanced hemocompatibility and support their further development toward long-term support as alternative to lung transplantation.

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Evaluation of Dry EMG Electrodes During Controlled Weight-Lifting Tasks

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Introduction

Surface electromyography (sEMG) is widely used to monitor muscle activity. Conventional wet electrodes provide high signal quality but require conductive gel and longer preparation. Dry EMG electrodes enable faster and more convenient application. However, their signal quality can be affected by motion artifacts. This study compares different dry EMG electrodes based on polymeric substrates and metallic thin films to conventional wet electrodes during controlled weight-lifting tasks to identify promising thin films for flexible, biocompatible electrodes for longterm use.

Methods

Nineteen healthy volunteers participated in the study. Surface EMG signals were recorded from the upper arm muscles during controlled weight-lifting tasks using three thin films compositions: aluminium (Al), Indium zinc oxide (IZO), and Titanium doped with silver (Ti-Ag), and Ag/AgCl wet electrode as reference. Participants performed isotonic and isometric contractions while lifting a 1 kg weight, with resting periods between contractions.

The EMG signals were recorded at 4096 Hz. Preprocessing included DC offset removal, band-pass (20-450 Hz) and notch filtering (50 Hz), rectification, and RMS envelope computation. Several metrics were calculated to evaluate electrode performance, including amplitude metrics (average rectified value - ARV, root mean square amplitude - RMS, variance - VAR), spectral metrics (power spectral density – PSD), and signal-to-noise ratio (SNR).

Results

The wet electrode showed the best result for ARV (38.55±31.9 μV), RMS (38.82±32.2 μV), VAR (37.94±67.6 μV²), SNR (3.46±1.6 dB), and PSD (2035.3±2881 μv²/Hz) in isometric condition. Among the dry electrodes, the TiAg electrode achieved the highest ARV (41.15±36.8μV), RMS (41.39±37.1μV), VAR (36.55±68.2μV²), SNR (2.8±1.7 dB), and PSD (2184.5±3541.3μv²/Hz) in isometric condition. Clear EMG activation and deactivation patterns were visible for all electrode types and conditions.

Conclusion

While conventional wet Ag/AgCl electrodes provide superior signal quality across all metrics, the dry thin-film electrodes also allowed acquisition of comparable, physiologically meaningful EMG signals. Therefore, these electrodes, particularly Ti-Ag, represent a promising alternative for long-term and continuous EMG monitoring applications involving repetitive self-application in rehabilitation systems.

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Comparative SEM analysis of porcine Fallopian tube regions and a 3D ALI oviduct cell culture model for biocompatibility testing

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Introduction

Fallopian tube disorders are a major cause of female infertility, and current treatments remain limited. A minimally-invasive alternative is the endoscopic microstent implantation to restore tubal patency.
Porcine fallopian tubes closely resemble human tissue, but segment-specific differences be considered to mimic native properties *in vitro*. Here, we describe a method to prepare fallopian tube sections for scanning electron microscopy (SEM) analysis of morphology. These data validated a 3D air-liquid interface (ALI) model with porcine isthmus epithelial cells, providing a biomaterial testing platform.

Methods

Fallopian tube sections obtained from six-month-old German Landrace pigs (*Sus scrofa domesticus*) were either mounted on custom-made Teflon holders or sewed onto nylon meshes, and then chemically dried prior to SEM. Epithelial cells were isolated from fresh porcine isthmus using collagenase, and seeded into 24-transwell inserts with collagen-coated porous PET membranes. After reaching confluence, apical medium was removed, and cells were differentiated under ALI conditions, followed by SEM analysis.

Results

Suturing isthmus sections onto nylon meshes stretched the tissue and improved SEM accessibility. SEM revealed the spatial organization of the fallopian tube sections, including primary and secondary folds and crypts. Secretory cells predominated on sharp minor folds, whereas ciliated cells were mainly located below, and within the crypts, suggesting a sperm reservoir function. After 21 days under ALI conditions, porcine isthmus epithelial cells formed a monolayer with morphology comparable to native tissue, including secretory cells with microvilli and ciliated cells.

Conclusion

High-resolution SEM provided detailed insight into segment-specific native oviduct morphology and ciliation and enabled validation of differentiated ALI isthmus cultures. Marked regional differences were confirmed, with the isthmus showing predominantly flat secretory cells and fewer ciliated cells, whereas the ampulla and infundibulum exhibited elongated secretory cells embedded in dense ciliary bundles. The validated ALI model represents a physiologically relevant base for microstent biocompatibility testing.

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Validating COMISA on Wearable and Digital Sleep Diary Accuracy Against Polysomnography

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Introduction

Sleep disorders such as insomnia and obstructive sleep apnea (OSA), including their co-occurrence (COMISA), are increasingly prevalent and pose a significant public health challenge. Wearable consumer health trackers (CHTs) are increasingly used by individuals to monitor sleep health. However, they are often validated on small, healthy samples, leaving concerns about their reliability. World Sleep Society advocates for standardized fundamental sleep measures. The study aimed to determine if measurement biases in CHTs and digital sleep diaries differ between individuals with and without COMISA.

Methods

A total of 125 participants with a valid polysomnography (PSG) ≥ 4h wore a CHT device, answered a digital sleep diary, and completed the Insomnia Severity Index (ISI). The cohort was stratified into 2 groups based on ISI and Apnea/Hypopnea Index (AHI) scores: Non-COMISA (ISI Health/Subthreshold; AHI < 15, n=23) and COMISA (ISI Moderate to Severe; AHI ≥ 15, n=102). Total Sleep Time (TST) of the same night was analyzed using Bland-Altman (BA) plots. The measurement differences between COMISA groups were tested using Welch´s T-test.

Results

Overall, the CHT's mean bias (MB) was slightly lower (MB = 50.1 min) than the diary's (MB = 63.7 min). However, the diary´s MB was more stable across the non-COMISA vs COMISA groups (62.3 vs 70.3 min) than the CHT's bias (43.8 vs 78.4 min). This was supported by a significant difference in measurement bias between the two groups for the CHT ($t = 2.24$, $p = 0.02$), but not for the diary ($t = 0.395$, $p = 0.70$).

Conclusion

CHT generally had a lower mean bias than the digital sleep diary for TST. However, the accuracy of CHTs worsened significantly when measuring participants with COMISA, whereas the digital sleep diary had a slightly higher bias overall but provided consistent measurements regardless of whether a subject had COMISA or not.

Funding acknowledgments:

This work was funded by the European Union's Horizon 2020 Research and Innovation Programme (965417).

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StrokePointer: Dry-electrode EEG for pre-hospital triage of suspected stroke patients

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Introduction

Stroke is the third leading cause of death and disability across Europe. Endovascular therapy (EVT) for large vessel occlusions (LVO) is only available in 20% of hospitals, meaning many patients are initially transported to non-EVT-capable facilities, causing critical treatment delays. Objective pre-hospital identification of LVO stroke can enable direct transport to EVT-capable hospitals, improving outcomes. Dry-electrode EEG has been proposed by Amsterdam UMC, The Netherlands (ELECTRA-STROKE, AI-STROKE) for LVO triage in the prehospital setting. Over the past 3 years, we have developed the StrokePointer™ device, which is currently being evaluated on usability and speed in the CROSSROADS-EEG project.

Methods

StrokePointer™ is a rugged, portable dry-electrode EEG device, designed for rapid deployment in the ambulance. The system applies an automated algorithm to estimate LVO likelihood in real time within minutes of application, without requiring specialist EEG expertise. The device features an intuitive interface optimized for prehospital emergency workflows and was co-designed with ambulance professionals. The CROSSROADS-EEG study (N = 275) has been recruiting suspected stroke patients in 9 ambulances since July 2025. We will present the study design, including how it builds on earlier scientific findings (ELECTRA-STROKE, AI-STROKE) and evaluates StrokePointer™.

Results

The CROSSROADS-EEG study (NCT06871969) is ongoing; final results are not available yet. We will present the design of the CROSSROADS-EEG study and describe the modular design of the dry-electrode EEG based system that performs real-time artifact detection and applies an algorithm to detect LVO stroke based on a 2-minute recording.

Conclusion

Dry-electrode EEG, as part of the StrokePointer™ system, holds strong promise for prehospital LVO triage. First insights from the CROSSROADS-EEG study mark a critical milestone towards real-world clinical implementation. StrokePointer™ aims to transform ambulances into active first responders for suspected stroke patients, cutting treatment delays and improving stroke triage across Europe.

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MEDtechBIO – an open experimental and research laboratory for students of Medical Engineering and Technical Biology at the University of Stuttgart

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Introduction

The School for Talents (S4T) at University of Stuttgart seeks to inspire students to take an interest in basic reserach at an early stage of their curriculum. Funded by the DFG's university grant it comprises a general annual programme and specialised faculty projects.

Methods

The MEDtechBIO S4T supports committed students of the Technical Biology and Medical Engineering Bachelor programs through interdisciplinary research and teaching in both fields. It allows students to run independent projects that complement existing courses and established teaching formats. Its curiosity-driven environment aims to stimulate a scientific mindset where own hypotheses are formulated and directly tested. Equipment and software for e.g. mechatronic systems, rapid prototyping, and genetic engineering is provided.

Results

Between 2020 and 2025, <60 students voluntarily pursued numerous project ideas from very practical goals to strong basic research. Two projects exemplify the creativity and motivation:

- System for monitoring dementia progression. It regularly tests those affected in a playful way with regard to a number of cognitive abilities. The software runs on a single-board computer with a touch display and performs randomised tests. In addition, a simple dispenser for e.g. tablets is triggered when the patient assessment session is finished. So, students learned to to deal with patient and process requirements and engineering solutions.
- Stratospheric balloon for acquiring DNA: A capsule opens at a 35,000 m altitude and inhales air through a filter. Microbes, pollen, dust, etc. are collected and then subjected to DNA sequencing. Bad weather conditions and a flight control software glitch resulted in no DNA retrieved. Consequently, students learn to deal with common setbacks in research.

Conclusion

MEDtechBIO School for Talents, offered <60 students an opportunity to pursue their own project ideas. Evaluation showed that project-based learning during the first semesters in the two Bachelor programs improves commitment and interest.

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System Performance and Environmental Field Characterization of the Berlin OPM-MEG Center

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Physikalisch-Technische-Bundesanstalt (PTB)

Introduction

Optically pumped magnetometers (OPMs) enable femtoTesla-level magnetic field measurements for biomagnetic investigations of brain and muscle activity. The Physikalisch-Technische Bundesanstalt (PTB) and Charité Universitätsmedizin, Berlin have established the **OPM Center for Magnetoencephalography and Biomagnetism (OMCB)** at the Charité Mitte campus, combining clinical access with metrological sensor characterization to advance OPM-based MEG and related biomagnetic applications.

The OMCB houses a magnetically shielded room (MSR) with a passive shielding factor of approximately 1000 at 10 mHz under a 1 μT rms excitation and additional active shielding that improves low-frequency attenuation by a factor of 3.4. A 96-sensor dual-axis OPM array is used for biomagnetic data acquisition. An integrated stimulus system enables synchronized audiovisual stimulation and response acquisition.

Methods

Facility performance was characterized through evaluation of the magnetic environment and the performance and reliability of the OPM sensor array. This included measurements of residual magnetic fields, temporal field stability, sensor noise characteristics (ASD), sensor availability and replacement history.

Results

Residual magnetic field mapping of the empty MSR showed a maximum static field magnitude below 400 pT within the central 1 m^3 volume after degaussing with a PTB custom-built system. With external active shielding enabled, field stability better than 230 pT peak-to-peak was achieved over 1000 s. Noise characterization showed that, in dual-axis mode, approximately 78–82% of Bz channels met the manufacturer noise specification, compared with 10–15% of By channels.

Conclusion

The presented characterization demonstrates the suitability of the OMCB for OPM-based biomagnetic measurements and provides an initial assessment of the magnetic environment and sensor performance. Future work will focus on transfer-function and gain measurements, monitoring of internal zeroing fields, establishing a sensor performance database, and validation of source localization accuracy. These developments will provide a more detailed assessment of the OPM array and increase confidence in the acquired data.

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From Sensor Data to Clinical Decision Support: Translating Digital Biomarkers into Interoperable Health Data Infrastructures

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Introduction

Digital health technologies enable the continuous acquisition of patient-related data through sensors and wearable systems. Digital biomarkers derived from such data are increasingly investigated for monitoring functional status, disease progression, and therapy outcomes. While methodological advances have enabled robust biomarker generation and validation, their translation into routine clinical systems remains limited. This gap persists, even though there is growing evidence of its clinical relevance

Methods

Using gait analysis and gait speed as illustrative examples, we examine the transformation of sensor-derived movement data into digital biomarkers and analyze their integration into interoperable health data infrastructures. Based on current literature on digital biomarkers and health data interoperability, we assess requirements for standardized data representation, semantic interoperability, and integration into clinical information systems.

Results

Gait-derived digital biomarkers demonstrate strong potential for assessing motor function, disease progression, and functional impairment. However, their limited use in clinical practice is not primarily caused by insufficient signal processing or lack of analytical methods. Instead, the main barrier lies in the absence of interoperable data structures and system-level integration. Sensor-derived parameters are rarely represented in standardized data models, lack consistent semantic annotation, and face additional barriers related to governance, consent management, data protection, and cybersecurity requirements. Although frameworks such as HL7 FHIR and initiatives like the German Medical Informatics Initiative (MII) provide essential foundations, their application to digital biomarkers remains fragmented and is rarely considered during system design.

Conclusion

The translation of digital biomarkers into clinical decision support does not fail at the level of data acquisition or analysis, but at the interface to interoperable systems. Interoperability must therefore be treated as a prerequisite for clinical translation and as a core design requirement in biomedical engineering. Without this shift in perspective, digital biomarkers will remain confined to isolated prototypes rather than becoming scalable and interoperable components of digital healthcare systems.

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Towards Gender-Sensitive Health Data Infrastructures: Interoperability Challenges and Design Implications for Biomedical Engineering

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Introduction

Sex and gender differences significantly influence disease manifestation, diagnosis, and treatment outcomes. Despite increasing recognition in biomedical research, these aspects remain insufficiently represented in clinical datasets and digital health infrastructures. This limitation is particularly critical in data-driven biomedical engineering and artificial intelligence (AI), where incomplete or biased data representations can directly affect model performance and clinical applicability, reflecting underlying limitations in data representation and interoperability.

Methods

This contribution provides a structured synthesis of existing literature and interoperability frameworks from medical informatics and biomedical engineering. It analyzes implementations in national and European health data infrastructures, including the German Medical Informatics Initiative (MII) and the European Health Data Space (EHDS), focusing on interoperable data models, HL7 FHIR-based exchange mechanisms, and metadata frameworks. The analysis is guided by a conceptual categorization of challenges across semantic, structural, and operational dimensions.

Results

Four key challenges are identified. First, semantic limitations arise from binary representations of sex and inconsistent or missing definitions of gender across systems. Second, structural gaps in interoperability frameworks, including HL7 FHIR-based implementations and standardized datasets such as the MII Core Dataset, hinder integration of multidimensional gender-related attributes and limit cross-site comparability. Third, operational deficiencies in data collection, mapping, and governance lead to incomplete and heterogeneous datasets. Fourth, metadata limitations reduce dataset discoverability and restrict reuse in federated infrastructures. These limitations propagate into downstream applications, particularly AI systems, where missing or inconsistently represented sex- and gender-related variables may contribute to reduced model generalizability and systematic bias.

Conclusion

Addressing these challenges requires coordinated extensions of interoperability standards, enrichment of metadata frameworks, and improved implementation and governance practices. Biomedical engineering plays a central role in translating these requirements into robust and scalable infrastructures. Strengthening gender-sensitive interoperability is essential to ensure that future health data ecosystems, including EHDS, enable interoperable, inclusive, and clinically meaningful data-driven innovation.

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Automatic Estimation of Cervical Spine Alignment from X-ray Images Using Deep Learning Segmentation

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Introduction

Accurate assessment of sagittal cervical spine alignment on lateral radiographs is essential for diagnosing deformities, treatment planning, and evaluating clinical outcomes. Key parameters such as the C2–C7 Cobb angle, segmental angles, C2 slope, and sagittal vertical axis (SVA) are commonly used, but their manual measurement is time-consuming and subject to observer variability. Deep learning methods offer a promising approach for automating this process.

Methods

We propose a segmentation-based pipeline for automatic estimation of cervical spine alignment. A U-Net model is trained to segment vertebral bodies C2–C7 from lateral radiographs. The predicted masks are postprocessed to extract anatomical landmarks corresponding to vertebral endplates. These landmarks are then used to compute clinically relevant alignment metrics, including the C2–C7 Cobb angle, segmental angles, C2 slope, and SVA. Unlike many existing approaches, the proposed method evaluates performance directly using clinically meaningful measurements.

Results

The proposed pipeline enables reliable extraction of vertebral structures and subsequent computation of alignment parameters. On the test set, the method achieves mean absolute errors of approximately 1.6–2.5 degrees for angular measurements, while SVA reaches an MAE of 1.6 pixels, indicating good agreement with reference annotations.

Conclusion

The results demonstrate that segmentation-based deep learning can provide accurate and interpretable estimation of cervical spine alignment. By combining vertebral segmentation with geometric analysis, the proposed approach enables automated computation of clinically relevant parameters and has the potential to support faster and more objective radiographic assessment.

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Development of an Immunocompetent Primary Cell–Based 3D Peri-Implant Tissue Culture Model

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SIIRI – Safety-Integrated and Infection-Reactive Implants funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – SFB/TRR-298-SIIRI – Project-ID 426335750

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Introduction

Despite the substantial clinical benefits of biomaterials in tissue regeneration, functional restoration, and implant-based therapies, biomaterial-associated infections remain a major clinical challenge. In this context, advanced three-dimensional (3D) cell culture models integrating cell lines, implant materials, and biofilms enable the study of complex host–material–microbe interactions under physiologically relevant conditions. Notably, primary cell-based 3D models offer improved biological and translational relevance by more closely reproducing native tissue architecture and patient-specific cellular responses.

Methods

Human monocytes were isolated from peripheral blood by density-gradient separation of PBMCs and CD14+ enrichment, then differentiated into macrophages in RPMI containing 10% FBS, 1% penicillin/streptomycin, M-CSF, and IL-3. A 3D tissue model was established by co-culturing primary macrophages and human gingival fibroblasts in a collagen matrix with an implant. After 11 days, the model was exposed for 24 h to patient-derived multispecies clinical biofilms. Tissue–biofilm interactions were assessed by histology, gene expression analysis, and measurement of cytokines and OD600 in the supernatants.

Results

Macrophage differentiation directly from patient-derived blood monocytes was successfully achieved. Preliminary findings suggest that macrophages in the 3D tissue model suppress bacterial growth, as indicated by significantly lower OD values. Future 16S rRNA sequencing will assess biofilm composition. Direct co-cultivation of macrophage-containing 3D peri-implant tissues with patient-derived clinical biofilms induced patient-specific cytokine responses, with variable expression of IL-1β, IL-6, IL-8, MCP-1, TNF-α, and GRO-β. Histological analysis confirmed preservation of tissue architecture after biofilm challenge, supporting the robustness and physiological relevance of this 3D peri-implant model. Gene expression and transcriptomic analyses will be performed to further elucidate tissue–biofilm interactions.

Conclusion

Our findings show that the 3D model incorporating primary macrophages significantly inhibited clinical biofilm growth compared with controls, confirming the viability and functional activity of the macrophages against a clinically relevant, multispecies biofilm challenge. Ongoing analyses will further characterize the tissue response, while organotypic primary cell-based 3D models are being developed to investigate clinically relevant, patient-specific host–pathogen interactions.

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Graph-Theoretic Functional Connectivity Analysis of EEG for Discrimination of Interictal, Preictal, and Ictal States in Epileptic Seizure Dynamics

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Introduction

Epileptic seizures are associated with complex and dynamic alterations in functional brain connectivity. Accurate characterization of seizure states such as interictal, preictal, and ictal conditions is essential for developing reliable seizure prediction systems. Conventional EEG analysis methods often fail to fully capture nonlinear and time-varying interactions within brain networks. Therefore, graph-theoretic approaches provide a powerful framework for modeling and analyzing functional brain connectivity.

Methods

In this study, a graph-theoretic framework is proposed for EEG signal analysis to distinguish interictal, preictal, and ictal states. Functional connectivity is computed using Phase Locking Value (PLV), Phase Lag Index (PLI), and Pearson correlation, capturing both phase- and amplitude-based interactions between EEG channels. These connectivity matrices are transformed into graph representations, from which network-level features such as node degree, clustering coefficient, betweenness centrality, and global efficiency are extracted. Statistical evaluation is performed using one-way ANOVA and Kruskal–Wallis tests to assess differences across seizure states.

Results

The extracted graph-theoretic features show statistically significant differences across interictal, preictal, and ictal states. All connectivity-derived features exhibit p-values consistently below 0.001, indicating strong discriminative power. The results demonstrate that epileptic seizures are associated with pronounced reorganization of brain functional networks. Preictal states exhibit intermediate connectivity characteristics between interictal and ictal conditions, reflecting a gradual transition in brain dynamics prior to seizure onset.

Conclusion

The proposed graph-theoretic EEG analysis framework effectively captures functional brain network alterations associated with seizure dynamics. The combination of PLV, PLI, and correlation-based connectivity with graph features provides an interpretable and physiologically meaningful representation of seizure states. This approach demonstrates strong potential for EEG-based seizure characterization and early prediction systems.

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Evaluating Reconstruction Methods Smart Devices

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Introduction

Continuous monitoring with wearables often yields inco
outs or transmission errors. Reliable reconstruction o
cardiac-waveform morphology - is crucial for downstrea

Methods

Three reconstruction techniques (cubic spline interpol
modeling) were evaluated on (i) simulated breathing-li
recordings from the piezoelectric VitaLog sensor-. Dow
pling. Reconstruction quality was quantified by n-ormali
minat^{2}i.on r

Results

Cubic spline interpolation and GP^{2}R≈ clo.n0s0i s,t ewnhtelrye aasch ARe vo
for DF ≥ 16. Both spline and GPR recover periodic brea
piezoelectric data.

Conclusion

Cubic spline interpolation and GPR provide robust, low
telemedical scenarios, enabling reliable analysis even

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Accessible Digital Twins for Medical Laboratories with 3D Gaussian Splatting

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Introduction

Creating digital twins of medical learning environments usually requires substantial expertise and effort. This paper examines whether current 3D Gaussian Splatting workflows can lower that barrier for technically inclined non-expert users. The focus is on medical laboratory scenes, where reflective materials, cluttered layouts, and room-scale capture make reconstruction particularly demanding.

Methods

To compare three different workflows in an exploratory pilot study, five first-time users captured and reconstructed two targets with each workflow: a glossy and diffuse object-scale scene and a room-scale medical laboratory. Usability, workload, and subjective reconstruction quality were analyzed after each reconstruction task. The three workflows were: (1) the open-source smartphone pipeline Splatflow, our own workflow that combines multiple software tools into a unified process with few required user inputs, (2) the closed-source smartphone pipeline Postshot, and (3) the specialized PortalCam device.

Results

The pilot results suggest that all three workflows were generally usable by the target group. PortalCam achieved the highest usability and the best overall reconstruction quality, especially for the room-scale laboratory. Among the smartphone-based approaches, Postshot produced more consistent high-quality reconstructions compared to Splatflow, while Splatflow remained promising as a flexible open-source workflow with strong potential for further development.

Conclusion

Within the scope of this exploratory pilot study, 3D Gaussian Splatting appears to be a practical basis for accessible digital twins in medical learning settings. PortalCam currently offers the most novice-friendly and robust workflow, whereas Postshot provides a capable smartphone-based alternative. Splatflow is not as robust as Postshot, but its open-source nature offers strong potential for future improvement and broader accessibility.

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Bayesian Optimizer for Realistic PPGI Video Synthesis

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Introduction

Current approaches in photoplethysmography imaging (PPGI) rely on deep learning models for vital sign estimation, requiring large datasets that are difficult to obtain due to privacy constraints. To address this problem, synthetic data can be utilized, as done by the SCAMPS approach. However, SCAMPS is missing deeper information about the subsurface color change modelling parameters, subsurface color (scattering) and radius (light penetration depth). Thus, this work presents a method that analyses these parameters more deeply by reducing the sim-to-real gap.

Methods

A Bayesian optimizer is applied to 12 paired real and synthetic videos to optimize scaling factors for subsurface color and radius. The synthetic environment is designed to mimic real conditions. Spatial variations in amplitude and phase are modelled using the FLAME head model and 3D blood pulsation maps from *Pulse3DFace*. As the optimization metric, the absolute difference between the real and synthetic color amplitude is computed at selected facial positions. Signal-to-noise ratio filtering and median peak selection reduce interference in the final metric.

Results

The results show that the subsurface color has a stronger influence on the skin color changes, but too large scales increase the error by a factor of more than 6. In contrast, the influence of the subsurface radius scale is lower, as poor scaling leads to a maximum error increase of 72%. These findings indicate that the subsurface color is essential for generating fundamental skin color changes, while the subsurface radius enables finer adjustments. Variability across the mimicked scenarios indicates remaining gaps in the synthetic environment.

Conclusion

This work presents a method based on Bayesian optimization to reduce the sim-to-real gap and enable more realistic synthetic PPGI data. Furthermore, *Pulse3DFace* is successfully applied for data generation. Future work will focus on improving skin color-dependent light penetration modelling and evaluating the approach in real-world scenarios.

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From Point to Mask: Interactive Segmentation for 3D Ultrasound

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Introduction

Segmentation is a widely used tool in the clinical workflow, hindered by high manual effort. Nowadays a large number of trained models exist, often trained on a broad spectrum of data. In this work we evaluated how existing large-scale models perform for the task of 3D ultrasound (3DUS) segmentation, comparing several models across a multitude of datasets and prompt types.

Methods

Three openly available models were used for comparison: SAM2, MedSAM2 and nnInteractive, representing general-purpose, domain-adapted, and medically dedicated architectures. All methods were tested on four different 3DUS datasets with varying anatomies and four different prompt types, to evaluate how well the models generalize and how prompt type impacts the prediction. We evaluated point-based prompts with one positive point only or one positive and four negative points, and bounding box and mask prompts. All prompts were calculated from the available ground truth masks. 3D volumes were split into image stacks across the sweep axis and prediction was done in video mode for SAM-based models, while nnInteractive used 3D segmentation methods.

Results

Segmentation results were evaluated using the Dice Similarity Coefficient (DSC) and the 95th percentile Hausdorff Distance. A clear prompt-dependent trend was observed. Point-based prompts performed worst overall (single-point: mean DSC 0.27-0.63, multi-point: mean DSC 0.41-0.57), while bounding box and mask prompts produced clinically usable results across all models (mean DSC 0.73-0.78 and 0.80-0.82 respectively). HD95 varied substantially across datasets (mean HD95 15-95 voxels) displaying anatomical variability in datasets.

Conclusion

For prompt types with higher manual effort, all models performed reasonably well for clinical use. Bounding box prompts in particular offer a practical trade-off between annotation effort and segmentation quality suitable for clinical workflows. Future work should focus on varying prompt placement to resemble real-life clinical practice and incorporate multi-axis processing into SAM-based methods to better exploit volumetric information.

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Complex multicompartment scaffolds - 2-photon-polymerization and integration in microfluidic chip setups

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Introduction

In order to use physiologically accurate 3D tissue- and disease-models in research and diagnostics, these require a precise scaffold architecture that enable cell supply and co-cultivation. For example, in bone marrow niches, spatially separated, but biochemically coupled trabecular architecture determine cell fate and, consequently, disease progression. Current methods for scaffold fabrication and cell cultivation are limited in print resolution, as well as in the ability to create complex, perfusible systems within microfluidic platforms.

Methods

By combining a specially developed photoreactive copolymer (lactide-caprolactone-methacrylate) with a highly efficient two-photon photoinitiator, we are able to utilize laser writing within a sealed microfluidic chip. The Schwarz-P geometries produced by two-photon polymerization (2PP) form triple-periodic minimal surface architectures as the elementary repeating unit (5 x 5 x 0.2 to 1 mm), thereby separating a cellular from a vascular region. Additionally, the resolution of the 2PP technique allows microporous openings to be created in the scaffold walls (~5 µm nominal perforation), which enables diffusive exchange while simultaneously preventing cell migration.

Results

The In-Chip-2PP technology enabled the high-precision fabrication of compartmentalized and perfusable scaffolds, minimizing leaks, fluid short-circuits, and contamination risks while simplifying handling. Under perfusion, the distinct internal (cellular) and external (vascular) flow-pathways were preserved. Material-cell interaction remained unaffected, enabling efficient cell seeding and cultivation within the chip platform. The combination of chip based microfluidics and 2PP scaffolds was successfully applied to address acute myeloid leukemia and osteoarthritis as in vitro models.

Conclusion

The direct integration of compartmentalized Schwarz-P scaffolds into sealed microfluidic chips combines materials science, high-resolution manufacturing, and microfluidic systems, thereby offering a scalable approach to creating physiologically relevant in vitro models for complex, niche-specific tissues and disease states that are suitable for research, drug testing, and diagnostics.

This work was supported by TAB-funded projects “Arthrosis-on-a-Chip” (2023 VFE 0024), Bone-Infection-on-an-Chip” (2021 VF 0034), and “3D-Tumor-on-Chip analysis” (2024 VFE 0040).

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Testing the permeability of porous membranes using High Performance Liquid Chromatography (HPLC) and photometry

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Introduction

We present an experimental system in which the permeability of a polymer membrane is measured based on the concentration change of a solution as a result of diffusion in front of and behind this membrane. Porous polymer membranes are of particular interest for vascular repair applications, where these structures must simultaneously prevent blood leakage while enabling tissue ingrowth.

Methods

Polymer samples were produced as cast films. A round sample of the film was inserted into a standard HPLC vial. The vial was filled with analyte solution and placed in a beaker filled deionized water. After 24 hours the vial was removed and the analyte concentration was determined via photometry or HPLC.

Results

Two polyurethane samples with pore volumes of 30% and 50% were examined, respectively. An ePTFE membrane was examined as reference. For methylene blue it was found that the membranes are permeable and that permeability increases with increasing pore size. Only the PU membrane with 50% pore content is permeable to insulin. In summary, it can be said that the migration of molecules through a polyurethane membrane can be influenced by parameters such as porosity and layer thickness.

Conclusion

A simple test setup is presented that can be used to characterize the permeability of various molecules through porous polymer membranes. The investigation included two porous polyurethane samples with 30% and 50% porosity, respectively, and an ePTFE membrane as a reference. Methylene blue and insulin were used as analytes that passed through the membrane.
While methylene blue migrated through all three materials tested, insulin could only be detected passing through the polyurethane membrane with 50% porosity. The test results are being used to find a material that has high biocompatibility for vascular repair applications.

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Biomechanical material characterization of the equine accessory carpal bone: A constitutive modeling

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Introduction

The accessory carpal bone (ACB) is one of the seven bones of the equine carpus. Fractures of the ACB are rare but primarily occur in racehorses and other equine athletes. Although their etiology is not fully understood, their occurrence during exercise suggests a strong link to biomechanical loading. This study aims to develop a three-dimensional finite element (FE) model of the equine ACB to analyze its mechanical behavior and failure characteristics for improved understanding of injury mechanisms. Reliable biomechanical material parameters are essential for such FE analyses. Therefore, this work focuses on the determination of biomechanical parameters of the ACB using uniaxial force-to-failure compression tests.

Methods

The material parameters were determined according to the following procedure. First, eight ACB specimens from slaughtered Warmblood horses (age 13–18 years) were prepared. Second, quasi-static uniaxial compression tests were performed using a four-column testing machine until specimen failure (strain rate: 1.33 s^{-1}). Finally, material parameters were identified by fitting isotropic incompressible hyperelastic material models to the experimental stress–strain curves.

Results

Experimental force-to-failure curves of the ACB specimens exhibited typical compressive behavior with a non-linear, near-linear, and failure region. Maximum stress and strain were derived from the near-linear region (stress: 27.8–46.7 MPa; strain: 2.8–10.1%). The coefficient of determination (R^2) ranged from 0.90 to 0.99. Among the tested models, the Ogden formulation provided the best fit ($\mu = 1.89 \pm 0.55$ MPa, $\alpha = 2.61 \pm 0.15$). The Young's modulus was 7.38 ± 2.44 MPa.

Conclusion

All applied material models accurately described the experimental stress–strain curves ($R^2 > 0.90$). The calculated material parameters were in the lower range of values reported in the literature. Future work will therefore focus on parameter identification considering bone microstructure, anisotropy, and geometry-dependent effects with respect to loading direction. This is essential for improving FE model accuracy and clinical relevance.

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Design and Realization of a Low-Cost Instrument Adapter for the da Vinci Surgical Telemanipulator

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Introduction

Robot-assisted minimally invasive surgery using the da Vinci telemanipulator system has transformed modern surgical practice. However, the high cost of these systems limits access for educational institutions and research groups. This paper presents the design and implementation of a low-cost, modular instrument adapter that enables the actuation of original da Vinci surgical instruments using standard industrial robots.

Methods

The adapter employs four Dynamixel servo motors controlled by an OpenRB-150 microcontroller, with a Python-based dashboard for user interaction. The mechanical design features 3D-printed components with a spring-loaded force coupling mechanism for reliable torque transmission and a modular robot flange for compatibility with different manipulator systems. Components were manufactured using FDM on a Bambu Lab P1S printer. PLA was used for standard structural parts due to its ease of processing, while PETG was employed for snap-fit connections requiring higher elasticity and impact resistance. Current-based homing enables automatic limit detection without additional sensors.

Results

The complete adapter was successfully assembled and tested with original da Vinci generation 1 instruments. The current-based homing procedure reliably detected all mechanical end stops without additional sensors. The system achieved reproducible instrument movements controllable through the Python dashboard interface. The complete system was realized within a budget of <400 EUR, demonstrating a viable approach for making surgical robotics technology accessible for teaching and research purposes. The 3D-printed construction using PLA and PETG proved sufficient for the intended laboratory and educational use. The snap-fit force coupling mechanism provided reliable and repeatable instrument attachment and detachment.

Conclusion

This work demonstrates the feasibility of a low-cost, 3D-printed instrument adapter for actuating original da Vinci surgical instruments using standard industrial robots. The project results including software and CAD-files for re-construction and 3D-printing are fully available via https://gitlab-forschung.reutlingen-university.de/camed-public/da-vinci-instrument-adapter.git.

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A Multi-Method Radiomics Pipeline for Survival Analysis: Robust Feature Identification in Computed Tomography Data

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Introduction

Although imaging data contain high-dimensional information potentially relevant to outcomes, their use in survival analysis is limited by manual interpretation and the lack of systematic feature extraction. Radiomics derived from computed tomography (CT) imaging offers promising biomarkers. This study presents a CT radiomics pipeline for partially automated survival analysis and evaluates its robustness across complementary analytical methods.

Methods

The proposed pipeline integrates partially automated CT processing, feature extraction, statistical analysis, and machine learning. CT scans were automatically processed from the hospital PACS using the Body and Organ Analysis framework (University Hospital Essen), integrating TotalSegmentator and body composition analysis to extract radiomic features from organs, bones, muscles, and fat tissue. A multi-step analysis workflow was applied: (1) association analysis using Pearson correlation with Benjamini-Hochberg correction, (2) univariate Cox regression and Kaplan-Meier log-rank tests, and (3) XGBoost with SHAP-based feature importance. Results were compared to identify consistently relevant features.

Results

The proposed approach was evaluated in 972 TAVI patients who underwent pre-procedural CT imaging (mean age 81.7 years, 50% female, 1-year survival 88.8%, 3-year survival 52.3%) as a clinical use case. It identified clinically plausible features associated with survival, including established risk markers (e.g., age, STS score, cardiac biomarkers) alongside imaging-derived features. Notably, several of these established markers were consistently identified across all analytical approaches, indicating robust associations independent of the applied method. The XGBoost model showed predictive capability for survival group classification (short ≤12m, intermediate 12-36m, long >36m), with class-dependent performance (F1-score: long 0.81, intermediate 0.22, short 0.39).

Conclusion

This study demonstrates the usefulness of our multi-method radiomics pipeline for survival analysis in clinical imaging data. Consistent findings across approaches highlight the robustness of identified features and support their potential relevance for clinical research. Future work will extend the pipeline to additional applications and develop end-to-end solutions for practical use.

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Automated Parametric Tooth Model Generation — From Intraoral Scans to Finite Element Analysis

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Introduction

Finite element analysis is widely used in dental research to study the biomechanical behaviour of teeth and surrounding tissues. However, it is not yet routinely used in clinical practice. Yet the finite element method has significant potential to enhance prosthetic treatment planning by providing a biomechanical basis for decision-making. One major barrier is the labour-intensive generation of simulation-ready tooth models from scan data. Additionally, structures that are not accessible to intraoral scanning, including roots and pulp cavities, must be reconstructed separately.

Methods

A rule-based parametric modelling approach was developed in Grasshopper 3D to automatically generate complete tooth geometries, including roots and pulp cavities, from scanned crown surfaces. The approach was applied to a right maxillary first premolar (tooth 14). Using literature-derived parameters, tooth variants with varying root lengths, root numbers, periodontal ligament (PDL) thicknesses, PDL material models (linear-elastic vs. hyperelastic Ogden model), and levels of clinical attachment loss (CAL) were generated. Subsequently, finite element simulations were conducted to evaluate the effects of these parameters on stress distributions in the alveolar bone and PDL under a 100 N axial load.

Results

Greater CAL and PDL thickness led to higher stresses in the alveolar bone, while root length and number of roots mainly affected stress distributions at the apices and furcation. The hyperelastic PDL model produced near-zero tensile stresses in the PDL, effectively transferring tensile loading to the surrounding bone.

Conclusion

The proposed approach automates the creation of simulation-ready tooth models from intraoral scan data. Furthermore, it enables systematic investigation of the effects of morphological and clinical parameters on the biomechanical behaviour of teeth and their supporting structures.

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Evaluation of the Swarming Behavior of Magnetic Enzymatic Nanorobots Using Magnetic Particle Imaging

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Introduction

Superparamagnetic iron oxide nanoparticles (SPIONs) are versatile nanomaterials whose surface can be functionalized. Therefore, SPIONs show great potential in biomedical applications such as targeted drug delivery and Magnetic Particle Imaging (MPI). Their magnetic properties enable them to be controlled by external magnetic fields, allowing them to be directed to otherwise hard-to-reach regions. Enzymatically functionalized nanoparticles show self-propelling properties and are commonly referred to as nanorobots (NR). Their motion is driven by catalytic reactions of surface-immobilized enzymes that convert specific substrates into chemical propulsion. However, conventional optical imaging techniques are typically limited to two-dimensional observation and lack the temporal resolution required to capture dynamic behavior in real time. In this work, the swarm behavior and three-dimensional propagation of urease-powered NR will be visualized and analyzed using MPI.

Methods

Urease-powered NR were synthesized from commercially available magnetic nanoparticles (Synomag®, Micromod, Rostock, Germany) by covalent attachment of urease (Sigma-Aldrich, St. Louis, USA) to the particle surface. MPI measurements were performed using a preclinical MPI scanner (MPI 25/20 FF, Bruker BioSpin, Ettlingen, Germany). The three-dimensional, real-time propagation and swarm behavior of NR were investigated to evaluate their influence on catalytic propulsion. Non-functionalized nanoparticles served as controls to distinguish passive diffusion from enzyme-driven motion.

Results

MPI is expected to enable real-time visualization of the spatial distribution and propagation of urease-powered NR in three dimensions. Experiments show that enzymatically powered NR exhibit enhanced spreading compared to non-functionalized nanoparticles.

Conclusion

This work demonstrates the potential of MPI as a non-invasive imaging technique for analyzing the dynamic behavior of enzyme-powered nanorobots. The ability to visualize NR swarm propagation in 3D and in real-time provides insights into factors governing their propulsion. Such knowledge is essential for optimizing nanorobot-based systems for future biomedical applications.

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Detection of micro- and nanoplastic contamination (co-plastic) in laboratory environments using Raman Spectroscopy

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Introduction

Micro- and nanoplastics in biological tissues have become a highly relevant research topic. However, their analysis can be significantly biased by contamination introduced during laboratory processing. The aim of this study is to systematically assess and quantify the introduction of contamination- derived plastic (co-Plastic) originating from laboratory environments and materials.

Methods

To assess contamination originating from laboratory materials, representative consumables and equipment were intentionally tested under typical laboratory use conditions. For example, deionized water was repeatedly aspirated and dispensed through pipette tips to evaluate potential particle release caused by material abrasion. In addition to negative controls, positive controls containing known plastic particles were analyzed to verify the reliability of particle detection and polymer identification. Commercially available silicon filter membranes (SmartMembranes GmbH) were used for particle collection and subsequent Raman microscopic analysis.

Results

The results demonstrate that co-plastic is detectable even under controlled conditions in negative controls. The smallest detected particle had a size of approximately 500 nm, with the overall analyzed size range spanning from about 500 nm to 25 µm. Various polymer types, including typical laboratory plastics such as polyethylene and polypropylene, were clearly identified.

Conclusion

These findings highlight that laboratory procedures represent a relevant source of co-plastic and emphasize the necessity of rigorous negative controls to ensure reliable interpretation of analytical results, particularly in studies investigating microplastics in biological tissues.

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Prediction of ventricular contractility after orthotopic heart transplantation based on myocardial microcirculation

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Introduction

Strictly trusting lactate to classify a donation after circulatory death (DCD) heart as transplantable or not during *ex vivo* blood perfusion (EVBP) has been criticized. Here, we verified novel prediction parameters based on myocardial microcirculation, which we had developed in previous porcine Langendorff experiments, in canine orthotopic heart transplantation (HTx) with DCD.

Material and Methods

The hearts (n=7) were maintained by EVBP for 4 h. We measured lactate, monitored the myocardial microcirculation in the left-ventricular (LV) anterior wall during EVBP, using a Laser-Doppler Perfusion (LDP) needle probe, and computed prediction parameters based on LDP shifts. The previously identified LDP shift of main interest was the shift between the first and last 30-minute perfusion interval, thus called First-to-Last$_{interval}$ shift. After 4 h, the hearts were transplanted, and the LV-end-systolic pressure volume relationship (ESPVR) was determined using a conductance catheter.

Results

A combination of the LDP shift and venous lactate in a linear model showed the highest r (0.950) and r^2 (0.902) for LV-ESPVR and thus served best for a prediction model. The respective, exemplary formula to predict the percentage of the donor-LV-ESPVR that will be reached in the recipient after HTx is: LV-ESPVR = 1.166 l/mmol*Lac$_{ven}$ +5.638 mmHg/ml*First-to-Last$_{interval}$ shift –4.468. The model resulted in a sensitivity of 100% and a specificity of 83.3% to predict that at least 80% of the donor-LV-ESPVR will be reached after HTx.

Conclusions

We conclude that the LV-ESPVR after orthotopic HTx with DCD can be predicted by combining the microcirculatory parameter First-to-Last$_{interval}$ shift during, and the Lac$_{ven}$ at the end of EVBP in a linear model. The prediction formula might need to be refined based on larger data sets.

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Non-Invasive Physics-Informed Cardiac Output Estimation

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Introduction

Cardiac output (CO) is a key parameter of the cardiac function. Reduced CO can lead to insufficient organ perfusion. However, accurate CO measurement typically requires invasive methods, limiting CO's availability. Recent works try to estimate CO from easily available biosignals. In this study, we investigate an approach to estimate CO using a physics-informed multilayer perceptron based solely on photoplethysmography (PPG) features.

Methods

Features from different measurement sites (finger, ear, and facial remote PPG) are evaluated individually and in combination. To incorporate physiological knowledge, the IHAR feature, defined as the normalized harmonic area divided by the inflection point area ratio, (strong correlation between IHAR and CO were shown previously) is embedded into the training process via a physics-based loss function. The data used originates from an own study (43 participants included) comprising multiple stimuli inducing changes in CO. CO was derived using the volume clamp technique, thus representing an estimate. Model performance is evaluated using mean absolute error (MAE) and Pearson correlation coefficient.

Results

Incorporating the physics-based loss improves CO estimation compared to models without physiological constraints across all PPG configurations by up to 28 %. The best performance of leave one subject out cross validation is achieved using facial remote PPG, yielding a MAE of 1.07 l/min and a Pearson correlation coefficient of 0.37, matching the literature for CO estimations using solely PPG.

Conclusion

This work demonstrates the potential of integrating physiological knowledge into neural network training for non-invasive CO estimation. However, the limitations of the underlying dataset highlight the need for further validation using independent databases with clinically measured CO. Expanding the range and quality of reference data, alongside a deeper integration of physiological mechanisms, will be crucial for improving model accuracy and clinical applicability.

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Towards a Compact Robotic System for Multimodal Medical Imaging

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Introduction

Multimodal imaging systems (e.g., PET/CT, PET/MRI) achieve high diagnostic performance but are limited by system complexity and size. This work proposes exploiting complementary physical contrast mechanisms and shared hardware architectures to realize a compact multimodal imaging platform augmented by robotic actuation to enable flexibility and precise guided imaging.

Methods

The imaging system combines photon-counting (PC) spectral CT with Compton-based gamma imaging and local electrical tissue characterization. Direct-conversion PC detectors provide energy-resolved measurements with high quantum efficiency, enabling material decomposition, artifact reduction, and dose-efficient acquisition. The Compton imaging (CI) subsystem utilizes collimator-free 4π gamma sensing and 3D source reconstruction.
A robotic gantry enables arbitrary source–detector trajectories, supporting non-circular and ROI imaging while reducing redundant projections. The system employs a hybrid architecture in which a six-axis robotic arm carries the source, while the detector is integrated into a compact flat gantry underneath the patient. A Zero-G interaction mode allows repositioning with detector adaptation.

Results

The system enables multimodal imaging capabilities with substantially reduced footprint, infrastructure complexity, and system weight compared to conventional clinical systems.
System-level analysis indicates that combining spectral CT and CI provides complementary contrast channels. CI is providing for limited angular resolution (10–15° FWHM), whereas for robotic CT and PET we expect to approach clinical resolution levels. PC detection improves signal-to-noise ratio, while flexible trajectories enhance sampling efficiency and reconstruction robustness. A dynamic source–detector coupling reduces geometric constraints compared to fixed gantries. A shared detector concept reduces system complexity and enables compact, multifunctional design.

Conclusion

The proposed system demonstrates a hardware-efficient pathway towards compact multimodal imaging through co-designing. The integration of six-axis robotics, gantry motion, and Zero-G interaction enables intuitive and flexible imaging. It supports use in constrained environments and allows multifunctional operation with retractable robotics utilizing a standard patient table.

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12-lead ECG synthesis from reduced lead set using multi-lead convolutional autoencoder

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Introduction

The standard 12-lead electrocardiogram (ECG) is essential for diagnosing cardiovascular diseases but is impractical for continuous monitoring due to the need for multiple electrodes and complex setup. This limitation motivates the reconstruction of full 12-lead ECG signals from a reduced number of leads to enable wearable and long-term monitoring solutions. Existing approaches often rely on handcrafted feature extraction or signal transformations, increasing computational complexity and limiting real-time applicability. This study proposes a novel deep learning approach to directly reconstruct 12-lead ECG signals from a reduced lead set using raw signals..

Methods

A multi-lead convolutional autoencoder (ML-CAE) is proposed to reconstruct 12-lead ECG signals from three input leads (I, II, and V2). The model adopts a multi-input multi-output architecture, where each input lead is processed by an independent encoder to extract latent representations. These representations are merged into a shared latent space to capture inter-lead correlations. Parallel decoders are then used to reconstruct each target lead individually. The model operates directly on raw ECG signals without feature extraction. Experiments were conducted using the ST-Petersburg INCART 12-lead ECG dataset, with signals segmented, e.g., N=512 samples, and normalized. Performance was evaluated using correlation coefficient and root mean square error (RMSE).

Results

The proposed ML-CAE achieved superior performance compared to conventional convolutional autoencoders (CAE) and U-Net models. It obtained an average correlation of 0.993, outperforming CAE (0.972) and U-Net (0.983). High reconstruction accuracy was observed across all leads, with correlations above 0.98 and near-perfect reconstruction in key leads. Statistical analysis confirmed significant improvements over baseline models.

Conclusion

The proposed ML-CAE effectively reconstructs high-quality 12-lead ECG signals from only three input leads by leveraging inter-lead relationships. The model demonstrates improved accuracy and reduced electrode requirements, making it a promising solution for wearable and continuous cardiac monitoring systems.

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Volume Conductor Model of the Upper Arm

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Introduction

Reliable personal warning systems are critical for occupational safety. Electrocutaneous stimulation via clothing-integrated electrodes on the upper arm offers a promising alternative to visual or acoustic signals. However, the electric field distribution within the arm's heterogeneous tissue layers depends strongly on electrode configuration, with implications for nerve activation. To support systematic, model-based electrode optimization, a volume conductor model of the right upper arm was developed in COMSOL Multiphysics.

Methods

Starting from the BodyParts3D anatomical dataset, relevant muscles and nerves were identified, implausible nerve trajectories were corrected on the basis of anatomical course relationships, and fascicles within the nerves were modeled using histological cross-sections. To represent anisotropic material properties, curvilinear coordinate systems were defined in the fascicles and muscles. The structures of the upper arm model were assigned isotropic and anisotropic conductivity values, and physical boundary conditions were specified. The model was meshed with tetrahedral elements using individually defined resolution domains. The resulting upper arm model was used to analyze current density and potential distributions in the relevant muscles and nerves for different electrode geometries.

Results

The generated mesh exhibits good to very good tetrahedral element quality, which is maintained even in regions with strongly varying mesh resolution. Among the electrode geometries investigated, rectangular electrodes produce the highest maximum current densities and the largest potential ranges in the fascicles and muscles of the upper arm model, indicating limited suitability for electrocutaneous stimulation.

Conclusion

The developed volume conductor model provides a foundation for the systematic, model-based investigation of electrical pathways underlying electrocutaneous stimulation and for the optimization of electrode configurations in wearable warning systems.

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Dynamic OCT for Oral Tissue Diagnostics: Ex Vivo and In Vivo Evaluation

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Introduction

While Optical Coherence Tomography (OCT) is an established imaging modality in clinical ophthalmology, it still has high potential as a diagnostic tool for tumor or cancer treatment in a wide range of clinical applications.
While conventional intensity-based OCT imaging can resolve epithelial and subepithelial structures, it lacks cell-specific contrast, limiting its diagnostic sensitivity. The ability to reliably distinguish healthy from altered tissue, especially in transition zones, is thereby limited. Dynamic OCT (DyOCT) offers motion-based contrast that may enhance visualization of microstructural tissue properties. We aim to evaluate DyOCT for layer-specific imaging and its potential as a non-invasive diagnostic and monitoring tool in the oral cavity.

Methods

In this study, we focus on its diagnostic potential within the oral cavity. Dynamic OCT imaging was performed ex vivo on rodent buccal mucosa and in vivo on human lip tissue using a commercial PS-OCT system Telesto® (Thorlabs GmbH, Germany). For DyOCT measurements the A-scan rate was set to 48 kHz, with 1000 A-scans per B-scan and 500 B-scans at same position. The increasing the number of temporal B-scans leads to more stable and less noisy dynamic representations. Therefore, we used at least 250 and up to 500 B-scans to achieve optimal resolution and reliable frequency-contrast imaging.
The system provides a lateral and axial resolution of 13 µm and 6.8 µm in air, respectively. DyOCT processing and clustering analyses were implemented in MATLAB .

Results

Ex vivo DyOCT studies of rodent mucosa revealed distinct papillary structures that were less visible in intensity-based images but were highlighted by mapping on a Hue-Saturation-Value scale and K-means clustering. In vivo measurements on human lip tissue similarly showed clearer layer transitions than conventional OCT, indicating improved differentiation of microstructural features.

Conclusion

Dynamic OCT provides additional contrast mechanisms that may support non-invasive diagnostics in the oral cavity. Initial ex vivo and in vivo results demonstrate improved visualization of epithelial and subepithelial features, highlighting DyOCT as a promising modality for future clinical applications.

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Patient-Specific 3D-Printed Drug-Delivery Implants: Translating Additive Manufacturing into Clinical Practice

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Introduction

Additive manufacturing (AM) enables the fabrication of patient-specific medical devices and drug-device combination products but remains challenging to translate clinically due to scientific, manufacturing, and regulatory requirements. Local drug delivery may overcome limitations of systemic administration by achieving therapeutically relevant concentrations at the target site while reducing systemic side effects.

Methods

We developed patient-specific, drug-releasing implants manufactured by direct ink writing of medical-grade silicone. The implants are designed from patient imaging data to precisely fit the individual anatomy and provide sustained local drug delivery. The platform underwent preclinical evaluation of printability, mechanical properties, biocompatibility, drug loading and release, sterilization, and anatomical fit. Its first clinical application targets cochlear implant (CI) patients, in whom postoperative inflammation and fibrosis may compromise residual hearing and implant performance. Dexamethasone-releasing implants are positioned in the round window niche before CI surgery to provide local anti-inflammatory preconditioning.

Results

A reproducible workflow from medical imaging and anatomical segmentation to patient-specific implant design and additive manufacturing was established. Silicone formulations containing drugs could be reliably processed by direct ink writing while maintaining implant geometry and mechanical integrity. Preclinical studies demonstrated biocompatibility and sustained drug release, supporting local delivery to the inner ear. Anatomical fit and safe handling were confirmed in human temporal bone studies. Manufacturing, quality-control, sterilization, and release procedures were subsequently transferred into a GMP-compliant framework, enabling production of clinical trial samples. Based on these results, the technology is progressing toward first-in-human clinical evaluation.

Conclusion

Patient-specific AM provides a promising platform for localized and sustained drug delivery. Beyond technological development, successful clinical translation requires early integration of regulatory, quality, and GMP requirements. Our experience illustrates a translational pathway from preclinical development, and testing to validation of GMP manufacturing and first-in-human investigation of personalized drug-releasing implants.

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The Radiology Sparring Partner: A PoC Study of Multi-Agentic Workflows for Clinical Decision Support and Teaching

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Introduction

The escalating complexity of radiological data imposes a significant cognitive burden on clinicians. While Large Language Models like MedGemma-27B-IT offer transformative potential, monolithic architectures often lack the systematic reasoning required for clinical safety and pedagogical nuance. This Proof of Concept (PoC) evaluates two specialized agentic frameworks: a clinical "Sparring Partner" and a "Socratic Teacher".

Methods

For clinical decision support, we compared three architectures: (1) Raw Baseline (direct MedGemma-27B-IT output with no system prompt), (2) Minimal Prompted (a single-shot prompt with role and output formatting), and (3) Multi-Agentic, employs a 4-stage sequential pipeline (Image Analysis, Clinical Reasoning, Protocol, and Synthesis). Separately, the educational track evaluates a distinct dual-agent architecture, with three-level progressive scaffolding and an Assessment Agent for gap identification. Both tracks were evaluated via a pooled LLM-as-a-judge review of 120 interaction transcripts at the University Hospital of Magdeburg. To mitigate automated leniency bias, results were anchored against 20 expert-validated reference interactions (n=5 per architecture) using a Bühlmann credibility calibration.

Results

The Multi-Agentic architecture outperforms monolithic baselines in high-level reasoning. Most notably, Pathophysiological Logic scores rose from 3.20 (Raw) to 4.14 (Agentic) on a 5-point Likert scale, while Clinical Safety improved from 3.59 to 4.20. Notably, all architectures maintained a consistently high Anatomical Accuracy, suggesting robust base-model knowledge, modular orchestration is essential for reliable clinical synthesis. In the pedagogical track, the system achieved moderate to high results, such as a 4.06 mean for Socratic Effectiveness, prioritizing independent discovery over direct revelation.

Conclusion

Transitioning to modular, multi-agent architectures enhances clinical logic and pedagogical safety, though it introduces a measurable "latency tax". While expert-anchored calibration improves the reliability of PoC results, automated evaluations remain subject to formulation bias favoring structured agentic outputs. Future work will focus on longitudinal clinical validation and technical optimization of memory architectures to refine the interaction potential of these frameworks.

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RGB-D/CT Registration for Preemptive Patient Pose Alignment in Longitudinal CT Scans

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Introduction

Longitudinal CT scanning is essential for monitoring treatment responses, yet its precision is compromised by inconsistent patient positioning between sessions. Current post-hoc image registration corrects these inconsistencies after acquisition, but remains computationally intensive, error-prone, and limited by the magnitude of initial pose discrepancy. This work proposes a paradigm shift: addressing variability at its source by aligning the patient's pose before the follow-up scan to complement post-hoc registration.

Methods

A top-mounted RGB-D camera acquires a surface image of the patient immediately before the follow-up scan. The surface is extracted from the prior CT-scan using the Marching Cubes algorithm and segmented into torso and limbs. The RGB-D point cloud is segmented using 2D skeleton keypoints projected into 3D. Registration has two stages: the CT torso mesh is converted to a 2.5D point cloud via Poisson disk sampling and Hidden Point Removal, then aligned to the RGB-D torso through PCA-based coarse matching and point-to-plane ICP refinement. After this anchoring, each CT segment undergoes independent coarse and refined alignment to its RGB-D counterpart. Correction vectors, defined as the displacement between the torso-anchored ideal limb position and the current registered position, are projected onto the 2D RGB image via a pinhole camera model, providing intuitive visual pose guidance for clinical staff.

Results

Validated on an anthropomorphic whole-body-phantom across three poses, torso anchoring achieves an average centroid error of 2.69cm and PCA angle error of 3.46° over repeated iterations. Limb surface registration yields mean point-to-surface errors between 1.61cm and 1.84cm with high repeatability. The visual guidance successfully communicates the required direction of postural adjustment.

Conclusion

This proof-of-concept demonstrates the feasibility of proactive, pre-scan patient pose alignment using RGB-D/CT registration. By reducing initial pose discrepancy before acquisition, the approach has the potential to improve raw data quality and reduce the burden on subsequent post-hoc registration.

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Multiscale investigation of bone quality at the interface formed by biodegradable magnesium implants using imaging and diffraction

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Introduction

The majority of implants used for fracture treatment are made from non-degradable materials like titanium, which remain in the body unless surgically removed. Magnesium (Mg) alloys offer an innovative alternative due to their biodegradability, biocompatibility, and mechanical properties resembling those of cortical bone, making them promising for osteoimplants. However, understanding the interaction of the degradation process of Mg implants with tissue remodeling remains challenging. This study investigates the influence of Mg-based implants on bone mechanical properties and ossification processes. It aims to analyze the multiscale impact of Mg alloys on bone quality, focusing on early-stage healing for this it combines modalities addressing different lengthscale from the micro- to the ultrastructure.

Methods

The femur of rats were implanted with Mg alloy (WE43) and titanium, which served as control. The rats were sacrificed after 3, 7, 14, 28 and 90 days. Synchrotron micro-CT measurements were utilized to provide detailed assessments of bone volume fraction (BV/TV), implant degradation and the spatial organization of lacunae/vessels. Moreover, synchrotron radiation was used to perform *in situ* nanoindentation experiments in combination with SAXS/WAXS measurements. This approach enabled the simultaneous assessment of hydroxyapatite crystal structure and orientation, together with the analysis of differences in the mechanical response of the bone.

Results

We observed observed a 20% lower BV/TV around the bioactive WE 43 implant compared to the Ti implant after 90 days, while morphological parameters such as vessel and lacunae density did not show any significant variation between the implant materials. In contrast, ultrastructural analysis showed that diffusion-driven degradation processes altered the crystal structure characterized by larger crystallite sizes and more irregular d-spacings for the WE43 implant. Additionally, indentation experiments revealed structure-dependent mechanical behavior. Specifically, areas with modifications in their HAp crystal structure tend to show higher strain levels.

Conclusion

Due to the bioactive environment created by the degradable implant, a reduction in osteointegration has been observed. Furthermore, the incorporation or substitution of Ca by Mg within the hydroxyapatite lattice alters the crystal structure and affects the mechanical properties of the bone surrounding the WE43 implants.

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Predictor-based Equalization of Magnetoelectric Sensor with Integrated Coil

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Introduction

Magnetoelectric (ME) sensors provide high sensitivity at their mechanical resonance but suffer from a strongly limited bandwidth due to their resonant behavior. This restricts their applicability in broadband sensing and multi-channel measurement systems. In biomedical applications, such as motion tracking or biomagnetic signal acquisition, a broader and more uniform sensitivity is required to reliably capture dynamic processes. To overcome these limitations, an equalization approach is required that compensates both amplitude and phase characteristics of the sensor response.

Methods

In this work, a prediction-based equalization method is proposed using noise excitation generated by an integrated PCB coil. A preprocessing pipeline consisting of cascaded filtering and downsampling is applied to isolate the relevant frequency range around the resonance. Based on the resulting signal, an equalization filter is derived using linear prediction, where the prediction error filter implicitly approximates the inverse sensor response. To ensure numerical stability, a spectral regularization is introduced in the power spectral density domain.

Results

Experimental results demonstrate a significant reduction of the resonance peak and a substantial extension of the usable bandwidth. The effective bandwidth increases from approximately 10 Hz to 150 Hz around the resonance frequency. The equalized sensor response shows a more uniform spectral distribution, indicating a successful compensation of the resonance-dominated behavior. Furthermore, the group delay analysis reveals a reduction of frequency-dependent delay variations, resulting in a nearly constant temporal response of the system.

Conclusion

The proposed method enables a robust and efficient equalization of resonant sensor systems. Both amplitude and phase characteristics are improved, leading to enhanced bandwidth and more stable temporal behavior. Future work will focus on achieving a more linear group delay and extending the approach to multi-channel and adaptive scenarios.

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AIDA – Efficient Intent Recognition for Human-Robot Interaction

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Introduction

This paper presents AIDA (Adaptive Intent Detection Architecture), a hybrid intent recognition framework that combines a lightweight Sentence-BERT classifier with selective LLM verification and automatic intent adaptation. A Random Forest-based error detector identifies potentially erroneous BERT predictions and forwards only these cases to a large language model for verification. In addition, previously unseen linguistic variants are automatically incorporated into an expandable intent reference database. Experimental results based on about 90,000 intent classification tasks across 40 intents show that approximately 90% of all BERT misclassifications can be detected while requiring LLM processing for only 7–13% of user requests. The results demonstrate that AIDA combines the efficiency of conventional intent-based dialog systems with the adaptability of modern LLM-based approaches.

Methods

AIDA is a hybrid intent recognition architecture that combines a lightweight Sentence-BERT classifier with selective verification by a Large Language Model (LLM). User utterances are matched against a database of intent-specific reference utterances using embedding similarity. The resulting intent prediction is analyzed by a two-stage Random Forest (RF) error detection mechanism. First, an intent-specific local RF classifier evaluates whether the prediction is reliable based on intent-specific failure patterns. Predictions classified as reliable are subsequently analyzed by a global RF classifier trained across all intents to capture general error characteristics. Only predictions accepted by both classifiers are processed directly, while potentially erroneous predictions are forwarded to the LLM for verification.

Whenever the LLM is invoked for intent verification, its decision is considered ground truth. The verified utterance is hence used to extend the intent reference database and incorporated into the training data of the local and global RF classifiers. As a result, the system continuously improves both its intent representation and its ability to identify potentially erroneous BERT predictions.

Results

The proposed approach was evaluated using 40 intents and 91,924 intent classification tasks. During the adaptation phase, the intent reference database was automatically expanded. Experimental results showed that the RF-based error detector identified approximately 90% of all BERT misclassifications while requiring LLM verification for only 7–13% of user requests.

Conclusion

The results demonstrate that AIDA successfully combines the efficiency of conventional intent-based dialog systems with the flexibility of LLM-assisted verification and adaptation. By selectively invoking computationally expensive LLMs only for potentially problematic cases, the system achieves high intent recognition performance while maintaining low computational costs. Furthermore, the automatic acquisition of new linguistic variants enables continuous adaptation to evolving user language and reduces the manual effort required to maintain intent-based dialog systems.

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Towards privacy-preserving medical image processing using homomorphic encryption

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Introduction

The use of cloud-based services for medical image processing is limited by strict data protection requirements (e.g., HIPAA, GDPR). This is particularly critical for volumetric data such as 3D head CT scans, where anatomical structures can enable reconstruction of facial geometry and thus potential re-identification, even when metadata are removed. Fully homomorphic encryption (FHE) offers a promising approach by enabling computations directly on encrypted data.

Methods

We present a framework for processing multidimensional medical imaging data using the Cheon–Kim–Kim–Song (CKKS) scheme. A common characteristic of FHE is that it natively supports only one-dimensional vector operations, which complicates the implementation of algorithms for inherently multidimensional data such as 2D/3D CT or multi-parametric MRI. To address this, we introduce a simple, high-level multidimensional array abstraction built on top of ciphertext vectors, together with corresponding shift operations, enabling the direct formulation of stencil- and convolution-based algorithms.

Results

As a demonstrator, we implement Laplacian of Gaussian (LoG) filtering for 2D and 3D head CT data using different kernel sizes. The results show that the encrypted computations reproduce the unencrypted "plaintext" results with high numerical accuracy, while remaining straightforward to implement using the proposed abstraction. However, the computational cost remains significant: while plaintext implementations run in seconds, encrypted 3D computations can require more than an hour for large kernels on a single CPU core. We further analyze performance characteristics and discuss optimization strategies.

Conclusion

We demonstrate the feasibility of using FHE for privacy-preserving medical image processing on realistic 3D data, and that multidimensional array abstractions remove a key barrier for implementing such algorithms. At the same time, the results highlight current challenges in performance and indicate the limitations in handling more complex, non-linear operations, which remain important topics for future work.

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Sleep-Temperature Dynamics and Social Jetlag Across Menstrual Cycle Phases

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Introduction

The interaction between sleep–wake rhythms and the menstrual cycle remains insufficiently understood. A clearer understanding of sleep timing and temperature dynamics could optimize fertility-tracking technologies and support applications in family planning and management of menstrual-related disorders. In this work, we investigated how these mechanisms vary across menstrual cycle phases.

Methods

Fully anonymized data were retrospectively analyzed from 50 women who provided consent and were regularly using the wearable Trackle system (trackle GmbH, DE), a certified intravaginal temperature sensor designed for contraception and family planning. The dataset comprised 25,107 recorded nights across 2018 menstrual cycles, during which ovulation times were determined using the system's symptothermal method. The data were then segmented into follicular, periovulatory, and luteal phases, as well as into weekdays and weekends. Sleep onset and sleep duration, as well as basal temperature timing and amplitude, were extracted. To quantify social jetlag (SJL), using weekends as a proxy for work-free days, the difference between the individual mean mid-sleep point on weekdays and that on weekends was calculated. Analyses included descriptive statistics and Pearson correlation analyses.

Results

The mean sleep duration showed no strong variation across menstrual phases, with only a slight reduction during the luteal phase. The individual mid-sleep point was, on average, delayed by 53 minutes on weekends, indicating the presence of SJL. The basal temperature occurred 12-14 minutes later on weekends across all phases. It was generally delayed in the luteal phase. The correlation between individual SJL and the average weekend basal temperature delay was moderate ($r = 0.35$, $p < 0.05$). In contrast, basal temperature amplitude showed negligible differences between weekdays and weekends.

Conclusion

Our results provide quantitative insights into the interaction between circadian timing and menstrual cycle–related physiological changes, which suggest that menstrual cycle phase and social behavior are associated with sleep–temperature relationships.
Future work may explore testing phase-dependent interactions and whether integrating sleep timing enhances the accuracy of ovulation and phase prediction with wearable systems.

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Stochastic Polarization State Tracing in Single-Input PSOCT for Examining Tooth Enamel

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Introduction

Tooth enamel exhibits exceptional hardness due to its hierarchical structure, particularly the decussated arrangement of enamel prisms in deeper layers. While histology remains the gold standard, it is invasive. Polarization-Sensitive Optical Coherence Tomography (PSOCT) enables non-invasive, in vivo imaging of birefringent structures. However, conventional PSOCT methods struggle to resolve the local optic axis in deep enamel due to cumulative polarization effects and eigenpolarization artifacts.

Methods

We introduce a novel Polarization State Evolution (PSE) model and a stochastic Polarization State Tracing (sPST) method. The sPST uses a local transformation to generate a local Stokes vector environment, enabling estimation of the local retardation and the local optic axis. An eigenpolarization detection scheme ensures reliability of the iterative reconstruction even beyond local eigenpolarization occurrences. The method operates on single-input PSOCT data, making it compatible with standard clinical systems.

Results

Using ex vivo tooth samples, we demonstrate depth-resolved reconstruction of the local optic axis up to 2 mm depth. Stripe-like patterns with ~50 µm width - consistent with Hunter-Schreger bands - were clearly resolved in the deeper enamel. Additionally, the local relative DOP change (lrDOPc) revealed features matching striae of Retzius, indicating mineralization gradients. The method successfully visualized decussation architecture even below bands of eigenpolarization, where conventional methods fail.

Conclusion

Our sPST method enables high-resolution, in vivo visualization of enamel's microarchitectural features—previously inaccessible with single-input PSOCT. By reconstructing the local optic axis and the local relative DOP change, it opens new pathways for early caries detection, enamel health monitoring, and understanding developmental pathologies. The approach is directly translatable to fiber-based PSOCT systems and holds strong potential for transforming dental diagnostics through non-invasive, real-time assessment of enamel integrity.

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Rethinking Safety for Autonomous Medical Motion

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Introduction

Autonomous medical systems with mechatronic motion, such as mobile X-ray devices and autonomous medical robots, are discussed as a means to reduce workload in healthcare. These systems rely on perception-based functions for navigation and collision avoidance in highly dynamic clinical environments. While established medical device standards primarily address hazards caused by hardware or software failures, hazardous situations may also arise without malfunctions due to perception uncertainty or incomplete scenario coverage. In the automotive domain, such risks are addressed by Safety of the Intended Functionality (SOTIF, ISO 21448). This contribution examines the relevance of SOTIF concepts for autonomous medical motion.

Methods

An autonomous mobile medical system is used as an example to illustrate safety-relevant situations beyond system failures. The example shows that perception-based autonomous functions in medical technology may exhibit SOTIF-like limitations. Based on this motivation, core concepts of ISO 21448 are analyzed for autonomous medical systems.

Results

The analysis shows that functional safety alone is insufficient for autonomous medical motion relying on environment perception. Even correctly operating sensors and software may lead to hazardous behavior due to inherent limitations of sensing principles, scene interpretation, and scenario variability. ISO 21448 provides a structured, scenario-based framework to identify such functional insufficiencies and to reason about system limits using concepts such as scenario classification and the Sense–Plan–Act model. Applied to medical technology, these concepts support transparent safety argumentation beyond failure-oriented risk analysis and enable systematic derivation of validation activities without requiring exhaustive scenario coverage.

Conclusion

Although ISO 21448 is not directly applicable to medical devices, its concepts offer valuable guidance for addressing perception-related risks in autonomous medical systems. Complementing established medical device safety standards with SOTIF-inspired, scenario-based reasoning allows safety arguments to explicitly address uncertainty and real system limits, which becomes increasingly important as autonomy in medical technology advances.

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Design and implementation of a European multicentric clinical study with AI-assisted AF screening methodologies

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Introduction

Atrial fibrillation (AF) is a major and often undiagnosed risk factor for stroke, heart failure, and mortality in cardiovascular patients. Digital monitoring technologies combined with artificial intelligence (AI) enable continuous rhythm surveillance and scalable screening strategies. Within a European research initiative, an integrated eHealth platform was developed to support long-term cardiac management and to enable different AI tools including AI-supported AF detection using multimodal physiological data streams.

Methods

The medical device study follows a multicenter randomized controlled design (Germany, Spain, the Netherlands), targeting 360 patients with coronary artery disease. Participants are allocated to usual care or to a digital intervention combining mobile application support, wearable sensors, and a clinician dashboard. Continuous home monitoring over 6 months includes patient reported outcomes, physical activity, hemodynamic assessments, and a 3-lead mobile Holter ECG. A telemetric infrastructure supports data processing, analysis, dashboards, decision support, and risk prediction. Recorded hemodynamic and ECG signals are analysed using deep-learning models to identify arrhythmias, including AF, with expert confirmation.

Results

Implementation across sites demonstrates that the platform can harmonize data acquisition, enable automated AF screening workflows, and support remote clinical supervision. Deep learning-based AF screening identified patients in long-term monitoring without previous diagnosis. Operational findings indicate high technical stability, consistent device integration, and reliable cross-border data transfer, supporting the feasibility of large-scale AI-assisted monitoring trials in routine rehabilitation pathways.

Conclusion

This RCT illustrates how AI-enabled infrastructures can support AF screening within cardiovascular care. The approach may enhance early detection, allow risk-adapted interventions, and provide a framework for future European digital health studies integrating clinical workflows, remote sensing, and intelligent analytics. Such infrastructures facilitate standardized data governance, reproducible analytics, and collaboration between clinical, technical, and research partners, thereby strengthening methodological quality, supporting regulatory readiness, and improving the translation of AI-based screening solutions into sustainable, patient-centered cardiovascular prevention programs.

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Seeing Healthy: Behavior Comparisons Between PC and VR Visual Search Task

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Introduction

A visual search task is a psychological experiment in which participants are asked to find a specific target among a set of distractors. It is commonly used to study attention and perception, but can also be used as a training tool, for example, to help individuals practice identifying healthy food options while ignoring unhealthy ones in a visual display. The goal is to retrain attention patterns, helping to reduce automatic focus on unhealthy food cues and support healthier eating behavior

Methods

This paper explores the implementation of a visual search task with food in virtual reality (VR) and compare it to a standardized PC-based version. These two applications were developed with a consistent structure and functionality to ensure comparability. Forty participants completed both conditions.

Results

The results indicate that the core aspects of visual search performance, the reaction time and error patterns, were comparable across VR and PC. The strong positive correlation between reaction times and error rates in both conditions suggests that search behavior is stable and consistent, although the controls caused significantly slower reaction times in VR and the immersion potentially increases the cognitive load.

Conclusion

Despite these differences, the findings suggest a promising transferability of visual search tasks into immersive environments, which opens up possibilities for a VR visual search based training to improve healthier eating habits

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Development of a Multimodal Imaging System for Assessing Local Microcirculation

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Introduction

In recent years, microcirculation diagnostics have gained increasing attention in intensive care medicine. Microcirculation reflects organ perfusion and has been shown to serve as a sensitive indicator of changes in organ perfusion in various conditions, such as sepsis and shock. This is in contrast to classical hemodynamic parameters, which primarily assess the macroscopic systemic circulation. However, the evidence from clinical studies is insufficient, largely due to the lack of measurement techniques capable of providing reliable and reproducible parameters for evaluating microcirculation.
The aim of this project is to enable bedside microcirculation diagnostics through multimodal imaging and to derive structural and functional parameters for its assessment.

Methods

A prototype was developed that enables simultaneous imaging of the local microcirculation in the upper layers of the skin using time-resolved multispectral imaging (MSI) and optical coherence tomography angiography (OCT-A). While MSI primarily provides functional parameters such as changes in blood volume and oxygen saturation, OCT-A enables three-dimensional structural visualization of blood vessels and the estimation of perfusion parameters such as vascular density and flow index. To enable standardized measurement of recapillization time following a pressure test, additional force sensors were implemented to measure tissue pressure during imaging.

Results

Studies on volunteers demonstrated that combined imaging using time-resolved MSI and three-dimensional OCT-A is suitable for assessing local microperfusion. The simultaneous use of force sensors on the applicator allows for reproducible and standardized measurements of capillary filling time, as potential diagnostic parameter. The portable design enables bedside use for examining central and peripheral measurement sites. Qualitative and quantitative results from the subject study will be presented during the conference presentation.

Conclusion

Multimodal imaging of local microperfusion at the patient's bedside and the standardized measurement of structural and functional parameters enable patient-specific diagnostics and may serve as a decision-making aid for treatment management in the future.

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Ground Reaction Force Segmentation Using Long-Short Term Memory Neural Network in Acoustic-Kinetic Joint Analysis

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Introduction

Acoustic-kinetic joint analysis is a method to assess the arthritic state of the cartilage of the knee joint and is used in various fields (orthopaedics, physiotherapy). The analysis of a patient's state comprises data from acoustic emission, joint angles and ground reaction forces (GRF) which is taken with three non-synchronous measurement systems. Currently the synchronization is done manually through a time consuming laborious process. To synchronize GRF and knee joint angle data, movement phases were defined and segmented which returns triggerpoints for synchronization.

Methods

In this paper we propose a method that employs an artificial neural network called GRFSegNet to automate parts of the synchronization by segmenting the movement phases in the GRF. GRFSegNet is constructed using a Bidirectional Long Short-Term Memory (BLSTM) network with regularization methods such as Batch Normalization, Dropout and L2-Regularizers. The data used to train the network comprises 395 datasets of GRF data from 110 subjects from previous studies. Four features are derived from the raw GRF data using smoothing filters of different lengths and a differentiation filter to emphasize the underlying signal patterns.

Results

After training, an accuracy of 87.24% and a loss of 0.45 was achieved on the test set. The synchronization with neural network supported segmentation reached in 75% of the 20 synchronization test cases a synchronization accuracy of less than ±0.1 s compared to 90% accuracy for the previous state of the art manual synchronization.

Conclusion

The results indicate that the network segments GRF data sufficiently well, though the classification accuracy of the extension and flexion phases needs improvement for more reliable triggerpoint detection. More training data from new subjects is necessary to improve generalization. The results suggest that continued development of AI-supported methods in acoustic-kinetic joint analysis is promising, with the integration of acoustic emission data as a next step.

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Investigation of the elastic hollow fiber melt spinning process

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Introduction

Peripheral arterial disease (PAD) affects about 20% of people over 70 years of age in Germany. Without treatment, PAD can progress from rest pain and impaired mobility to tissue necrosis and eventual limb amputation. Surgical treatment often requires bypassing the diseased artery using either autologous vessels or synthetic textile grafts. However, currently available textile grafts show limited long-term patency, partly due to compliance mismatch with native arteries. We aim to develop a textile vascular graft for above-knee applications with improved kink-resistance under repeated knee flexion and extension, biocompatibility, and a native-like compliance across the physiological pressure range.

Methods

We investigated the impact of the spinneret geometry (4-C vs 3-C, inner/outer diameter ratio, outer diameter) and extrusion temperature on the properties of the hollow reinforcing fiber.

Results

We successfully produced hollow TPU fibers with linear densities between 100 dtex and 400 dtex and controllable hollowness and circularity. Increasing extrusion temperature resulted in higher fiber circularity but lower hollowness. The maximum possible ratio of bending stiffness to axial stiffness is achieved at a hollowness of 0.5.

Conclusion

Hollow TPU fibers with tunable hollowness and circularity were successfully fabricated and represent a promising reinforcement concept for future textile grafts

Acknowledgements

This project is supported by the Federal Ministry for Economic Affairs and Energy (BMWE) on the basis of a decision by the German Bundestag.

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Digital Sleep Medicine: Telemonitoring, Wearables, and Clinical Decision-Making

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Introduction

The increasing prevalence of sleep disorders such as sleep-disordered breathing, sleep-related movement disor-ders or chronic insomnia requires scalable and patient-centered diagnostic pathways. Conventional polysomnog-raphy remains the gold standard but is resource-intensive and insufficient for broad population screening. AI-powered wearable devices combined with telemonitoring offer new opportunities in familiar sleeping environ-ment for continuous, ecologically valid sleep assessment in and may support earlier diagnosis and personalized management in digital sleep medicine.

Methods

This contribution presents a translational overview of clinical applications of wearable sleep technologies inte-grated into telemedical care pathways. Examples are drawn from real-world implementation in digital sleep med-icine programs, including wearable-derived multimodal biosignal acquisition (oxygen saturation, pulse wave analysis, movement, respiratory surrogates), AI-supported risk stratification, and remote monitoring platforms for longitudinal patient management. Particular focus is placed on clinical decision-making processes supported by automated signal interpretation and wearable-generated phenotyping data.

Results

Recent advances demonstrate that AI-enabled wearable systems can reliably detect sleep-wake patterns, estimate respiratory event burden, and identify clinically relevant trends in therapy adherence and residual disease activi-ty. In telemonitoring settings, these systems improve access to diagnostic evaluation, shorten time to treatment initiation, and facilitate dynamic therapy adjustment. However, challenges remain regarding data interoperability, explainability of AI algorithms, validation across heterogeneous patient populations, and integration into regulat-ed clinical workflows. Wearables are particularly promising for longitudinal disease monitoring and multimor-bidity phenotyping beyond episodic sleep laboratory diagnostics.

Conclusion

AI-powered wearable devices are reshaping digital sleep medicine from episodic diagnostics toward continuous, personalized, and telemedically integrated care. Their greatest potential lies in augmenting—not replacing—clinical expertise by enabling data-driven decision support, earlier intervention, and scalable management of comorbid sleep disorders. Further standardization and prospective validation are essential for widespread clini-cal adoption.

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Biomechanical evaluation of the stabilizing effect of wrist orthoses and cast treatments on an arm phantom

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Introduction

Standardized testing procedures are required for the objective assessment of mechanical stabilization provided by wrist braces. While early functional mobilization using orthoses is clinically favored, objective comparisons of their stabilizing effects compared to rigid casts remain scarce. The aim of this study was the biomechanical investigation and classification of the "Actimove Manus Air", a novel ready-to-wear fracture wrist brace, compared to four established standard treatments.

Methods

Five types of immobilization devices (Cast, Splint, DJO Exos Manus, ActiMove Manus Forte, Manus Air) were tested on a silicone measurement phantom with a 3D-printed hand skeleton. Stiffness was recorded in dorsal extension, palmar flexion, radial abduction, and ulnar abduction using a custom-built measurement system.

Results

The circular cast application exhibited the highest overall stiffness (0.70 Nm/°), followed by the DJO Exos Manus (0.56 Nm/°). The open-design Manus Air ranked with an overall stiffness of 0.25 Nm/°, surpassing the conventional splint (0.18 Nm/°) and the ActiMove Manus Forte (0.16 Nm/°). Notably, in dorsal extension and radial abduction, the Manus Air clearly exceeded the stiffness of the splint.

Conclusion

The innovative, open design of the Manus Air enables essential wound inspection and positions itself biomechanically as a highly valid alternative to conventional splints. It provides adequate stiffness required for safe early functional mobilization.

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Development of a measurement device and a lower leg phantom for standardized biomechanical testing of ankle braces

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Introduction

Orthoses are frequently used to prevent and rehabilitate ankle injuries, yet objective information comparing their mechanical support is often lacking. Because in vivo biomechanical tests are subject to strong inter-individual fluctuations, measurement phantoms are indispensable for isolating purely mechanical stabilization properties. The aim of this project was to construct a highly precise measurement device for recording passive joint stiffness alongside a lifelike, two-axis anatomical silicone phantom.

Methods

A mechanically rigid measuring system was custom-made from aluminum profiles to determine ankle joint stiffness in plantarflexion/dorsiflexion and eversion/inversion. To replicate human anatomy, a two-axis silicone phantom with an inner skeleton consisting of a double universal joint was developed. The measurement device was validated using a standardized mechanical spring phantom, while the silicone phantom's mechanical parameters were calibrated and validated against native in vivo reference data collected from 11 healthy subjects.

Results

Validation of the measurement device against a theoretical spring stiffness of 487 Nmm/° showed an average error of only 1.3% and a maximum relative deviation of 1.8%, proving extremely high reliability and accuracy. When compared against the averaged native in vivo data, the constructed silicone phantom demonstrated excellent simulation of human biomechanical parameters. For instance, the phantom achieved an extension stiffness of 284 ± 9 Nmm/° compared to the human subjects' average of 240 ± 47 Nmm/°.

Conclusion

The developed two-axis phantom and measurement apparatus represent a significant methodological advancement over purely in vivo human subject studies by offering a constant, reproducible basic stiffness that mirrors the human average. This system successfully enables standardized, subject-independent testing to evaluate the purely mechanical supportive properties of orthoses in complete isolation from physiological variables.

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AI-OPTIMUS: Artificial Intelligence-Supported Optical Precision Therapy and Integrated Management of Basal Cell Carcinoma

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Introduction

Basal cell carcinoma (BCC) is the most common skin cancer worldwide. Conventional diagnostic and therapeutic workflows require separate procedures, increasing treatment time and patient burden. AI-OPTIMUS aimed to develop an integrated system combining non-invasive optical diagnostics, targeted therapy, and artificial intelligence (AI). Optical coherence tomography (OCT) was integrated with a long-pulsed infrared laser to support automated BCC diagnosis, treatment planning, and therapy guidance, providing a basis for personalized, minimally invasive treatment.

Methods

The project comprised data preparation, AI development and system integration. A curated dataset of OCT images from 73 histologically confirmed BCC lesions of 36 participants and adjacent healthy skin was annotated, quality-controlled, and augmented. Deep learning learning models were trained to detect BCC subtype, tumor thickness, and spatial extent. The models were integrated into the OCT-laser platform for real-time image analysis and automated adjustment of treatment parameters.

Results

The best configuration used a multi-dataset pre-training with 981 images from a legacy dataset, random 2D slices from the Dresden in vivo dataset, and a retinal OCT dataset provided by Jiaxuan Li. A custom nnU-Net trainer loaded pretrained weights and froze all layers except the final segmentation layer for 10 epochs, using an initial learning rate of 0.01 and a factor of 0.1. Five-fold cross-validation and majority voting produced an overall Dice similarity coefficient (DSC) of 0.3807. Tissue-specific DSCs were 0.9323 for healthy skin, 0.1000 for infiltrative BCC, 0.1803 for superficial BCC (sBCC), and 0.3102 for nodular BCC. The algorithms identified characteristic BCC morphology, estimated clinically relevant tumor parameters, and enabled real-time therapy planning within a closed diagnostic-therapeutic workflow.

Conclusion

AI-OPTIMUS demonstrates the feasibility of integrating OCT, AI, and laser therapy for BCC diagnosis and treatment. This approach may streamline workflows, personalize therapy, and reduce invasiveness, while providing a technological basis for futre clinical studies and further development toward routine clinical application.

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Effects of UV irradiation on the thermal and mechanical properties of PLLA-films doped with metal nanoparticles

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Introduction

Due to their antimicrobial properties, metallic nanoparticles are increasingly being incorporated into biomedical materials. Metals, such as silver and copper are already used in medical products such as wound dressings and contraceptives. Investigating the effects of metal ions on cells and tissues in vitro requires sterile systems that enable the sustained release of metal ions. In this study silver and copper nanoparticles were incorporated into poly(L-lactic acid) (PLLA) films. Their thermal and mechanical properties were characterised.

Methods

PLLA films with embedded silver and copper nanoparticles were manufactured using dip-coating. Therefore, PLLA-solutions in chloroform mixed with the corresponding particles were used. The resulting composites sterilized by UV and investigated by differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) to assess the glass transition (T_g), melting (T_m) and decomposition temperature (T_d). Moreover, tensile tests were performed in comparison to pure PLLA.

Results

Thermal analyses showed no significant effect of the incorporation of metallic nanoparticles on characteristic temperatures of PLLA. Crystallinity decreased slightly in the composites compared to pure PLLA. UV irradiation led to a slight increase in measured values for T_g only. T_d was not influenced by either metal incorporation or UV irradiation. In mechanical tests, metal addition led to changes in Young's modulus (E), tensile strenght (σ_m) and elongation at break (ε_B). Exposure to UV radiation resulted in a significant increase in σ_m, accompanied by a marked decrease in ε_B.

Conclusion

Our results show that neither the incorporation of metallic nanoparticles nor subsequent UV irradiation alters the thermal properties of the composites. The residual mass values measured using TGA correspond to the calculated weight percentages only with limited accuracy, indicating that the manufacturing process may require adjustment. Particularly in mechanical tests, UV irradiation led to a significant change in material properties, implying that this finding must be considered in in vivo tests. These results serve as the basis for a degradable release system designed to enable continuous and long-lasting ion release.

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Lempel-Ziv complexity of simultaneous surface electromyography and magnetomyography during muscle fatigue

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Introduction

Complexity metrics have been applied to surface electromyography (sEMG) to characterize fatigue-related changes beyond conventional amplitude and spectral features. Optically pumped magnetometers (OPM) enable non-invasive recordings of magnetomyographic (MMG) signals, but it remains unclear whether complexity measures derived from MMG provide information comparable to sEMG. This study aimed to directly compare fatigue-related changes in conventional and complexity-based features across both modalities.

Methods

Healthy participants performed sustained isometric elbow flexion at either 20% maximal voluntary contraction (MVC; 20 min) or 60% MVC (3 min). Simultaneous sEMG and OPM-MMG recordings were obtained from the biceps brachii. Median frequency, root mean square (RMS), and Lempel-Ziv (LZ) complexity were quantified over time.

Results

Both sEMG and OPM-MMG showed consistent fatigue-related changes, including increased RMS, decreased median frequency, and a progressive reduction in LZ complexity over time (all $p < 0.001$). Multiple regression analyses indicated that RMS and median frequency explained only part of the variance in LZ complexity, suggesting that complexity captures additional aspects of signal organization. Furthermore, sEMG showed higher LZ complexity and median frequency at 60% compared to 20% MVC (both $p < 0.001$), whereas no comparable intensity-dependent differences were observed in OPM-MMG.

Conclusion

Lempel-Ziv complexity captures fatigue-related changes beyond conventional amplitude and spectral measures and is applicable to both electrophysiological and biomagnetic recordings. However, modality-specific differences, particularly in the response to contraction intensity, indicate that sEMG and OPM-MMG are not fully equivalent. Future studies combining complexity measures with motor-unit-level analyses may help to better distinguish between peripheral and central contributions to fatigue.

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ROCKMIND: Multimodal neurophysiological assessment of grip force control and fatigue in sport climbing

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Introduction

Sport climbing performance critically depends on sustaining submaximal grip forces under fatigue while maintaining precise force control. From a neurophysiological perspective, this process requires coordinated recruitment of motor units in the forearm musculature and effective corticospinal control originating in motor cortical areas. Despite the importance of these mechanisms for force regulation and fatigue, the neurophysiology of sustained gripping in climbing remains insufficiently understood. Hangboard training represents a central component of climbing-specific training. These exercises involve repeated or sustained isometric contractions using body weight and induce controlled loading of the forearm musculature. Importantly, hangboard tasks provide a highly standardized and experimentally tractable paradigm, making them well-suited for investigating neuromuscular and neural mechanisms of grip force control.

Methods

The ROCKMIND project introduces a multimodal experimental framework combining high-density surface electromyography (HD-sEMG) of the forearm musculature, electroencephalography (EEG), and force measurements during standardized hangboard tasks to investigate peripheral and central mechanisms of force control and fatigue. Ninety participants will be stratified according to the International Rock Climbing Research Association (IRCRA) reporting scale into non-climbers, recreational climbers (IRCRA 10-17 men, 10-14 women), and elite climbers (IRCRA >24 men, >21 women). Participants will perform controlled isometric grip contractions (finger flexion) on the hangboard at 20%, 35%, and 50% of their maximal voluntary contraction.

Results

Preliminary measurements in one participant using HD-sEMG of the forearm musculature show the feasibility of the hangboard setup and reflect clear fatigue-related changes in electromyographic activity during sustained contractions. EEG acquisition and corticomuscular coherence analyses will be performed as part of the ongoing study.

Conclusion

The preliminary findings support the feasibility of the proposed methodology for investigating grip force control and fatigue in sport climbing. By examining how grip force is maintained and how control strategies change as a function of fatigue and climbing expertise, the project aims to identify neurophysiological markers relevant for performance assessment and training monitoring.

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Minimal-Input Deep Learning for Remote Screening of REM Sleep Behavior Disorder

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Introduction

Rapid Eye Movement (REM) Sleep Behavior Disorder (RBD) is a critical clinical precursor to neurodegenerative synucleinopathies, such as Parkinson's disease, with up to 73.5% of patients progressing to such conditions within 12 years of diagnosis. Despite its clinical importance, current gold-standard screening via video-polysomnography (video-PSG) is limited by high costs, specialized lab requirements, and subjective manual analysis. This work addresses the need for a scalable, objective, and remote screening solution by introducing a fully automated, two-step deep learning pipeline optimized for minimal electrophysiological input from wearable devices.

Methods

The proposed architecture mimics clinical procedures by first localizing REM sleep and then screening for RBD-specific markers. First, an established U-Sleep architecture identifies REM stages using 30-second epochs of electroencephalogram (EEG) and electrooculogram (EOG) signals. Thereafter, a custom-built Convolutional Neural Network (CNN), featuring four inverted residual bottleneck blocks, analyzes the time-frequency characteristics of these epochs to classify the presence of RBD, with Grad-CAM applied to the final convolutional layer for additional interpretability. The model was trained and validated on an aggregated dataset comprising 18 RBD patients and 178 healthy controls, utilizing synthetic oversampling to address class imbalance.

Results

Experimental results demonstrate that a single EOG channel is the most efficacious minimal input, achieving 100% per-night sensitivity and 97.7% specificity for the CNN stage classifying RBD. Furthermore, Grad-CAM interpretability analysis identified a 22% increase in feature importance within the 9–22 Hz frequency band for RBD patients, potentially reflecting the loss of facial muscle atonia.

Conclusion

Our findings suggest that high-performance RBD screening can be successfully transitioned from controlled sleep labs to home-based monitoring using only EEG and EOG signals obtainable via wearable headwear. This automated approach provides a scalable pathway for the early detection and entry-level screening of neurodegenerative disorders without video-PSG.

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Comparative Analysis of Marker-based vs. Marker-less Computer Vision for a Gamified Lower Limb Rehabilitation

Abstract: Gamified computer vision systems offer low-cost alternatives to supervised rehabilitation, yet direct comparisons of marker-based and marker-less approaches using identical hardware remain limited. This study compared two ankle rehabilitation systems using the same webcam (eMeet C960): a custom HSV-based marker tracking system and a marker-less system based on MediaPipe Pose. Both were integrated into a Unity game targeting dorsiflexion, plantarflexion, inversion, and eversion. Ten healthy participants evaluated the systems using a 5-point Likert questionnaire. The marker-based system achieved lower angular error (3.2° vs. 7.16° ± 1.21%) and higher usability ratings, particularly for standing play and elderly users. These findings suggest marker-based tracking is better suited for clinically precise rehabilitation, whereas marker-less tracking offers greater accessibility and ease of use for home-based applications.

Keywords: Marker-based tracking, computer vision, gamification, lower limb rehabilitation, MediaPipe, HSV segmentation.

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A Cost-Effective Multi-Camera Calibration System for 3D Reconstruction in Real-World Biomechanical Gait Analyis

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Introduction

Computer-vision based evaluation of movement kinematics is a promising candidate for affordable biomechanical gait analysis outside clinical or laboratory environments. In this context, accurate 3D reconstruction of anatomical key points and their dynamics is essential. Conventional approaches rely on marker-based systems that are expensive and limited in scalability. Alternative 2D pose estimation methods cannot capture movements outside the recording plane. Recent advances in estimating multi-view geometry and the availability of open-source tools have enabled cost-effective 3D reconstruction using multiple consumer grade cameras. However, there is limited guidance regarding optimal camera placement and calibration for an accurate setup. To address this, we developed and tested a structured calibration pipeline for an affordable 3D pose estimation framework in a real-world environment.

Methods

We placed eight DJI Osmo Action 5 Pro cameras around a 6-meter walkway to ensure comprehensive coverage of a large volume that allows capturing performance of unconstricted whole-body movements. We tested multiple ChArUco boards of different dimensions for intrinsic and extrinsic calibration in Caliscope (https://mprib.github.io/caliscope/) to estimate camera parameters and reconstruct their 3D spatial configuration. To assess accuracy, we calculated the relative error between the reconstructed and real-world camera positions for all inter-camera distances and recorded movement from 20 volunteers.

Results

The estimated camera positions demonstrated strong agreement with ground truth measurements, indicating reliable calibration and spatial alignment across all viewpoints (mean and standard deviation of relative error over inter-camera distances = 3.58% ± 3.43%). The framework also enabled real-world data collection, consistently reconstructing movement from 20 subjects.

Conclusion

We present a practical and cost-effective framework for multi-camera calibration tailored towards 3D movement analysis in real-world settings. The system captures a large area, allowing to investigate unconstrained whole-body movements. We thus established a strong foundation for 3D motion analysis in low-cost environments.

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Feasibility of Motor State Differentiation Using a Cost-Effective 8-Channel EEG

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Introduction

Current trends in neurotechnology point toward more accessible, cost-effective, and portable solutions, particularly in the context of neurorehabilitation. This study investigates whether motor execution (ME) and motor imagery (MI) can be reliably differentiated using a cost-effective 8-channel EEG.

Methods

EEG data were recorded from 12 participants performing hand-clenching tasks (ME and MI). The signals were acquired using the Unicorn Hybrid Black system with a sampling rate of 250 Hz. A minimalist setup of 8 active wet electrodes was used, focusing on the motor cortex areas. The analysis focused on event-related spectral perturbations (ERSP) within the μ and β frequency bands. Two different feature extraction approaches were compared: a Mean-Approach, calculating the average power decrease across the activation window, and a Peak-Approach, focusing on transient extremum values.

Results

Results indicate that all three spectral features μ-ERD, β-ERD, and β -rebound exhibit significantly higher intensity during ME compared to MI. In the time domain, the signal power reaches markedly lower levels during ME, representing a more pronounced desynchronization. The Mean-Approach provided superior discriminative power for the sustained β-ERD, whereas the Peak-Approach demonstrates increased sensitivity in characterizing the transient μ-ERD and β- rebound modulations.

Conclusion

This study highlights the potential of a minimalist 8-channel EEG setup as a low-cost and efficient solution for BCI applications. Our findings demonstrate that, despite the reduced number of channels, a combined analysis of spectral features allows for a reliable differentiation between ME and MI. While limited spatial resolution and sample size represent constraints for universal classification, this approach provides a practically viable foundation for everyday neuroreha bilitation and portable brain–computer interfaces.

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Validation of a Signal Processing and Sensor Data Fusion Pipeline for Cochlear Implant Insertion Force Measurement

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Introduction

Insertion forces acting during cochlear implant surgery have been associated with intracochlear trauma and loss of residual hearing, but are almost imperceptible. To enable intraoperative insertion force measurement, our group developed the Forception Tool, a handheld device integrating a force sensor and an inertial measurement unit (IMU) for correcting gravity-related bias in force signals. While the tool and its data acquisition pipeline are established, the signal processing and sensor fusion validation required for reliable force interpretation are yet to be performed.

Methods

Sensor-specific noise was characterized, and low-pass filters were designed for the force and IMU accelerometer signals. The existing pipeline was then extended to acquire, filter, and fuse the sensor data, yielding a filtered gravity-compensated force signal. Filter performance was evaluated using data from 30 automated linear insertions with the tool, employing two metrics: Peak Preservation Ratio (PPR) and Residual Root Mean Square (Residual RMS). To verify synchronicity in the sensor fusion, 20 drop experiments were conducted, and the onset times of the sensor responses were compared.

Results

With filtering, relevant force peaks were preserved, achieving a mean PPR of 99.81 % ± 0.02 % and a Residual RMS of 0.26 mN ± 0.03 mN. Temporal synchronization between the streams was verified with a mean offset of 11 ms ± 4 ms.

Conclusion

The implemented pipeline successfully integrates and validates signal processing steps and confirms temporal alignment between the sensor data streams. The results demonstrate the reliability of measurements with the Forception Tool and pave the way for real-time force feedback to surgeons.

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Classification of Valvular Heart Diseases Using Nonlinear Heart Rate Variability Indices in Concurrent Electrocardiograms, Seismocardiograms, and Gyrocardiograms

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Introduction

Valvular heart disease (VHD) is a major clinical burden, but simple signal-based methods for outpatient assessment remain limited. This study assessed whether nonlinear heart rate variability (HRV) indices derived from concurrent electrocardiograms (ECG), seismocardiograms (SCG), and gyrocardiograms (GCG) can classify five VHD labels: aortic regurgitation (AR), aortic stenosis (AS), mitral regurgitation (MR), mitral stenosis (MS), and tricuspid regurgitation (TR). Because the dataset used in the study contains only VHD patients, the task was not healthy control versus VHD screening, but comparison of VHD classification across signal modalities.

Methods

The study used 100 concurrent ECG, SCG, and GCG recordings from "An Open-access Database for the Evaluation of Cardio-mechanical Signals from Patients with Valvular Heart Diseases". After beat detection and inter-beat interval estimation from the the SCG z-axis, and the GCG y-axis, nine nonlinear HRV indices (SD_1, SD_2, SD_1/SD_2, S, VAI, VLI, PAL, PBL, PAL/PBL) were computed from each modality. Eight classifiers were evaluated with hyperparameter optimization using grid search in a one-versus-rest setting under 5-fold cross-validation. Performance was assessed mainly with macro F1 score, supported by accuracy.

Results

Macro F1 score was more informative than accuracy because some tasks showed relatively high accuracy despite weaker class-balanced discrimination. The best result was obtained for SCG-based aortic stenosis classification with Linear SVM (accuracy: 0.780 ± 0.081, macro F1 score: 0.755 ± 0.109). Averaged across all classifiers and targets, GCG achieved the highest mean macro F1 score (0.518), followed by SCG (0.503) and ECG (0.491). Aortic stenosis and tricuspid regurgitation were classified most effectively, whereas mitral regurgitation was the most difficult target.

Conclusion

Nonlinear HRV indices provide an interpretable benchmark for comparing ECG, SCG, and GCG in VHD-oriented classification. Mechanical modalities, especially GCG on average and SCG for AS, showed slightly stronger class-balanced performance than ECG in this restricted feature representation. The results should be interpreted as a preliminary, reproducible benchmark rather than a complete clinical screening system; future work should include independent validation, ECG-independent mechanical beat detection, and multimodal fusion.

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Design and Implementation of an Inline Coater for Solvent-Based Polyurethane Microelectrode Insulation

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Introduction

The increasing use of microelectrodes in neuroprosthetic systems, particularly in transcutaneous osseointegrated prosthetic systems (TOPS), demands reliable, scalable insulation technologies. Ultrathin microwires (25–50 µm) offer improved mechanical compatibility with soft tissue but require defect-free, durable insulation to ensure long-term functionality. This study presents the development of a continuous coating process for polyurethane-based insulation of microwires intended for implantable electrodes.

Methods

An automated inline coating system (“PolyCoat – inline”) was designed to enable continuous dip-coating of microwires. The system uses a PTFE roller with independently controlled rotational and translational motion, governed by a microcontroller. Stainless steel microwires (25 µm diameter) were coated using a polycarbonate-based polyurethane dissolved in chloroform. Coating thickness was controlled via linear wire speed (120–1000 $mm \cdot min^{-1}$). The resulting films were characterized using confocal laser scanning microscopy (CLSM).

Results

The inline coater enabled stable and continuous coating of microwires, producing homogeneous polyurethane insulation layers. A clear correlation between linear wire speed and coating thickness was observed, consistent with dip-coating theory (Landau–Levich and capillary regimes). At a wire speed of 1000 $mm \cdot min^{-1}$, a uniform, defect-free coating with a thickness of approximately 4.5 µm was achieved. The system demonstrated reproducibility and suitability for extended wire lengths, supporting scalable manufacturing.

Conclusion

The developed inline coating system provides a robust and scalable approach for producing uniform polyurethane insulation on ultrathin microwires made of stainless steel or other metal alloys in a diameter range of 25 µm to 250 µm. Controlled process parameters enable reproducible coating quality, making the method promising for manufacturing mechanically compliant and electrically reliable implantable electrodes for neuroprosthetic applications.

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Microsleep Raw-EEG Classification

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Introduction

Falling asleep at the wheel is one of the most common causes of fatal traffic accidents. Driver assistance and fatigue warning systems are important technical countermeasures. Their evaluation requires laboratory standards, with EEG analysis potentially serving as a central real-time approach. Microsleep (MS), as a key feature of advanced fatigue, should be reliably detected in EEG signals. Machine learning is intended to identify patterns and develop real-time detectors.

Methods

The study dataset originates from nighttime driving sessions conducted in a laboratory. During these sessions, multichannel EEG recordings and video data from 84 participants were collected. Microsleep (MS) episodes were identified behaviorally based on the video recordings. Using systematically optimized 1D convolutional neural networks (1D-CNNs) and support vector machines (SVMs), an attempt was made to distinguish MS from periods of sustained attention (SA) based on the EEG signals.

Results

With simple preprocessing of the raw EEG segments and optimization of a 1D-CNN, MS and SA can be distinguished with an accuracy of 95.2 ± 0.2%. Standard machine learning using spectral analysis and SVM achieves a slightly higher accuracy of 96.3 ± 0.0% after spectral feature extraction and parameter optimization.

Conclusion

It was shown that raw EEG data can be successfully processed using deep learning. Classifiers based on spectral feature extraction achieve slightly better results. Combining 1D-CNNs with LSTM networks could further improve accuracy and thereby enable a real-time analysis approach directly based on raw EEG data.

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Real-Time Feedback and Stress Monitoring in Guided Breathing Exercises

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Introduction

Stress is a widespread health challenge affecting both physical and mental well-being. While guided breathing is an effective stress regulation intervention, adherence to the breathing pattern is often difficult to track without objective feedback. This project introduces a real-time system that combines physiological monitoring with interactive feedback to support effective stress management through guided breathing exercises.

Methods

Using a Polar H10 BLE chest strap, we recorded ECG and 3-axis accelerometer (ACC) data. We developed a system architecture in Python/Streamlit consisting of data acquisition, real-time signal processing, and a visualization interface. Two respiration phase estimation methods were implemented: a signal-based approach using ACC data with probabilistic phase tracking and a model-based approach using a U-Time convolutional neural network for ECG-derived respiration. Additionally, stress levels were quantified through variations in the heart rate variability parameters, such as the root mean square of successive differences of 20s intervals (RMSSD).

Results

Pilot tests verified the system's functionality. The signal-based ACC classification correctly identified inhalation and exhalation phases approximately 70% of the time. Offline analysis of the fused ACC and ECG signals showed an RMSE of 0.591 compared to the target breathing pattern. Quantitative stress assessment revealed a progressive increase in RMSSD from 40 ms to 130 ms over the course of a 4-7-8 breathing exercise, indicating a measurable shift toward a relaxed state.

Conclusion

The system demonstrates that consumer-grade wearables can provide effective real-time feedback for breathing exercises and objective metrics for stress reduction, potentially improving user adherence to such practices.

This work was supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under the grant numbers 493169211 (TherapAI) and 471909988 (LEAF).

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Comparative Investigation of Substrate Effects on the Surface Free Energy of Self-Assembled Monolayers on Au, TiO_2, and Al_2O_3

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Introduction

Self-assembled monolayers (SAMs) are widely used to tailor surface properties of biomaterials and implant surfaces. They are typically assumed to determine surface characteristics independently of the underlying substrate. However, the extent to which substrate effects persist despite SAM functionalization remains unclear. This study investigates the influence of different substrates on the surface free energy (SFE) of SAM-coated surfaces.

Methods

Thin films of gold (Au), titanium dioxide (TiO_2), and aluminum oxide (Al_2O_3) were functionalized with structurally analogous thiol- and phosphonate-based molecules. Specifically, 11-mercaptoundecanoic acid (MUA) and hexanethiol (MC6) were used on Au, while 11-phosphonoundecanoic acid (PUA) and hexylphosphonic acid (HPA) were applied on metal oxide substrates. The molecules were selected to ensure comparable alkyl chain lengths and terminal functional groups. Contact angle measurements were performed using water and diiodomethane, with n = 10 per liquid and sample. The SFE was determined using the Owens–Wendt–Rabel–Kaelble method. Long-term stability was assessed after 28 days of storage under ambient conditions.

Results

SAM functionalization resulted in a significant decrease in SFE compared to plasma-activated reference samples. Short-chain, non-polar SAMs (MC6, HPA) showed pronounced substrate-dependent differences, with Au exhibiting higher SFE than TiO_2 and Al_2O_3. In contrast, long-chain SAMs (MUA, PUA) yielded more similar SFE values across all substrates. All coatings remained stable over 28 days, with only minor variations within experimental uncertainty.

Conclusion

The results demonstrate that substrate effects on SFE can still be observed despite SAM functionalization, particularly for short-chain monolayers. Increasing alkyl chain length appears to reduce this influence and leads to more similar surface properties. These results suggest that molecular structure should be considered when interpreting SFE measurements and designing SAM-functionalized biomaterial surfaces.

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Hybrid Rule-Based and Machine-Learning-Based Post-Processing of Dynamic Contact Angle Measurements

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Introduction

Dynamic contact angle measurements provide insight into biomaterial surface wettability, crucial for protein adsorption and cell adhesion. Automated baseline detection, droplet contour fitting, and contact point localization are prone to errors, producing physically implausible frames. Manual correction is time-consuming, subjective, and limits reproducibility of advancing and receding contact angle (ARCA) measurements. This study presents a hybrid post-processing pipeline combining deterministic pre-filtering and machine-learning-based classification to identify faulty frames, improving reliability and efficiency of ARCA evaluations.

Methods

ARCA measurements were performed on water and diiodomethane droplets using the Needle-In method on gold and native oxide substrates (SiO_2, Al_2O_3, TiO_2). Image sequences comprising 19,902 frames were acquired, and geometric and contact-angle-related parameters extracted. Deterministic rules removed clearly invalid frames based on missing values, implausible contact point positions, droplet width deviations, and extreme contact angles. The remaining frames were manually annotated as good, bad, or ultrabad based on contact point detection and droplet plausibility. An optimized Naive Bayes classifier using selected contact-angle and geometry-related features was trained and evaluated on a held-out test set. The hybrid pipeline thus combines deterministic pre-filtering with supervised machine-learning classification to handle both obvious and subtle errors.

Results

After cleaning, 15,889 frames were used for training and 2,979 for evaluation. The classifier achieved 95.33% accuracy, 90.42% macro-precision, 95.95% macro-recall, and 92.77% macro-F1 score. All ultrabad frames were correctly identified, while errors were mostly limited to borderline good/bad frames. Post-processing removed spikes, smoothed ARCA curves, and ensured continuous contact angle signals, improving interpretability and comparability across substrates.

Conclusion

The hybrid workflow enables objective, reproducible, and efficient post-processing of dynamic contact angle measurements, reducing manual inspection. Reliable detection of severely faulty frames ensures consistent ARCA evaluation, providing a robust foundation for further automation and generalization to diverse biomaterial surfaces.

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Investigation of Surface Free Energy Changes of Peptide Self-Assembled Monolayers under Different Storage Conditions

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Introduction

Peptide-based self-assembled monolayers (SAMs) are used in biomedical surface engineering to enhance biocompatibility and control cell interactions. However, discrepancies between storage and application environments may alter SAM structure and functionality. This study investigates storage-induced changes in peptide SAMs by analyzing variations in surface free energy (SFE).

Methods

Gold-coated glass substrates were prepared, yielding six peptide-coated samples (C-KKKK-IKVAV, 0.1 mmol L^{-1} in HEPES buffer) and two uncoated references. All samples were cleaned, immersed in solution for 44 h, and rinsed. Reference samples were treated identically using pure HEPES buffer. Initial contact angle measurements were performed after preparation.
Samples were stored under two conditions: (i) ambient laboratory conditions (room temperature, air) and (ii) physiological conditions (37 °C, PBS) with three coated samples and one reference each. Contact angles were repeatedly measured on the same samples after 1, 4, 7, and 14 days using water, diiodomethane, and ethylene glycol ($n = 10$ per liquid and sample); samples were rinsed with ethanol and DI water after measurements. SFE was calculated using the Owens–Wendt–Rabel–Kaelble method.

Results

Initially, coated samples showed uniform SFE, while higher values were observed for references; divergence developed over time. Samples in PBS showed consistently higher SFE than those in air, with differences becoming significant by day 7 (LMM, likelihood-ratio test, $p < 0.001$). Coated samples in PBS showed increasing SFE, whereas those in air decreased slightly. Reference samples decreased under both conditions, especially in air.

Conclusion

Storage conditions significantly affect peptide SAM properties. Physiological storage leads to increased SFE, possibly due to peptide reorganization at the interface, whereas ambient storage leads to a decrease in SFE. These findings highlight the importance of storage protocols for maintaining functional SAM performance in biomedical applications.

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Assessment of cognitive load and stress among nursing staff in an elderly home

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Introduction

Due to demographic changes, the nursing sector faces increasing demands and staff shortages. To address this, we implemented continuous monitoring of heart rate (HR) and heart rate variability (HRV) via chest strap sensors, complemented by self-reported stress levels and activity documentation using a custom smartphone app.

Methods

Data preprocessing ensured quality and reliability, with HRV serving as physiological stress indicators. Individual workload was modelled as a multidimensional Ornstein-Uhlenbeck process, integrating objective (vital signs, acceleration) and subjective (PROMs) stress measures

Results

Results reveal strong correlations between subjective stress ratings and physiological metrics, particularly lower HRV during high-stress activities. Break periods consistently showed the lowest stress levels. The drift matrix indicates that vital data robustly predicts possible future work stress and well-being, with recovery times to equilibrium spanning 1–3 days. Negative correlations were observed between HRV and other stress measures, validating HRV as an inverse stress marker. Background factors (sick days, days off) influenced workload dynamics, but non-significantly.

Conclusion

The study demonstrates that wearable-based vital sign monitoring can provide early warning of excessive cognitive and physical stress, enabling timely interventions to promote staff well-being. This approach presents a scalable, unobtrusive method for ongoing assessment and management of nursing staff stress in real-world care settings.

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The effectiveness of UV-C reprocessing for spirometry face masks and their components

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Introduction

The manufacturer of a medical device is responsible for providing reprocessing instructions. In order to achieve a high standard of hygiene, these procedures are often complex and require many manual and time-consuming steps. In this context, ultraviolet radiation could represent an effective method for reprocessing because it can rapidly inactivate microorganisms. This work investigates whether UV-C treatment has a disinfection effect comparable to that of a standard chemical reprocessing.

Methods

A bacterial suspension was inoculated at contamination points on the surface of the face mask. Swabs were taken from the same locations after reprocessing according to the manufacturer's instructions or reprocessing with UV-C light for 20 minutes under different procedures. In addition, the masks were contaminated by test subjects under realistic conditions to assess the effectiveness of the UV-C treatment in such situations as well.

Results

The masks that were neither pre-cleaned nor rotated during UV-C reprocessing showed the highest residual bacterial contamination. After UV-C irradiation, this specimen still had 126 CFU and 13 CFU residual bacterial load. The masks that were pre-cleaned showed a maximum bacterial contamination of 4 CFU after reprocessing. Ater reprocessing in accordance with the manufacturer's instructions a maximum of 3 CFU remained. Similarly, a bacteria reducing effect of UV-C treatment was demonstrated on masks and components contaminated under realistic conditions.

Conclusion

Both reprocessing methods, the manufacturer's instructions and UV-C irradiation, achieve acceptable results in terms of bacterial reduction, although both methods have advantages and disadvantages. If the surfaces are not sufficiently exposed to UV-C radiation the effectiveness may be reduced. In general, the UV-C irradiation method proves to be particularly practical and feasable. Nevertheless, further research should be conducted in some areas, for example to test the possible long-term effects of UV-C irradiation on the materials or the consistent effectiveness of the procedure.

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Comparison of Dimension Reduction Methods for EEG Seizure Detection Using Autonomous AI-Driven Optimization

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Introduction

Automated seizure detection from electroencephalography (EEG) is critical as manual review of long-term monitoring data does not scale. While research focuses on classifier design, the choice of input representation is equally critical: discriminative information discarded upstream cannot be recovered. We compare four signal-space dimension reduction methods, Principal Component Analysis (PCA), Dynamical Component Analysis (DyCA), Dynamic Mode Decomposition (DMD), and Average Volatility Dimensioning (AVD), for deep learning-based seizure detection.

Methods

We use the Temple University Hospital Seizure Corpus (TUSZ v2.0.3) restricted to adult recordings. Signals are resampled to 256 Hz, filtered, and remontaged to 27 channels, then segmented into 2-second windows. Each method reduces the 27 channels to 4 dimensions. To ensure a fair comparison, an autonomous AI-driven research framework, adapted from the autoresearch pipeline, independently optimizes classifier architecture and hyperparameters for every representation, retaining only candidates that improve validation ROC-AUC.

Results

On the validation set, the variance-based methods AVD (89.78 %) and PCA (89.41 %) outperform the dynamics-based methods DMD (84.04 %) and DyCA (82.19 %) by 5-8 % in ROC-AUC. On the held-out test set, the gap widens to 11-14 %: AVD maintains the highest score (88.28 %), while DMD and DyCA drop to 74.56 % and 74.85 %, respectively. AVD and PCA also show smaller validation-to-test drops (1.50 % and 3.43 %) than DMD and DyCA (9.48 % and 7.34 %), indicating better cross-subject transferability.

Conclusion

Variance-based representations consistently outperform dynamics-based decompositions and transfer more reliably across subjects. Cross-channel dispersion heterogeneity, as captured by AVD, emerges as a robust seizure signature. The autonomous search reveals that the best-performing classifier architecture differs across representations, underscoring the need for joint optimization of representation and classifier. Our results indicate the viability of autonomous AI-driven experimentation in biomedical signal processing.

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Instance-based Aortic Valve Segmentation and Landmark Detection on RGB Images

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Introduction

Valvular heart diseases represent a major global health burden, with aortic valve stenosis being one of the most prevalent conditions and the leading valvular disease requiring intervention in Europe and North America. Accurate intraoperative assessment of valve anatomy is essential for successful surgical repair or replacement. Current assessment methods rely on manual measurements, which can be time-consuming and prone to inter-observer variability, and are limited to non-physiological conditions. Intraoperative endoscopic assessment under pressurized conditions enables physiological evaluation, while deep learning offers the potential for automated and objective analysis. In this study, we extend existing semantic segmentation approaches to an instance-based formulation with landmark detection.

Methods

The Mask R-CNN framework is employed and evaluated using different ResNet and Swin Transformer backbones. The model is extended with a heatmap-based landmark detection head. Furthermore, a refined model is trained with optimized hyperparameters to further enhance performance. The approach is evaluated on a dataset of porcine aortic valves acquired using a specialised imaging setup from ex vivo hearts.

Results

The proposed method achieves competitive segmentation performance (mIoU 0.8794), slightly below the dataset benchmark (0.9158), while enabling landmark detection with recall values of up to 0.74 and extending applicability to pathological valves with varying cusp configurations. These results demonstrate the feasibility of combining instance segmentation and landmark detection for more comprehensive valve analysis.

Conclusion

In this study, we extend the current approach for the analysis of aortic valve images by incorporating instance-based segmentation and landmark detection. This approach enables the analysis of valves with varying anatomical structures, including pathological cases with non-tricuspid configurations. The detected landmarks provide a basis for quantitative assessment, for example enabling 3D measurement of the valve in intraoperative settings.

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Optimizing IPG-Based Heart Rate Estimation: A Systematic Analysis of Complex Tissue Impedance

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Introduction

IPG is a promising non-invasive method that captures hemodynamic parameters by measuring pulsatile arterial impedance changes, making it unaffected by limitations like skin pigmentation or ambient light. However, common IPG applications neglect the complex electrical properties of biological tissue by relying on single-frequency measurements, ignoring how varying frequency influences the real and imaginary impedance. Thus, this paper investigates the effect of varying excitation frequencies and the choice of the complex signal component on heart rate estimation accuracy.

Methods

A study involving 40 healthy participants was conducted using a tetrapolar electrode array placed at the left distal radial artery. Complex impedance measurements were obtained at five injection frequencies ranging from 3 kHz to 100 kHz. Heart rates were estimated from both the real and imaginary signal components using an autocorrelation-based algorithm. These estimations were then compared against an oscillometric blood pressure cuff reference. Mean Absolute Error and RM-ANOVA are used to quantify the change of estimation accuracy.

Results

The real signal component demonstrated consistent and robust performance across the five measured frequencies, achieving a minimum MAE of 6.0 ± 12.9 BPM at 27.3 kHz. Conversely, the imaginary signal component showed a statistically significant dependency on the excitation frequency. It performed poorly at 3 kHz with an MAE of 25.0 ± 18.6 BPM, but accuracy improved significantly to an MAE of 8.6 ± 14.4 BPM at 51.5 kHz. Moreover, the results show that HR estimation performs well for most participants, the results are heavily influenced by significant outliers.

Conclusion

The findings indicate that the real signal component is a more reliable and robust estimator for heart rate monitoring across various frequencies and exceeds the accuracy of the imaginary component. The results suggest using the real signal component for more reliable HR estimation.

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High-Precision Insertion Force Measurements for Cochlear Implant Surgery: Accuracy Analysis of an Improved Device

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Introduction

Insertion force measurement in cochlear implant surgery aims to improve hearing outcomes by detecting events during implantation that may lead to intracochlear trauma. Our group recently developed the Forception Tool, which enabled the first intraoperative insertion force measurements. This work examines the measurement accuracy of an updated tool design.

Methods

This current design iteration comprises improved force and inertial sensors, chosen to provide improved accuracy as well as a smaller footprint. A comprehensive series of test was carried out to quantify systematic and random measurement errors. These included noise, drift and creep measurements as well as insertion experiments where the tool data was compared to a gold standard measurement.

Results

The experimental results confirm the high accuracy of the device with negligible drift and noise characteristics, moderate creep and an effective compensation of orientation-dependent gravity influences. The comparison to the gold standard shows a systematic error well below 1 mN, even with exaggerated movements during the insertion. Compared to the first published tool iteration, the uncertainties are reduced by over 80%.

Conclusion

The refined version of the Forception Tool provides a higher level of accuracy, resulting in more reliable measurements. After this verification, the next step is to obtain improved intraoperative insertion force data. This will enable a more detailed analysis of the forces and thus better understanding of their impact.

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A Study on the Measurement of Calcification in Bicuspid Aortic Valves

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Introduction

Transcatheter aortic valve implantation (TAVI) is widely used in the clinical treatment of severe aortic stenosis. Functionally bicuspid patients are increasingly included in TAVI cohorts. However, their pronounced geometric variability introduces additional challenges for device deployment and procedural outcomes. This underscores the importance of analyzing this subgroup in greater detail. Virtual cohorts and *in silico* studies provide a suitable framework for systematically investigating such anatomical variations.

Methods

To assess whether synthetically generated calcification patterns reproduce the constrictive effects observed in real functionally bicuspid patient data, we defined a parameter describing the calcified connection between the leaflets as quantitative criterion. Using pyVista, we quantified the maximum extent of these calcified connections in 40 segmented, functionally bicuspid human aortic valves.

Results

The measurement demonstrated a high degree of reproducibility, with six independent observers obtaining comparable results. The longest and most frequent calcified connections were observed between the right-coronary cusp (RCC) and the left-coronary cusp (LCC). Among patients exhibiting only a single calcified connection, the mean normalized bridging extent was 62 % for RCC and LCC, 54 % for non-coronary cusp (NCC) and RCC and 34 % for LCC and NCC.

Conclusion

These findings provide essential quantitative insight into calcification-induced leaflet constriction in functionally bicuspid anatomies and support the validation of virtual TAVI cohorts.

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High-Frequency Simulation of Crosstalk between Transmission Lines on Biocompatible Circuit Boards

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Introduction

Novel, deep-lying, distributed implant networks, supplied by ultrasound with energy, hold great promise for treating diseases more efficiently by delivering therapy simultaneously at multiple sites. A two-plane biocompatible, high-frequency (HF) capable circuit board (CB) serves as platform to electrically and mechanically connect all components of these implants. As substrate alumina (Al_2O_3, d_{Al2O3} = 630 µm) is used, with Platinum (d_{Pt} = 500 nm) as metal conductors and Tungsten-Titanium (d_{WTi} = 50 nm) as adhesion promoter. To quantify HF behavior of signal lines and their crosstalk to nearby traces, HF simulations were conducted.

Methods

The simulation was built in ANSYS (Synopsys, USA) and analyzed with the 3QD-Extractor tool for crosstalk analysis. Four realistic trace topologies were simulated and also fabricated and measured: single traces, parallel traces, overlaying traces and a mixed configuration. Trace lengths vary from 5 mm to 20 mm, widths from 300 µm to 500 µm, parallel trace distances from 300 µm – 500 µm, overlapping distance was d_{Al2O3}, all simulated at f_{Meas} = 5 MHz, typical frequency for medical ultrasound.

Results

Equivalent circuit extraction yielded values for resistance, conductance, series inductance, plate and fringe capacitances. These values were further simulated in ANSYS Circuit. For all trace combinations the signal was attenuated at most between 5 % (single trace) and 8 % (adjacent traces), with most values ranging between 0 – 2 % for most variations. Voltages were induced by parasitic crosstalk maximal between 0.07 % (overlapping traces) and 0.2 % (mixed configuration). Additionally, field crosstalk (electromagnetic coupling) effects have been simulated graphically.

Conclusion

The simulations showed that resistance and series inductance are responsible for signal attenuation, while parasitic and field crosstalk couple to nearby traces. All simulated values have been validated by measurements, showing that simulations can provide guidelines for trace geometry, spacing and material selection while reducing reliance on invasive in-vivo testing.

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Enhancing Fiducial Point Detection in Imaging Photoplethysmography Through Spatial Fusion

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Introduction

Imaging photoplethysmography (iPPG) enables contactless measurement of pulsatile blood volume changes but is susceptible to noise, particularly under impaired hemodynamic conditions. At the same time, pulse wave morphology analysis has gained importance, as it provides richer cardiovascular information than frequency-based metrics. This approach relies on the detection of fiducial points (FP), which requires preserved waveform integrity. However, conventional iPPG processing often fails to maintain these features under noisy conditions, limiting its applicability for morphology-based analysis.

Methods

A spatial fusion approach is proposed that accounts for local signal quality variations within the region of interest (ROI). The image is divided into overlapping sub-ROIs, from which local iPPG signals are extracted and weighted using signal quality metrics (SNR, PI, and SQI). The weighted signals are fused into a global iPPG signal. Performance is evaluated using the detection rate (DR) of FP against synchronized reference PPG and compared to conventional spatial averaging across baseline and two cuff-induced perfusion states.

Results

Under baseline conditions, both methods show comparable performance, with high DR for Onset (ON) and Systolic Peak (SP). For morphology-sensitive features, spatial fusion yields consistent improvements. Under light impairment, DR increases by up to 6%p for Diastolic Peak (DP) and 4%p for Dicrotic Notch (DN). Under moderate impairment, improvements reach up to 8%p for both DN and DP ($p<0.01$). In contrast, ON and SP remain largely unaffected by the extraction method. The results indicate that spatial fusion enhances the preservation of subtle waveform features, particularly under degraded signal conditions.

Conclusion

The proposed spatial fusion method improves morphology preservation in iPPG by leveraging local signal quality information. It enables more reliable detection of FP under impaired perfusion, highlighting the importance of quality-aware preprocessing for morphology-based iPPG analysis

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In the Spotlight: Contactless Vital Sign Measurements for Improving Post-COVID Aftercare

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Introduction

After a COVID-19 infection, many people struggle with persistent symptoms known as post-COVID syndrome. These symptoms, ranging from respiratory issues to chronic fatigue, significantly impair quality of life even years later and require ongoing health monitoring and long-term medical care. The shortage of personnel in healthcare, particularly in specialized clinics, necessitates self-monitoring in a home environment.

Methods

The KoVit app is a digital health tool for post-COVID care, combining contactless heart rate (HR) measurement via smartphone PPG, respiratory rate (RR) measurement via motion analysis, and a structured symptom diary. A clinical pilot study assessed usability and technical accuracy over eight weeks in a home setting. Twelve post-COVID participants recorded vital signs and symptoms twice daily. Following the 8-week study period, app usability was assessed using two validated questionnaires: the GER-MAUQ covering the dimensions of usability, interaction quality, and perceived usefulness (7-point Likert scale, 1–7), and the System Usability Scale (SUS; 5-point Likert scale). Data were analysed descriptively and summarized using means (M).

Results

The KoVit app achieved 61.1% of the maximum GER-MAUQ score and a SUS score of 65.8%, both indicating moderate usability. It was rated as user-friendly (M = 5.33), useful (M = 4.83), and socially acceptable (M = 5.83). Self-efficacy remained high (M = 5.27), and 72% of users intended to continue using the app (M = 4.83). HR and RR measurement was reliable under standardized conditions. Navigation (M = 3.83), feature access (M = 3.75), and offline use (M = 3.67) scored below 4.0. Due to the small sample size (n = 12), no result reached statistical significance; however, the SUS score exceeded the critical threshold (p = .006).

Conclusion

The KoVit app shows clear potential as a digital health tool for post-COVID care. It enables continuous remote monitoring by combining contactless vital sign measurement with structured symptom tracking. Future development should address measurement accuracy, long-term reliability, personalization, and gamification. The app may establish new digital care standards, supporting not only post-COVID patients but also broader chronic disease management.

This project “KoVit” was funded by the Federal Ministry of Education, Technology and Space (BMFTR) (Funding ID: 16SV9173).

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Heterogeneity and Intercellular Coupling Prevent Sinus Arrest in Rabbit Sinoatrial Node Model

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Introduction

The sinoatrial node (SAN) is the primary pacemaker of the heart, initiating each regular heartbeat through the spontaneous activity of specialized pacemaker cells. Its automaticity is governed by a tightly regulated interplay between ionic membrane currents and intracellular calcium cycling and is highly sensitive to changes in the extracellular milieu. Electrolyte imbalances are common in patients with chronic kidney disease undergoing haemodialysis (HD), a population with a markedly increased incidence of sudden cardiac death (SCD), which is frequently preceded by sinus bradycardia and asystole. Previous single-cell *in silico* investigations demonstrated that hypocalcemia slows the beating rate; this effect can be offset by sympathetic stimulation, whereas abrupt withdrawal of sympathetic tone can abolish automaticity

Methods

To determine whether these mechanisms are preserved at the tissue level, we implemented a discrete intercellular coupling framework in openCARP. Therefore, a calibrated population of models generated from the extended Severi DiFrancesco model was embedded in a two-dimensional patch. Subsequently, hypocalcemia and graded autonomic modulation were simulated over a wide range of coupling resistances.

Results

Our results demonstrate that intercellular coupling and cellular heterogeneity can prevent sinus arrest at the tissue level, even under severe hypocalcemia and sympathetic withdrawal. Although sympathetic stimulation reduced the cycle length and increased the proportion of spontaneously depolarizing cells, it was not essential to maintain global tissue automaticity, in contrast to single-cell predictions.

Conclusion

These findings indicate that tissue-level interactions and cell-to-cell heterogeneity mitigate the deleterious effects of hypocalcemia predicted in isolated cells, suggesting that the mechanism underlying HD patients SCDs needs to be further investigated by considering the interaction between the SAN and the surrounding atria.

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Effect of Various Gases for Plasma-Induced Surface Modifications of sPES for *In Vitro* Cell Culture Applications

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Introduction

Sulfonated polyethersulfone (sPES) membranes exhibit poor microglial adhesion due to low surface energy (polar component: 20 mJ/m²), limiting their use in *in vitro* neurodegenerative disease models. This study aims to enhance HMC3 microglial adhesion on sPES by increasing surface energy via plasma treatment (Ar, NH_3, O_2, CO_2) without altering morphology while maintaining the membrane's inherent properties.

Methods

SPES membranes (3M™ MicroPES™ 1F PH) were plasma-treated (Ar, NH_3, O_2, CO_2) to enhance surface energy without altering morphology (except O_2-induced oxidation). Surface energy (OWRK model) and HMC3 microglial adhesion under shear stress (300 rpm) were quantified.

Results

Plasma treatment elevated total surface energy to 77–79 mJ/m² (vs. untreated 67 mJ/m²), with NH_3 and O_2 plasma increasing the polar component to 30 mJ/m² (vs. 20 mJ/m² untreated). CO_2 plasma (polar: 24 mJ/m²) and Ar plasma (no functional groups) showed minimal polar enhancement. This correlated with higher HMC3 adhesion on NH_3/O_2-treated membranes versus untreated controls. Under shear stress (300 rpm), untreated membranes lost cells, while plasma-treated surfaces maintained adhesion. SPES surface morphology remained unchanged except for O_2 plasma.

Conclusion

Polar surface energy (≥30 mJ/m²) is the dominant factor governing HMC3–sPES interactions, outweighing topographical effects. NH_3 and O_2 plasma (introducing –NH_2/–COOH groups) significantly enhanced polar energy, driving superior cell adhesion and shear stability. CO_2 plasma (polar: 24 mJ/m²) and Ar plasma demonstrated limited bioactivity in correlation to the other plasma treatments.

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A novel 3D-bioreactor system for in vitro endothelialization analysis of polymer-based vascular implant structures

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Introduction

Endothelialization is crucial for the hemocompatibility and long-term performance of vascular implants. To evaluate biomaterial–cell interactions under controlled, physiologically relevant conditions while reducing animal experiments, we developed a novel 3D bioreactor system for in vitro analysis of polymer-based implant endothelialization under static and dynamic conditions.

Methods

A PMMA-based 3D bioreactor with an integrated rotation mechanism was developed and connected to a dynamic flow system. Artificial vessels made of silicone-based and polycarbonate-based polyurethane were seeded with EA.hy926 endothelial cells (800,000 cells) and cultivated under physiological conditions (37 °C, 5% CO_2) at a flow rate of 3 ml/min for 24 h. Endothelialization was assessed using immunofluorescence staining and microscopy.

Results

The system operated reliably and enabled homogeneous cell distribution without air bubble formation. Endothelial cells adhered to both materials and formed a largely confluent monolayer with typical morphology. No significant differences in coverage were observed, although minor residues appeared on polycarbonate-based samples. The applied flow conditions supported stable adhesion without inducing cell alignment.

Conclusion

The developed 3D bioreactor system is a versatile platform for in vitro endothelialization analysis of polymer-based implants, enabling reproducible dynamic cultivation and homogeneous cell distribution. Both materials supported endothelial adhesion and monolayer formation. Future work should address long-term cultivation, physiological shear stress, and functional assessment. Overall, the platform offers a promising in vitro alternative for preclinical evaluation of vascular implants and supports the 3R principle.

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Steering Magnetic Nanoparticles with Moving Magnetic Fields – A Feasibility Study

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Introduction

Magnetic drug targeting (MDT) uses magnetic nanoparticles as carrier for cancer drugs. In classical MDT, these nanoparticles are injected in the vicinity of the tumor and accumulated at the tumor region by using external magnetic fields. In addition, in current research the magnetic steering of the nanoparticles through the cardiovascular system towards the tumor region is discussed. However, a major problem in particle steering is that numerous particles deposit themselves on the vessel wall below the steering magnet, which can lead to clogging of the vessel before the tumor area.

Methods

To overcome this problem, this paper introduces a novel steering approach using moving magnetic fields which propagate parallel to vessel and, thus, along the particle flow direction. The steering system is based on a hybrid linear Halbach array and was numerically compared to a corresponding static scenario using COMSOL Multiphysics.

Results

The results revealed that the dynamic steering approach with a 3-phase current system reduced the amount of trapped particles while maintaining the same steering performance in terms of particle distribution.

Conclusion

Thus, it can be concluded that the proposed dynamic steering approach shows high potential in enabling novel steering concepts in MDT.

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Influence of leaflet thickness on deformation behavior of a 3D-printed training heart valve for an implantation training bench

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Introduction

High-fidelity physical simulators are essential for transcatheter aortic valve implantation (TAVI) training. However, standard isotropic 3D-printing materials fail to replicate the anisotropic biomechanics of native valves, leading to unphysiological flow resistance and synthetic stenosis during direct 1:1 geometric replication. This study presents an automated computational solid mechanics (CSM) pipeline to optimize the macroscopic leaflet thickness, structurally compensating for material isotropy to restore physiological opening kinematics.

Methods

The valve geometry was parameterized via analytical tensor-product B-spline surfaces to ensure exact geometric offsets. The selected isotropic 3D-printing material (Formlabs Elastic 50A Resin) was experimentally characterized, yielding an effective Young's modulus of 2.0 MPa. A non-linear structural simulation was established in CalculiX using high-order shell elements. Boundary conditions were defined by transient transvalvular pressure gradients empirically acquired from an open-circuit mock circulatory loop. A systematic parametric grid search was executed to evaluate the effect of uniform thickness on the systolic Geometric Orifice Area (GOA) under a constant 3200 Pa load.

Results

Simulations demonstrated a highly non-linear, inverse relationship between leaflet thickness and GOA. At a uniform thickness of 2.0 mm, the valve exhibited severe resistance to opening, yielding a restricted GOA of only 74.3 mm^2. Reducing the thickness significantly improved the opening kinematics. The computational optimization identified 0.8 mm as the optimal viable thickness, maximizing the functional GOA to 124.9 mm^2 prior to the onset of structural buckling or element inversion.

Conclusion

Macroscopic geometric tuning effectively compensates for the stiffness discrepancies inherent to isotropic additive manufacturing materials. The developed experimental-computational framework demonstrates that optimizing leaflet thickness restores physiological kinematics and minimizes pressure impedance. This pipeline enables the robust fabrication of hemodynamically accurate synthetic heart valves for advanced surgical training simulators.

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Pneumatic endurance testing of blood pressure cuffs with automatic leak detection

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Introduction

Non-invasive blood pressure (NIBP) cuffs are essential medical devices whose pneumatic integrity directly affects measurement accuracy and patient safety. During everyday clinical use with repeated pumping and deflating multiple times a day, the possibility of additional air leakage due to product failure arises.

Methods

To examine this possibility, we created an endurance testing machine which uses off-the-shelf pneumatic parts in a custom setup to inflate and deflate the cuff to its maximum allowed pressure of 300 mmHg for its intended lifespan of 10000 cycles. To monitor degradation, the test includes a repeated air leakage test every 500 cycles. The leakage test is based on the international standard DIN EN ISO 81060-1, clause 7.2.1. During the test the pressure is held for five minutes to ensure accurate mesasurements. With this setup we tested four L-sized daisycuff blood pressure cuffs by daisygrip GmbH.

Results

All four cuffs completed the test without failure. The air leakage remained well within the 4 mmHg/min limit set by the standard. Visual inspection revealed no structural damage. Only minor surface wrinkles where visible upon inspection.

Conclusion

The developed test system provides a reliable platform for design validation and can be used for future endurance studies on other cuff types. The tested cuffs successfully completed the endurcance test.

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Towards Improved Emergency Care and Neuroprotection in Spinal Cord Injury: A Data-Driven and Bioengineering Approach

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Introduction

Spinal cord injury (SCI) is a life-altering condition in which a substantial portion of neurological damage occurs after the initial trauma, during early emergency response and initial hospital management. Secondary injury mechanisms including ischemia, inflammation, and metabolic dysfunction are highly time-sensitive and may be influenced by modifiable factors such as mean arterial pressure (MAP), timing of surgical intervention, and early treatment strategies. However, these factors remain incompletely understood, and current clinical practice lacks data-driven, field-adapted protocols for early SCI care.

Methods

This multidisciplinary study integrates clinical data analysis, computational modelling, and artificial intelligence to improve early SCI management. Retrospective data from 496 patients with traumatic spinal cord injury admitted to Landspítali between 2000 and 2023 were analysed. Mean arterial pressure (MAP) measurements were available for 436 patients and were used to investigate patterns in hemodynamic management. Additional linked hospital stay and operative datasets spanning 1996–2023 and 2008–2023, respectively, were used for selected analyses.AI-assisted extraction using GPT-4o was explored as a proof-of-concept approach for identifying predefined clinical variables from ten manually constructed Icelandic clinical note examples. In parallel, high-fidelity finite element modelling (ANSYS), using anatomically realistic human models from the IT'IS Virtual Population, was employed to investigate the physical feasibility of targeted spinal cord cooling.

Results

Retrospective analysis included 496 patients with traumatic spinal cord injury. MAP measurements were available for 436 patients and frequently fell below the recommended 85–90 mmHg target range. Variability was observed in surgical timing. GPT-4o successfully extracted predefined clinical variables from ten Icelandic free-text records in the proof-of-concept analysis. Computational modelling demonstrated that targeted spinal cooling may reduce spinal cord temperature toward the therapeutic hypothermia range (32–34°C) under selected cooling conditions, while remaining strongly dependent on anatomical and physiological constraints.

Conclusion

By integrating clinical data analysis, artificial intelligence, and computational modelling, this study addresses critical gaps in early SCI management. The findings provide a preliminary evidence base for future protocol development and support continued investigation of neuroprotective strategies in prehospital and early hospital care.

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2.5D Multimodal MRI Brain Tumor Segmentation: Beyond 2D Deep Learning Approaches

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Introduction

Accurate brain tumor segmentation in multi-sequence MRI is essential for diagnosis, treatment planning, and monitoring. While 2D deep learning models are computationally efficient but limited in capturing inter-slice context, and 3D models provide full volumetric information at high computational cost, 2.5D approaches offer a practical compromise. This study investigates a 2.5D input strategy within a U-Net architecture and compares it with a conventional 2D approach for glioblastoma segmentation.

Methods

A dataset of 119 glioblastoma patients with four MRI modalities (T1, T1ce, T2, FLAIR) was used. Two input configurations were evaluated: a 2D approach using single slices with four modality channels, and a 2.5D approach incorporating three consecutive slices per modality (12 channels). A U-Net model was trained under identical conditions for both approaches. Performance was assessed using Dice Similarity Coefficient (DSC) and Intersection over Union (IoU), along with qualitative analysis.

Results

The 2.5D approach outperformed the 2D model, achieving a higher Dice score on the test set (0.880 vs. 0.824), corresponding to an improvement of approximately 6.8%. It also demonstrated improved boundary delineation and better preservation of fine tumor structures. These improvements are achieved without increasing model complexity and are supported by a significant gain in Dice and a near-significant trend in IoU. Although the 2.5D model requires moderately higher inference memory and computational time, the overhead remains manageable.

Conclusion

Incorporating inter-slice contextual information via a 2.5D representation improves segmentation performance while maintaining manageable computational overhead. The approach provides a practical balance between 2D efficiency and 3D contextual modeling, with potential for clinical applications pending further validation.

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A telerobotic system for nursing care offering a realistic visual experince

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Introduction

The provision of nursing care is being met with increasing challenges, primarily due to demographic shifts. These developments highlighting the need for technological solutions that support caregivers. However, nursing is a highly complex field that extends beyond standardised procedures. Therefore, telerobotic approaches hold particular promise due to their capacity to integrate human judgement with robotic physical capabilities. In order to be considered for practical use in care settings, teleoperated systems must be intuitive to handle. The present study focuses on the development of a telerobotic system for supportive tasks, which is based on intuitive teleoperation and a realistic view of the scene.

Methods

In this approach, a stereoscopic display enhances the remote operator's sense of being physically present at the scene. To this end, the stereoscopic images are displayed on the operators VR headset. The VR headset's controller is used to move a robotic arm. A user study was conducted with eight participants, the objective of which was to evaluate the feasibility and user experience of the system. The paticipants were required to utilise the robot to transfer three objects across a bed.

Results

All participants successfully completed the experimental tasks, thereby demonstrating the approach's general feasibility. However, the efficacy of the task was found to be contingent upon the properties of the object in question. The usability of the system was evaluated as moderate. The reported levels of mental workload and cybersickness suggest the need for further optimisation.

Conclusion

These findings suggest that immersive teleoperation is a promising approach for supportive nursing tasks. However, improvements in system usability, operator comfort and assistance functions are necessary before its practical application.

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A Standardized Methodology for EMG-Based Fatigue Assessment during Electrical Muscle Stimulation

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Introduction

This study presents a methodological framework for standardized electromyographic (EMG) fatigue assessment during electrical muscle stimulation (EMS), with a focus on *M. biceps brachii*.

Methods

Based on existing literature, a protocol was developed and iteratively optimized through controlled trials. The approach addresses open research questions related to the complex interplay of physiological and technical factors in EMG-EMS measurements.

Results

Results demonstrate that individual motor threshold is the most appropriate parameter for normalizing EMS intensity in the context of pain-free fatigue measurements. Furthermore, arm positioning was identified as a critical factor for obtaining reliable M-wave recordings and artefact-free force signals.

Conclusion

The findings underscore the necessity of high methodological standardization to reduce variability and improve the comparability of EMG-based fatigue metrics. Key requirements include the definition of objective and inter-individually comparable stimulation intensities, as well as the application of protocols capable of inducing muscle fatigue without exceeding individual pain tolerance. The proposed framework provides practical guidance for reproducible data acquisition in EMS research and supports the development of objective, EMG-based monitoring approaches.

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Imaging System Combining Optical Coherence Tomography and Autofluorescence Imaging for Biomedical Applications

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Introduction

Early and reliable detection of pathological tissue changes is crucial for improving diagnostic accuracy and patient outcomes. This work focuses on the development of a multimodal imaging system designed to identify pathological alterations in biological tissue, by combining optical coherence tomography (OCT) and autofluorescence imaging (AFI). Potential applications of such a system include the identification of malignant tumors, where complementary structural and biochemical information may improve tissue characterization.

Methods

A multimodal imaging system based on OCT and AFI was developed and experimentally validated. The core element of the setup is a multimodal sample arm, in which the subsystems were optically combined using dichroic filters. The swept-source OCT employed a 1310 nm fourier domain mode locked laser to achieve high penetration depth and a balanced detector for noise reduction, while the fluorescence excitation was realized with a 375 nm laser diode and detection via a spectrometer.
Extensive software for data acquisition and control was developed, enabling automated parameter setting, galvo-scanner control, and synchronous collection of OCT data, fluorescence spectra, and bright-field images. The system was characterized comprehensively, including resolution, field of view, and sensitivity.

Results

Both, the OCT and the AFI subsystem achieved a near diffraction and bandwidth limited lateral resolution and axial resolution. The multimodal system offered a field of view of >5 mm². The OCT sensitivity was > 90 dB, consistent with the short integration time associated with the 1.68 MHz A-scan rate. Biological samples such as a rat brain and sheep brain tissue were successfully imaged multimodally.

Conclusion

Future work will focus on further system validation on fresh biological samples. Furthermore, in vivo studies are planned. Overall, the system represents a promising platform for combined depth-resolved and biochemical imaging, contributing to the advancement of non-invasive multimodal diagnostics.

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Integration of Regulatory Standards into Inkjet Biofabrication: The Inkjet-BioAM Project

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Introduction

The inkjet-BioAM project pioneers the integration of inkjet printing into the regulated value chain for medical and pharmaceutical product manufacturing, targeting the production of patient-specific biomaterial constructs. While advances in biofabrication and digital manufacturing have enabled unprecedented levels of customization, current regulatory standards and manufacturing paradigms are largely designed for standardized, high-volume products and therefore constitute a major barrier to the widespread clinical adoption of personalized medical and pharmaceutical solutions. This initiative addresses the urgent need for individualized regenerative therapies while systematically embedding inkjet biofabrication into a regulatory-compliant framework that meets the stringent requirements essential for clinical translation.

Methods

An inkjet biofabrication platform is developed to enable the precise deposition of compatible hydrogels and bioactive materials onto complex 3D scaffolds. Patient-specific geometries are generated from medical imaging data and translated into high-fidelity print instructions. The entire printing process, from printer design, ink formulation to construct fabrication, is to be established and validated under conditions that meet Good Manufacturing Practice (GMP) standards, ensuring traceability, reproducibility, and compliance with regulatory frameworks.

Results

The regulated inkjet-based manufacturing process enables the precise fabrication of scaffolds with highly complex, patient-specific architectures while maintaining exceptional structural fidelity. Critical process steps, from ink formulation and preparation to the printing procedure itself, are identified and prepared to be conducted within a strictly controlled environment to ensure reproducibility, product consistency, and compliance with quality requirements. Comprehensive mechanical and biological characterization was performed to verify that the resulting constructs meet the stringent criteria for clinical application. This includes demonstrating robust and reliable mechanical performance as well as high cell viability and functionality in vitro, confirming the suitability of the scaffolds for subsequent translational and clinical use.

Conclusion

Use Case 1 of the Inkje-BioAM project demonstrates that inkjet biofabrication can be successfully implemented within a regulated manufacturing environment. By establishing a GMP-compliant process, the project sets a new benchmark for the safe and effective production of personalized biomaterial constructs, paving the way for their clinical adoption in regenerative medicine.

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ALPS: An Automated Liquid Pipetting System for Spheroids Handling in Nanoliter Droplets

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Introduction

Cell spheroids are widely used as 3D culture models because they reproduce cell-cell interactions and tissue-like organization more faithfully than conventional 2D cultures. Hanging-drop culture is a simple and robust method for generating isolated spheroids, and droplet microarrays (DMAs) extend this principle to a miniaturized high-throughput format by confining cell suspensions in nanoliter droplets on patterned hydrophilic spots surrounded by a superhydrophobic background. When inverted, these droplets act as parallel hanging drops, enabling the formation of hundreds of individual spheroids while reducing reagent consumption. However, the downstream handling of spheroids on DMAs remains difficult, as manual collection and transfer from dense droplet arrays are labor-intensive, difficult to scale, and poorly standardized. To address this limitation, we developed ALPS, an Automated Liquid Pipetting robot for Spheroid Handling in Nanoliter Droplets. In this study, ALPS was evaluated using HEK293 spheroids generated in ~300 nL droplets on DMAs to examine automated spheroid transfer and post-transfer spheroid integrity.

Methods

ALPS is a benchtop robotic platform designed for the manipulation of nanoliter droplets on droplet microarrays. The system is based on a UFactory Lite 6 robotic arm combined with a wrist-mounted syringe pump for aspiration and dispensing of defined liquid volumes. HEK293 spheroids were generated on 672-spot DMAs by hanging-drop culture in droplets of approximately 300 nL. Transfer experiments were performed under different operating conditions by varying nozzle height, syringe pump steps, and needle gauge. Transfer performance was quantified as the percentage of spheroid-containing droplets successfully relocated to predefined target positions. In addition, post-transfer spheroid integrity was assessed by brightfield imaging immediately after transfer and during the following 48 h.

Results

Automated transfer of spheroid-containing nanoliter droplets (~300 nL) on dense droplet microarrays was demonstrated, with transfer rates ranging up to 81.5 ± 1.5% under optimized conditions. ALPS also enabled directed relocation of droplets in defined array regions, including representative 3 × 3 transfer groups. Brightfield imaging showed that transferred spheroids retained their morphology immediately after handling and continued to grow over the following 48 h. These results indicate that ALPS supports controlled spheroid handling in dense DMAs and is compatible with continued spheroid development after transfer.

Conclusion

This study demonstrates that ALPS enables automated transfer of spheroid-containing nanoliter droplets on dense droplet microarrays. The platform supports directed spheroid relocation while preserving spheroid morphology and allowing continued growth after transfer. By addressing a key bottleneck in downstream handling of DMA-cultured spheroids, ALPS expands the practical utility of droplet microarrays for miniaturized 3D cell culture workflows and provides a basis for future integration with downstream assay formats.

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KASPER, A Mechanical Energy Recuperating Knee-Ankle Prosthesis Designed to Support Sit-to-Stand Transitions in Elderly Transfemoral Amputees.

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Introduction

For elderly transfemoral amputees, standing up is often a difficult and physically demanding task. Most prosthetic legs available for this group are passive knee prostheses, which do not provide assistance during standing up. As a result, the sit-to-stand movement effectively becomes a single-leg task. Previous research has mainly focused on supporting the knee joint while keeping the ankle joint fixed. However, a fixed ankle makes it challenging for users to position their center of mass over the foot, which is essential for achieving a stable standing motion. The aim is to design and evaluate a knee-ankle prosthesis that supports the prosthesis user in a stable sit-to-stand transition.

Methods

We deloped a new prosthesis, called KASPER (Knee Ankle Stand-up Prosthesis with Energy Recuperation). This prosthesis features both a knee and an ankle joint actuated by a gas spring. During sitting down, energy is stored in the gas spring, which can subsequently be used to assist the user in standing up. Throughout both movements, the knee and ankle joints are able to move through the full range of motion required for sit-to-stand and stand-to-sit transitions.

A prototype of KASPER was built and evaluated on mechanical performance and in a pilot user test. In the pilot user test, the KASPER prototype was qualitatively evaluated by an experienced prosthesis user performing both stand-to-sit and sit-to-stand transitions.

Results

The mechanical performance tests demonstrated that the KASPER prototype is functional and capable of supporting the prosthesis user during a stable sit-to-stand transition. In the pilot user study, the participant successfully and safely executed both stand-to-sit and sit-to-stand movements with the assistance of KASPER.

Conclusion

The results indicate that KASPER has the potential to be a promising solution for supporting elderly transfemoral amputees during the sit-to-stand transition. The next step is to conduct an evaluation with the target group of elderly prosthesis users, in order to gather their feedback and assess their biomechanical performance.

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Automated Multimodal Driver Stress State Estimation Using Contrastive Learning-Based Missing Data Imputation

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Introduction

Stress is a major contributing factor to various lifestyle diseases as well as mental and emotional disorders. Stress can be detected using biosignals acquired from wearable sensors. Such sensors suffer from missing or corrupted data due to poor sensor contact and calibration issues.Existing approaches address this problem by discarding incomplete data or applying simple averaging and interpolation methods, which are error prone. In this study, we propose a contrastive learning-based framework to handle missing data in multimodal driver stress assessment.

Methods

For this, a dataset with N=30 was collected using a Hexoskin wearable sensor in a controlled driving scenario comprising Electrocardiogram, Abdominal Respiration, and Thoracic Respiration signals. The proposed model learns modality-invariant feature representations by aligning all three modalities to a shared latent space during pretraining. An imputation module with stacked autoencoders reconstruct missing modality features during prediction.

Results

Experimental results demonstrate that the framework was able to classify five levels of stress with one modality missing with an average accuracy of 81.4% and average F1-score of 81.2% across 5 fold cross validation. Moreover, ECG features were imputed most effectively with classification accuracy of 87.5% and an F1 score of 89%.

Conclusion

This study demonstrates a contrastive learning-based pipeline for multimodal driver stress estimation, addressing the challenge of missing data from wearable sensors. The five driving scenarios employed were designed to increase cognitive load from levels 1 to 5, which serves as a proxy for intensifying physiological stress. By aligning ECG and respiratory modalities into a shared latent space, the model maintains high classification performance even with missing signals, outperforming traditional imputation methods.

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From Lab to Life: A Magnetic Particle Imaging Journey

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Introduction

Magnetic Particle Imaging (MPI) is a radiation-free imaging modality enabling real-time and quantitative visualization of superparamagnetic nanoparticles. Despite promising preclinical results, clinical translation remains limited due to challenges in tracer characterization, system scalability, and safety. This abstract presents our MPI journey towards first clinical applications starting with the fundamental research in our physics labs.

Methods

We developed a multiscale framework covering the full range of MPI encompassing nanoparticle physics, system modeling, and hardware realization. **At the nanoscale**, a novel spectroscopic method, Critical Offset Magnetic Particle Spectroscopy (COMPASS), was introduced for highly sensitive tracer characterization. **At the system level**, a modular simulation framework acting as a digital twin enables optimization of scanner design, signal generation, and image reconstruction. **On the application level**, two approaches were followed to establish human-sized devices: the StrokeCap concept was developed as a portable, MPS-based system for prehospital cerebral perfusion assessment. In addition, a human-sized MPI scanner (iMPI) based on a traveling-wave field-free-line concept was designed.

Results

COMPASS demonstrated improved sensitivity to nanoparticle properties, enabling differentiation of subtle variations in relaxation behavior and tracer composition. The simulation framework enabled efficient system design and validation. The iMPI scanner achieved real-time imaging and was successfully evaluated using clinically approved tracers (Resotran®), with safety confirmed within physiological limits. Initial tests with the StrokeCap showed robust signal detection at clinically relevant penetration depths, enabling visualization of perfusion dynamics. This paves the way for early stroke diagnosis. Furthermore, first in-vivo human measurements with the iMPI scanner demonstrated feasibility for vascular imaging in a clinical environment.

Conclusion

This work demonstrates the transition of MPI from fundamental research to early clinical demonstration, highlighting its potential as a real-time, radiation-free imaging modality for future clinical use.

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Camera-Consistent RGB Generation for Medical Hyperspectral Reconstruction

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Introduction

Hyperspectral imaging (HSI) provides spatially and spectrally resolved information that is highly valuable for tissue characterization and multiple medical applications. However, conventional HSI systems remain expensive, complex, and slow. RGB-based hyperspectral reconstruction (HSR) is a promising alternative, but its practical use is limited by the ill-posed nature of the problem and weak generalizability of trained models for HSR. This contribution explores the generalizability of models for HSR and presents a modification in the training to improve generalizability.

Methods

To foster generalizability, camera-consistent RGB images were generated from hyperspectral reflectance data using an illuminant-dependent forward model based on spectral reflectance, illuminant spectral power distribution, and camera spectral sensitivities. In addition, sigmoid-based normalization was evaluated to reduce illumination-related intensity variations. MST++, a transformer model for HSR, and partial least squares regression (PLSR) were trained under different preprocessing settings. HyperSkin database was used for training and internal testing, while HSI-Perfusion database was used for external testing on independently acquired real RGB and HSI measurements.

Results

During internal testing, MST++ achieved the lowest mean relative absolute error (MRAE, while PLSR achieved the lowest spectral angle mapper (SAM). In external testing, our approach of using adapted RGB generation consistently improved generalization compared to the standard approach. On HSI-Perfusion, adapted RGB generation improved MST++ from an MRAE of 0.3591 to 0.3250 (9.5 %) and reduced SAM from 0.1841 to 0.1782 (3.2 %). For PLSR, adapted RGBs with sigmoid normalization reduced MRAE from 0.5855 to 0.3019 (48.4 %) and SAM from 0.3882 to 0.0781 (79.9 %).

Conclusion

Camera-consistent RGB generation improves HSR robustness on external data and helps improve the generalizability of trained models. The results further show that reconstruction performance and its assessment depends strongly on the chosen method and evaluation metric.

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Enhancing Patient Safety in Home Parenteral Nutrition

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Introduction

Parenteral nutrition is vital for some patients, but it carries risks such as catheter-related infection. When parenteral nutrition is administered at home (HPN: home parenteral nutrition), patients often remain dependent on professional care support. Digital assistive technologies may enhance safety during HPN care while also promoting patient autonomy. This study presents a mobile digital assistant application that provides step-by-step guidance for routine HPN administration and support in emergency situations.

Methods

The application was developed iteratively based on the expertise of care professionals, focus-group findings, and a structured risk analysis. Its usability and safety support potential were evaluated by twelve nursing professionals with HPN expertise. Participants completed a guided 12-step HPN workflow. Usability was assessed using a Cognitive Walkthrough (CW), based on Spencer's 3-point scale (0 = no problem, 1 = potential problem, 2 = clear problem), and the System Usability Scale (SUS). Qualitative remarks were thematically analysed.

Results

Across 576 CW ratings, 88.7 % received a score of 0, 7.7 % a score of 1, and only 3.6 % a score of 2, representing an improvement over the internal pilot (55 % and >15 %, respectively). Residual problems mainly concerned hygiene and visual confirmation of successful infusion (dis)connection. The mean SUS score was 80.4, indicating good to excellent usability. Thematic feedback highlighted the app's clear visual guidance and suggested optional voice control, extended multimedia instructions, and sensor-based air-bubble alarms. Expanded expert testing indicated that the app addressed most critical usability and safety support issues identified in earlier development stages.

Conclusion

The mobile digital assistant application showed promising usability and safety-support potential for guiding routine and emergency-related steps in HPN care. Next steps include integration with electronic health record systems and field evaluation with patients in real home settings to explore potential effects on HPN safety and autonomy.

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Sensitivity of OPM-MEG Source Analysis to Tissue Conductivity Uncertainties

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Introduction

A major advantage of (SQUID-)MEG over EEG is its relative insensitivity towards tissue conductivity uncertainties. However, previous studies have only evaluated this sensitivity for the radial part of the magnetic field, since this is the field direction predominantly measured with existing SQUID-MEG systems. With bi- or even triaxial OPM-MEG sensors, it is possible to also sample the tangential part of the magnetic field, which is known to be more affected by volume conduction effects. Therefore, we investigate the sensitivity of OPM-MEG forward solutions towards tissue conductivity uncertainties both for radial and tangential sensing directions.

Methods

Forward solutions of dipole sources regularly distributed in the gray matter compartment were simulated in a detailed five-compartment head model for a realistic OPM-MEG sensor configuration using the FEM multipole approach. Subsequently, a generalized polynomial chaos approach (gPC) was employed to rapidly calculate MEG leadfields for varying tissue conductivities. Based on these gPC expansions, the sensitivity of OPM-MEG forward solutions towards tissue conductivity uncertainties was investigated.

Results

We find that effects of tissue conductivity uncertainties on OPM-MEG forward solutions for tangential are similar to those for radial sensing directions. Accordingly, the conductivities most influencing the magnetic field and the affected source positions are also similar for tangential and radial sensors. In general, the sensitivity of MEG forward solutions towards tissue conductivity uncertainty remains smaller than for EEG, also for tangential sensing directions.

Conclusion

Even though the sensitivity of tangential OPM-MEG sensors towards tissue conductivity uncertainties is clearly weaker than for the EEG, it should not be neglected in practice. Not only the influence on the signal topography but also on the signal magnitude needs to be considered – and possibly compensated – when aiming for a joint analysis of radial and tangential sensors.

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Exploring RGBD Models for Force Estimation in Surgical Manipulation of Small Intestine

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Introduction

In gastrointestinal surgery, gentle tissue handling is a core principle and traction injury to the small intestine must be avoided in frequent manipulation for access improvement. Limited force feedback in conventional laparoscopy and robotic systems forces surgeons to deduce applied forces by vision with learned experience. We tackle this problem with stereo vision-based computer vision models for intraoperative assistance, introducing a silicone intestine phantom with mesentery and an RGBD video–force dataset for model training in future research.

Methods

To collect the dataset, our setup uses two robotic arms: one equipped with a force sensor and surgical grasper, and the other holding a stereo endoscope. A custom silicone intestine phantom is integrated into a laparoscopic environment. Stereo video, force, and robot states are recorded, producing 50 standardized retraction episodes over 10 camera views. Depth information is procured using FoundationStereo, while force signals are filtered via FFT. Three computer vision models - 3D-ResNet-18, (2+1)D ResNet, and Video Swin Transformer - are trained with regression outputs and pretrained weights from Kinetics-400. While monocular pipelines used the original version of the models, a depth channel has been added for RGBD cases. A five-fold cross-validation training regime is used with a 30/10/10 ratio.

Results

The Video Swin Transformer achieves marginally lowest test error, with RMSE loss in RGB mode very close to RGBD mode. The inclusion of the depth channel yields no observable benefits in accuracy while increasing inference time. That said, the effects of depth maps could be more evident in in-vivo environments where RGB images are noisy.

Conclusion

The proposed pipeline establishes a foundation for RGBD-based surgical force estimation. Future work will focus on expanding the dataset and transferring pretrained models to ex-vivo and clinical data to enhance generalization.

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Interactive VR-Based 3D Annotation of Aortic Valve Data from Stereo Endoscopy

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Introduction

Annotation of stereo endoscopic images is required to generate ground-truth data to train machine learning models, which is usually performed in 2D. However, 2D annotation can be time-consuming and error-prone for complex anatomical structures such as the aortic valve, particularly where biological boundaries are ambiguous. Calibrated stereo endoscopes capture two perspectives, but viewpoint-dependent differences prevent direct transfer of annotations between views. 3D reconstruction provides a consistent spatial reference enabling geometric consistency checks between independently annotated views, a task difficult to perform in 2D alone. This work presents a VR-based annotation system, featuring an intuitive graffiti-like spray interaction for segmentation and keypoint placement in 3D, designed for users without prior 3D scene understanding or modeling experience.

Methods

The system visualizes RGB data as a baked mesh from a stereo-reconstructed 3D point cloud. Annotation is performed via a transparent particle system overlaid onto the mesh using a spray-based metaphor. A cone-shaped search area constrains the active spray volume, reducing evaluated particles from millions to a local subset. Keypoints can be placed interactively alongside segmentation. Independently annotated left and right views can be projected as overlays onto the shared 3D mesh, making inter-view discrepancies directly visible and enabling plausibility assessment in 3D where 2D evaluation is insufficient.

Results

The cone-based spray restriction ensures stable real-time performance even for dense point clouds. Compared to conventional annotation tools (e.g.: LabelStudio), graffiti-like VR interaction enables direct and intuitive 3D surface annotation-with improved control, suggesting particular accessibility for users without 3D scene or modeling experience.

Conclusion

The system demonstrates feasible VR-based 3D annotation of aortic valve data while enabling direct consistency checks between stereo views. The efficient spray-cone approach is extensible to larger medical datasets, and the intuitive interaction design may reduce annotation time and barriers for users without prior 3D knowledge, though formal user and usability studies are needed.

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Towards Quality Control and Reliability in Tubular Melt-Electrowriting for Bio-Artificial Vascular Graft Scaffolds

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Introduction

In our end-to-end pipeline for autologous bio-artificial vascular grafts, we use melt-electrowriting (MEW) to produce porous tubular scaffolds made from biodegradable polymer, with 4−7 mm inner diameter and 10−200 µm fiber thickness. Scaffolds are produced on a modified commercial bioprinter (R-GEN 200) with a custom rotary mandrel collector. Tiny process variations in MEW require parameter re-tuning, but closed loop monitoring and control for tubular MEW was not yet demonstrated. Our work focusses on live monitoring, as well as post-printing dectection of defects using computer vision.

Methods

We integrated a CNC controlled microscope into the printer to acquire focus stacks of the printed scaffold. These stacks are processed using different depth-from-focus algorithms in order to compute a depth map representing the actual printed 3D structure. The reconstructed depth map is compared to a digital twin's rendered reference depth map.

Results

Our results indicate that estimating depth on a per-pixel basis yields very noisy depth maps, while approaches based on graph cut optimization (GCO) yield smoother depth maps which come close to the desired fidelity. However, even with GCO, thin features far above the background still present a challenge, and straight edges are sometimes not detected correctly. Specular reflections on the metal collector (mandrel) in the microscope images can confuse the depth reconstruction algorithm. Six layers of MEW-printed fibers of 135 µm thickness and 500 µm spacing are clearly discernible in the reconstructed depth map.

Conclusion

Using depth-from-focus algorithms to create a 3D reconstruction of the printed scaffold appears to be a viable strategy for 3D reconstruction and quality control of MEW scaffolds that we will pursue further in future work. The preliminary results show sufficient resolution to discern individual fibers, and potential for improvement, both on the algorithmic side, as well as the imaging system.

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Digital Twin for Non-Invasive Phrenic Nerve Stimulation in Respiratory Rehabilitation

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Introduction

Diaphragm inactivity during mechanical ventilation contributes to muscle atrophy and complicates weaning, posing a major challenge in respiratory rehabilitation. Electrical phrenic nerve stimulation represents a promising technique, yet the selection of effective non-invasive stimulation parameters remains empirical due to the difficulty of observing nerve activation. Digital twins provide a novel, predictive framework that enables the systematic evaluation of stimulation strategies.

Methods

An anatomically detailed multi-scale digital twin of the human neck was developed. By incorporating 13 tissue types, realistic neuroanatomy, and myelinated motor axons properties, the model enables for the calculation of the nerve activation threshold. Non-invasive phrenic nerve stimulation was simulated using surface electrodes positioned above the posterior border of the sternocleidomastoid muscle. Stimulation pulses were systematically varied, including monophasic and charge-balanced biphasic pulses, with modifications in pulse width, interphase delay, and pulse asymmetry. Sensitivity analysis of tissue conductivities, also including anisotropic properties, was performed to account for inter-individual variability and modeling uncertainty.

Results

Monophasic pulses yielded the lowest nerve activation thresholds, while clinically required charge-balanced biphasic pulses increased stimulation thresholds. Introducing interphase delays and asymmetric pulses effectively reduced these thresholds, approaching monophasic performance while preserving charge balance. Sensitivity analysis identified muscle, fat, nerve, and soft tissue conductivities as the dominant contributors to threshold variability. Anisotropic muscle conductivity was found to further increase the required stimulation intensity. The results of the simulated motor axons were consistent with the stimulation thresholds reported in the literature.

Conclusion

The proposed digital twin enables a systematic and reproducible evaluation of non-invasive phrenic nerve stimulation tailored to individual patient anatomy. It can be used to guide effective and safe phrenic nerve stimulation and highlights the necessity of incorporating patient-specific and anisotropic tissue properties. Furthermore, the digital twin establishes a foundation for integrating biosignal feedback into adaptive respiratory rehabilitation, thereby potentially improving patient outcomes.

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A Portable Multi-Stream Telemedicine System for First-Level Emergency Support in Crisis Environments

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Introduction

The ongoing armed conflict in Ukraine, which has continued since February 2022, has severely damaged the country's medical infrastructure. In liberated and still conflict-affected regions, functional healthcare facilities and qualified medical personnel are scarce. Consequently, first aid for injured civilians is frequently provided by laypersons who must act under extreme psychological stress, often with limited equipment and no professional guidance. Existing telemedicine solutions available on the market are either insufficiently portable for crisis deployment, require stable broadband infrastructure, or are not designed to operate in the heterogeneous and resource-constrained environments found in conflict zones.
The Ukrainian Remote Emergency Support Case project (URESC) developed a portable telemedicine system to support layperson first responders in crisis environments through real-time audio-visual consultation with remote medical specialists.

Methods

Following a structured requirements analysis involving 66 experts from Ukrainian emergency and clinical settings, the originally planned "suitcase" container was revised to a more mobile "backpack"-based design. The system integrates three simultaneous wireless video streams (scene view, responder communication, chest-mount perspective) based on the WebRTC standard, a ruggedized tablet, CE-certified vital sensors, and a 5G mobile router. A specially developed web-based client-server architecture enables first responders to initiate a video consultation with minimal interactions.

Results

Validation was conducted under realistic simulated scenarios with medical experts participating remotely. WebRTC-native streams performed reliably under variable network conditions; GoPro (RTMP-based) streams exhibited higher latency, identifying a clear path for further optimisation. The system demonstrates a viable, cost-effective approach with ruggedized components to structured telemedicine support in resource-constrained environments.

Conclusion

The URESC project established the technical foundation for a portable multi-stream telemedicine system that enables remote emergency support in crisis environments. Initial validation under realistic simulated conditions demonstrated the feasibility of the multi-perspective approach and provides a basis for further field-oriented development and evaluation

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Decentralized Digital Trials with AI Support: Methodology for DiGA and DTx Regulatory Evidence

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Introduction

DiGA and Digital Therapeutics (DTx) require robust, regulatory-grade evidence under real-world conditions. Decentralized clinical trials (DCTs) address limitations of site-centric designs by enabling remote participation, continuous monitoring, and scalable execution. Artificial intelligence (AI) enhances these capabilities through automated study setup, role-specific decision support, and predictive analytics. This contribution presents a methodology for AI-supported DCTs targeting regulatory evidence generation for DiGA and DTx.

Methods

The Fraunhofer IIS Digital Trial Manager (DTM) is a GCP-compliant platform for decentralized trial execution, validated in real-world study settings. Its architecture is based on a HAPI-FHIR backend implementing the FHIR standard, providing a unified data model for integrating heterogeneous data sources across sites and patient environments. The methodological approach centers on standardized orchestration of recruitment, eConsent, and longitudinal data capture from mobile applications and connected devices, ensuring traceability, auditability, and data consistency.

An AI-based extension layer introduces role-specific agent functions: patient guidance on study procedures and data protection, contextual decision support for study staff, and analytical assistance for statisticians, including evaluation and reporting support. Semi-automated study setup translates structured protocol inputs into executable system configurations, improving reproducibility and reducing manual variability.

Interoperability is ensured via integration with the German electronic patient record (ePA). Federated data exchange was demonstrated in the Gaia-X project TEAM-X using standardized connectors aligned with the European Health Data Space (EHDS).

Results

Operational deployments confirm feasibility of multimodal, FHIR-based decentralized study execution. Federated data exchange was validated in TEAM-X. The AI layer is in early prototype phase, with initial results indicating reduced protocol-to-configuration lead time.

Conclusion

AI-supported DCTs provide a robust path to regulatory-grade evidence for DiGA and DTx. Combining FHIR interoperability, agent-based decision support, predictive analytics, and alignment with ePA, EHDS, and Gaia-X enables scalable, regulatory-ready research infrastructures. Ongoing work focuses on validation under GCP constraints and standardization of digital endpoints.

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Ambient-Air Plasma Prototype: Proof-of-Concept *E. coli* Inactivation and PAW Characterisation

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Introduction

Cold atmospheric pressure plasma (CAP) is increasingly investigated for decontamination and wound-related applications because reactive oxygen and nitrogen species can be generated locally at low gas temperatures. Many clinically used systems remain bulky and depend on external gas supply and mains power, limiting use in mobile or resource-limited settings. Ambient-air plasma sources may overcome these barriers by enabling compact, autonomous device concepts. In addition, plasma-activated water (PAW) offers an indirect application route and a practical process fingerprint for device comparison.

Methods

A compact, battery-powered ambient-air plasma prototype ("Wolke") was developed with microcontroller-controlled high-voltage generation and guided airflow in a handheld housing. Optical emission spectroscopy (200–440 nm) was performed using an Ocean Optics HR4000. Proof-of-concept surface inactivation was tested on *Escherichia coli* DSM 613 using an agar diffusion setup (5 mm distance; 4 and 5 min exposure); growth-inhibited areas were assessed visually and measured with a fine ruler, while infrared thermography monitored non-thermal conditions. PAW was generated in 10 mL deionised water, tap water, and 0.9% NaCl in a glass Petri dish placed on a grounded conductive plate. Treatments were pulsed (0.5 s on/0.5 s off) for 1–8 min. pH, electrical conductivity (EC), and oxidation–reduction potential (ORP) were measured at t0, t1, and t10, and evaluated as Δx relative to baseline (n=3). PAW results were compared against an argon plasma jet prototype and kINPen® MED.

Results

Spectroscopy showed a pronounced emission feature at 337 nm, consistent with nitrogen-related air-plasma emission. The air-plasma treatment produced zones of reduced E. coli growth density rather than sharply defined inhibition halos. A reproducible "dead zone" of 8–11 mm directly beneath the device showed no detectable antibacterial effect. The mean diameter of growth-inhibited zones increased from 24.0 ± 7.8 mm (4 min) to 32.3 ± 6.7 mm (5 min). PAW fingerprinting indicated stronger parameter shifts for the air-plasma source than for the argon jet and kINPen® MED at 8 min (t1), with the largest EC increase in 0.9% NaCl ($\Delta EC = +696.7 \pm 45.1\ \mu S \cdot cm^{-1}$).

Conclusion

A portable ambient-air plasma prototype was successfully realised and demonstrated proof-of-concept antibacterial surface effects together with strong PAW activation. PAW fingerprinting, especially EC, provides a sensitive process marker for benchmarking and optimisation. Future work will focus on identifying key PAW chemical markers and validating PAW-driven antibacterial efficacy using quantitative *E. coli* assays.

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Development and Production of a Handy Cold Plasma Device for the Treatment of Skin Indications

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Introduction

Cold atmospheric plasma (CAP) is a promising technology for treating chronic and infected wounds due to its antimicrobial, anti-inflammatory, and tissue-regenerating potential. However, many existing CAP systems are bulky and depend on mains power and compressed gas, which limits their use in emergency medicine, military scenarios, and resource-limited environments. Therefore, the aim of this work was to develop a compact, battery-powered cold plasma device that operates independently of external power and gas supply by ionising ambient air, with a particular focus on applications in burn medicine.

Methods

A handheld device was developed using an ESP32-S3 microcontroller to control plasma ignition via a high-voltage transformer using PWM. A time-of-flight distance sensor enabled distance-controlled operation. The system was powered by three lithium-polymer cells and included an air compressor with a guided air-duct design in a PLA housing; the electrode configuration (copper, ceramic-insulated) represents a hybrid between DBD and plasma-jet concepts. Plasma emission was analysed using an Ocean Optics HR4000 spectrometer (200–440 nm). Proof-of-concept antimicrobial testing was performed on *Escherichia coli* DSM 613 at a constant distance of 16 mm and exposure times of 1–5 min; the inactivation zone was assessed visually and measured with a fine ruler.

Results

The transformer was operated at 62% duty cycle and 17.8 kHz (8.1 Vpp input). Spectroscopy showed a distinct peak at 337 nm, assigned to nitrogen-related emission and typical for air plasma. In-vitro tests showed clearly reduced E. coli development after 2 min and a pronounced defect region after 5 min (24 h incubation at 37 °C). The application temperature remained below 20 °C, excluding thermal inactivation; excessive airflow could displace bacteria and confound evaluation.

Conclusion

A functional, portable, battery-powered cold plasma device based on ambient air was successfully developed and demonstrated proof-of-concept antimicrobial activity together with air-plasma-typical spectroscopic signatures. The results indicate potential for mobile medical applications and motivate further optimisation of airflow, nozzle geometry, and plasma parameters, as well as expanded testing against broader microbial spectra.

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Development of an argon cold plasma treatment center and measurement of patient leakage current

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Introduction

Cold atmospheric plasma (CAP) is gaining increasing importance in medical research, especially in the treatment of chronic wounds. A crucial aspect in the development of plasma sources is the optimization of gas consumption, as existing systems have a high throughput of 5–11.8 L/min. This work presents an optimized CAP system that reduces gas consumption to 1 L/min. In addition, the measurement of the patient leakage current according to DIN SPEC 60601-1 is required for medical use to ensure patient safety.

Methods

This CAP system is based on an H-bridge in combination with a high-voltage transformer and a plasma jet electrode configuration made of tungsten, which is integrated into a nozzle. A printed circuit board (PCB) was developed for control and operation. In addition, a housing was designed that combines all components in a compact and ergonomic treatment station.
A test set-up in accordance with DIN 60601-1 was developed for measuring the patient leakage current. The measurement set-up consisted of two resistors (R1 = 10 kΩ, R2 = 1 kΩ) and a capacitor (C1 = 15 nF), which were connected in a circuit. The measurement was carried out using an oscilloscope (Agilent DSO-X 2002A). A MATLAB script was developed to process the data obtained from the oscilloscope measurements. In addition, a secondary discharge was observed at the plasma plume when a grounded object or biological tissue (e.g. a finger) was held near the cold plasma.

Results

The optimized CAP system reduced gas consumption from the previous standard of 5–11.8 L/min to just 1 L/min, which represents a significant improvement in efficiency. Measurement of the patient leakage current yielded a value of approximately 12 µA, which complies with the safety standards for medical applications.
The plasma plume is 3–5 mm long. Observation of the secondary discharge showed that the plasma plume was accelerated in the direction of a conductive object, resulting in increased ionization and a locally increased plasma intensity. This effect, which is favored by capacitive coupling and electrostatic interactions, offers a further perspective on the interaction between plasma and biological tissues.

Conclusion

The presented CAP system represents a significant improvement over existing plasma treatment methods. The greatly reduced gas consumption of 1 L/min contributes to the conservation of resources, while the measurement of the patient leakage current confirms the safety of the system for clinical use. The observation of the secondary discharge provides additional insights into the electrophysiological interactions of plasma with biological tissue. Future work will focus on a more extensive diagnosis of the plasma for the inactivation of in-vitro bacteria.

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Low-flow argon cold atmospheric plasma jet for surface decontamination: *E. coli* inactivation and PAW fingerprinting

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Introduction

Chemical disinfectants are effective, but may leave persistent residues and contribute to environmental contamination. In parallel, increasing antimicrobial resistance motivates alternative decontamination approaches. Cold atmospheric pressure plasma (CAP) is a promising physical option because reactive species are generated locally without requiring persistent chemical biocides.

Methods

A portable low-flow argon plasma jet prototype (12 kV AC, 60–130 kHz, argon 1 L/min) was evaluated for direct antibacterial surface activity and for plasma-activated water (PAW) fingerprinting. Surface inactivation was tested using an agar diffusion assay with *Escherichia coli* DSM 613 at 5 mm distance and 1–5 min exposure (n = 6). kINPen® MED served as reference under identical geometry at 5 L/min argon. PAW was generated in deionised water, tap water and 0.9% sodium chloride (10 mL; n = 3) and characterised by pH, electrical conductivity and redox potential at defined time points (t0, t1, t10) as a chemical process fingerprint.

Results

Direct plasma exposure produced a significant time-dependent inactivation of E. coli, with inhibition zone diameters increasing from 6.3 ± 1.2 mm (1 min) to 12.5 ± 1.0 mm (5 min). Under identical geometry, kINPen® MED yielded larger inhibition zones (10.0 ± 0.9 mm to 22.3 ± 2.5 mm) but operated at an approximately fivefold higher process gas flow. PAW fingerprinting revealed device- and matrix-dependent changes in pH, conductivity and redox potential; the prototype induced stronger changes in these sum parameters for selected matrices.

Conclusion

The low-flow argon plasma jet demonstrates reproducible surface inactivation of *E. coli* with substantially reduced gas consumption compared to the reference device. PAW characterisation provides a practical fingerprint for device comparison and process optimisation, while liquid-phase antimicrobial efficacy requires dedicated bioassays in future work.

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Active Shielding of Glass Capillaries for the Compensation of Parasitic Effects in Transepithelial Electrical Resistance Measurements of Organoids

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Introduction

The reliable determination of epithelial barrier integrity is essential for in vitro models in applications such as drug development and physiological research. While transepithelial electrical resistance measurements (TEER) are established for two-dimensional systems, their application in three-dimensional models such as organoids remains challenging. Glass capillaries provide a well-defined electrode configuration but introduce parasitic capacitive coupling between electrodes. This causes frequency-dependent distortions of the impedance and limits accurate TEER determination. To reduce these effects, an active shielding concept is developed.

Methods

Initial TEER measurements were performed using glass capillaries as electrodes, revealing pronounced parasitic effects in the impedance spectra. The influence of parasitic capacitances was analyzed using equivalent circuit simulations, which provided the basis for the design of the active shielding circuitry. Frequency-dependent impedance simulations were conducted for both conventional unshielded and actively shielded capillary configurations. Based on these analyses, the capillary design was modified by introducing a conductive outer layer that is electrically insulated from the surrounding medium and coupled to the inner electrode via an operational amplifier configured as a voltage follower, thereby forming an active shielding concept. The approach was subsequently evaluated using frequency-dependent impedance simulations.

Results

The simulation results show that active shielding suppresses parasitic capacitive effects. The characteristic parasitic behavior observed in unshielded glass capillaries can be reduced by the active shielding concept, resulting in a more stable and largely frequency-independent impedance response. Consequently, TEER values can be determined with increased robustness and reproducibility.

Conclusion

In summary, the proposed active shielding technique enhances the reliability of TEER measurements without modifying standard cell culture procedures. The method can be integrated into existing measurement systems and enables improved accuracy in impedance-based barrier assessments.

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Frequency Tuning and Sensitivity Enhancement of Surface Acoustic Wave Sensors for Magnetic Field Detection

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Introduction

Magnetoelastic surface acoustic wave (SAW) sensors combine piezoelectric and magnetostrictive materials to detect magnetic fields and magnetic nanoparticles (MNPs) with high sensitivity and wide bandwidth. The ΔE-effect in magnetostrictive thin films alters the elastic modulus under external magnetic fields, shifting the SAW velocity and producing a measurable phase change. This study investigates how the center frequency influences sensitivity, phase noise, and limit of detection (LOD) in SAW sensors based on 128° YX-cut $LiNbO_3$ with amorphous SiO_2 guiding layers and exchange bias-coupled FeCoSiB multilayers.

Methods

Two design strategies are compared: an invariant design, where delay line length, acoustic aperture, and sensitive element size remain fixed, and a frequency-scaled design, where all dimensions are proportionally scaled with center frequency. The sensors are fabricated for five center frequencies from 100 MHz to 750 MHz using gold interdigital transducers (IDTs). Decomposing the sensitivity into geometric, structural, and magnetic contributions allows identification of the origin of frequency-dependent trends.

Results

The invariant design showed a threefold increase in sensitivity with rising center frequency, yielding a LOD of 55 $pT/Hz^{1/2}$ at 10 Hz and 9 $pT/Hz^{1/2}$ at 100 Hz. Phase noise remained nearly constant, so the improvement is driven primarily by increased geometric sensitivity. The frequency-scaled design produced balanced sensitivity and phase noise, resulting in a rather constant LOD across the investigated frequency range. A residual frequency-dependent behavior, not explained by geometric or magnetic contributions alone, could be attributed to a frequency dependence of the ΔE-effect.

Conclusion

Center frequency is a critical design parameter for optimizing SAW-based magnetic field sensors. Higher center frequencies significantly reduce the LOD in invariant designs and can therefore improve the detection of weak magnetic signatures from MNP labels. Future work should determine the optimal guiding layer thickness for each frequency and explore operation near the ferromagnetic resonance to further enhance sensitivity.

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Clamp-based mechanism for in vivo wired electromagnetic sensor fixation enabling multi-day measurements

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Introduction

Accurate position and orientation measurements are essential for studying viscoelastic effects of dynamic implants such as in the spine during in vivo experiments. Wired electromagnetic sensors provide accurate, continuous real-time tracking and are sufficiently small compared to wireless sensors. However, their disadvantages are infection risks due to transdermal wiring and high costs. Thereto, we developed a fixation mechanism that ensures stable sensor positioning to a spinal implant for multi-day measurements while allowing controllable extraction afterwards.

Methods

The mechanism incorporates a leaf spring for sensor fixation and a snap-fit interface for implant attachment. Mechanical calculations were performed to determine the leaf spring dimensions using the clamping force required to prevent sensor damage. Following this, a prototype was manufactured from Nylon PA12 using Selective Laser Sintering (SLS). Experimental tests were performed to reinforce the sensor wire with different layers of shrink tubes and to tune the clamping force under varying extraction angles.

Results

Sensor wires were reinforced with double heat-shrink tubing to increase the yield force from approximately 9 N tot 25 N, thereby preventing sensor failure during removal. Pull-out forces between 16-29 N were measured at different extraction angles for sensor wires with double heat-shrink tubing. In vivo experiments demonstrated successfull use of the sensor fixation, where the sensors were safely removed and remained intact after a 11-days measurement period.

Conclusion

The proposed clamp-based fixation mechanism provides sufficient stable attachment of wired sensors to pedicle screws, while allowing controlled extraction after measurements. This approach enables real-time in vivo tracking for multi-day repeated measurements and subsequent removal of the sensors without breaking.

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User Intention Estimation for an Elbow Exoskeleton using Surface Myoelectric Pattern Recognition

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Introduction

This paper presents a neural network (CNN) for detecting the movement intention in an elbow exoskeleton. The exoskeleton is designed to provide stroke patients with a cost-effective, wearable, and easy-to-use therapy for hemiplegia of the arm. It can be used both during physiotherapy sessions in the clinic and at home. This flexibility allows more frequent training sessions and can thus improve therapy success and relieve physiotherapy centers.

Methods

The system uses electromyography signals of biceps and triceps (acquired by a dedicated portable EMG system), an elbow absolut angle encoder (AMT 222A-V, CUI Devices, Lake Oswego, OR, US) and an IMU (MPU6050 chipset, Joy-IT, SIMAC Electronics GmbH, Neukirchen, DE) all integrated in a specially-made active elbow orthosis. Data from 23 healthy participants performing six elbow movements resulted in twelve classes (flexion/extension). A CNN processes modality-specific inputs of the sensing modalities through convolutional and dense layers to extract local and global features, followed by a softmax output. Data was split 80/10/10.

Results

After 62 epochs, a validation data accuracy of 56.94 % is achieved. As shown by the confusion matrix, the network distinguishes movements with an top2-accuracy between 89 and 97 % but struggles with estimating the intended angle of movement (45° vs. 90° flexion / extension).

Conclusion

The network distinguishes movements well but struggles with precise target angle estimation. Improvements may require more data or architectural changes, with future work focusing on real-world testing and system integration. Future work will comprise system architecture optimisation, the implementation of hierarchical or multi-task classification strategies, and the inclusion of stroke patients in the training of the CNN.

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Development of PDMS-based Cranial Windows for Optical Recording of Neural Activity

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Introduction

Fluorescence microscopy is used to map brain signals to single neurons, providing unprecedented insights into functional brain dynamics. However, a stable, long-term optical access to the brain must be established for this type of high-resolution optical imaging. A common way to achieve that is by using the cranial window, where parts of the skull are made optically transparent. In this work, the goal was to structure silicone in a way that its bulk and surface grant optical properties comparable to a glass window. This was addressed by fabricating a PDMS-based cranial window with a solid ceramic frame for fixation and handling. Various ways of molding, dispensing, and casting silicone were tested to achieve the desired optical results.

Methods

Seven main processes were tested to fill the rings with PDMS to produce a smooth surface on both sides, and a homogeneous bulk, ensuring suitable optical properties for fluorescence microscopy. Each filling process is characterized by its filling material, the filling method, and the underlying substrate during filling. The filling material is divided into diluted and undiluted PDMS, the filling methods are dispensing as a dot or a spiraling path, vacuum centrifugation and doctor blading, while the underlying substrates are a PTFE mold or Parylene C-covered glass.

Results

Dispensing diluted PDMS into ceramic rings resulted in trapped air bubbles. Uncleaned ceramic rings combined with filling from the center caused bubble accumulations at the outer edges, while cleaned ceramic rings with a spiral dispensing path resulted in a homogeneous bubble distribution in the silicone. Vacuum centrifugation of cranial windows filled with diluted PDMS produced uneven surfaces with trapped bubbles. Utilizing pure PDMS without dispensing facilitates bubble-free filling of cranial windows. Smoothening the top surface was achieved through doctor blading, while utilizing Parylene C-coated glass as substrate produced a smooth bottom surface, granting high transparency.

Conclusion

A PDMS-filling process for cranial windows was developed that provides sufficient optical properties, as shown through transmission measurements of the finalized samples.

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Optical Property–Based Differentiation of Prostate Tissue Using Hyperspectral Imaging for Laser Enucleation Applications

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Introduction

Precise intraoperative discrimination between hyperplastic adenoma (BPH) and the surrounding surgical capsule remains a significant challenge in endoscopic enucleation procedures, such as Holmium Laser Enucleation of the Prostate (HoLEP). Inaccurate tissue identification may result in capsule perforation, residual adenoma, or excessive tissue removal. Hyperspectral imaging (HSI), in conjunction with quantitative optical property analysis, offers a label-free, non-destructive approach for real-time tissue characterization. While previous studies have documented prostate optical properties at discrete wavelengths, this work introduces a continuous 500–1000 nm spectral window to evaluate the potential of *ex vivo* HSI combined with optical property extraction for discriminating BPH from non-hyperplastic prostate tissue acting as a proxy for the surgical capsule.

Methods

Fresh ex vivo prostate specimens were obtained from 15 radical prostatectomy cases, encompassing regions of histologically confirmed BPH (transition zone) and adjacent benign, non-hyperplastic peripheral zone tissue. Diffuse reflectance spectra were acquired across the visible–to-near-infrared range (500–1000 nm) using a hyperspectral imaging system. Optical properties, including absorption (μ_a) and reduced scattering (μ_s') coefficients, were computed via the adding-doubling method. Principal component analysis (PCA) was employed for spectral analysis and feature extraction.

Results

BPH and benign peripheral zone tissue exhibited statistically significant spectral differences. Unsupervised PCA demonstrated effective class separation, driven by distinct physiological bands: macroscopic scattering and tissue morphology in PC1 (670–720 nm; t-test $p < 0.001$) and tissue water content in PC2 (930–980 nm; t-test $p = 0.0005$). Multivariate analysis confirmed that the two tissue groups form distinct, statistically significant clusters within the PCA coordinates (PERMANOVA $p = 0.001$).

Conclusion

The integration of *ex vivo* HSI with quantitative optical property extraction can differentiate BPH nodules from peripheral zone tissue. While these findings suggest a potential role for the technology in providing intraoperative guidance during endoscopic enucleation, further validation in *in vivo* studies is required to confirm its clinical utility.

This work has been supported by the ACMIT COMET Module SD-OpT, funded within the scope of the Austrian COMET program.

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Fast Continuous Tissue Oxygenation Visualization for Colorectal Surgery using Hyperspectral Light-Field Imaging

First name and surname of the first author, affiliation (Department, University), City, Country, e-Mail
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(10 pt type size and 12 pt line spacing)

Introduction

Reliable bowel perfusion assessment remains challenging because intraoperative judgment is still largely subjective, while many hyperspectral imaging (HSI) workflows are intermittent and difficult to integrate into routine surgery. For colorectal perfusion assessment, clinically useful HSI therefore requires both sensitivity to tissue oxygenation changes and workflow-compatible, low-latency operation. This work investigates hyperspectral light-field imaging (HSLFI) for fast continuous tissue oxygenation (SO_2) visualization during the extracorporal phase of colorectal surgery.

Methods

The proposed approach combines continuous intraoperative HSLFI acquisition outside the sterile field with reflectance reconstruction and a computationally efficient spectral correlation method for pixel-wise SO_2 estimation. The resulting oxygenation values are displayed as color-coded overlays similary to ICG visualization. Two HSLFI cameras (Cubert Ultris S5 and Cubert Ultris X20) were evaluated in parallel to assess the influence of camera-specific characteristics on visualization performance. Feasibility was assessed in two pilot colorectal cases by relating oxygenation transition zones to surgeon-defined transection regions and to routine intraoperative indocyanine green (ICG) assessment.

Results

In both pilot cases, the system enabled continuous visualization of bowel oxygenation throughout the relevant extracorporal preparation phase. The observed oxygenation transition zones corresponded well with surgeon-defined transection regions and supported temporal visualization of progressive devascularization. Profile-line analysis showed clear separation between well-perfused and ischemic tissue regions. Total processing times were 161.5 ms for the S5 and 397.2 ms for the X20, enabling continuous intraoperative image guidance despite different spectral and spatial sampling characteristics.

Conclusion

Fast continuous tissue oxygenation visualization using HSLFI is feasible in colorectal surgery. The method provided workflow-compatible perfusion visualization, showed good agreement with clinically relevant transection regions, and achieved processing speeds suitable for intraoperative guidance. HSLFI therefore represents a promising approach for objective perfusion support in colorectal surgery.

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Fifteen years of experiences from a living-lab in healthcare

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Introduction

The European Network "Living-Labs" characterizes such environments as "… user-centred open innovation ecosystems" integrating research and innovation through co-creation processes within real-world environments. Since first documented, "living-labs" have been emerging as highly promising, user-centred, innovation systems that foster research and knowledge exchange in real-life settings. Since then, "living-labs" have been established as research approaches to include the participation of end-users in the development, implementation and evaluation process of an innovation. For 15 years, we operated such a "living-lab" within the Universitätsklikum-Erlangen and used this environment to conduct many different types of studies and experiments.

Methods

Together with clinic and nursing experts, a plethora of interdisciplinary experiments and studies have been carried out. Hereby technical developments along the complete range of the technology readiness level (TRL) have been investigated, ranging from TRL-3 (experimental proof of concept) to TRL-8 (system complete and qualified). Technically, the experiments ranged from proof of concept studies (AI-based polyp-detection in bio-phantoms, haptic-visual hard tissue-milling), via gait analysis studies for Parkinson disease, to various exposure and arousal studies (using driving simulation or computer games) and clinicial trials (e.g. ECG-enhanced toilet seat).

Results

More than 1000 subjects, participants, patients, or healthcare experts have been involved in these studies, by interacting and using, or evaluating different types of technologies; and enhancing them — in a co-creation-approach —– by their professional background, experience and expertise. Based on critical viewpoints, all investigated ideas, concepts and technologies could be improved, enhanced or validated.

Conclusion

The following components are necessary to successfully operate a "living-lab": (1) For each experiment, the environment should offer realistic settings and reliable infrastructure (changing-rooms, Wi-Fi, data-storage, documentation). (2) Access to an interdisciplinary team of engineers, computer scientist, psychologist, physicians, and patients provides necessary expertise. (3) Ethical approval, study protocols, regulatory requirements, safety-standards, data-protection regulations are necessary to conduct these studies.

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Fusion of CNN and Level Sets for Skin Segmentation in Imaging Photoplethysmography

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Introduction

Imaging photoplethysmography (rPPG) is the technique of assessing superficial cutaneous perfusion in order to derive vital parameters. RPPG relies on camera recordings, which capture slight differences in light absorption due to varying blood perfusion in skin tissue. Because of the low signal to noise ratio of rPPG recordings, careful selection of video and signal processing methods is needed to enhance the signal quality. This work targets facial region of interest (ROI) identification and assesses the effect on heart rate (HR) estimation.

Methods

To minimize distortions induced by movement or changing light conditions, the method aims at defining a suitable ROI within each video frame. Thereto it combines neural networks with the generalization strength of a classical segmentation method. Fore- and background labelling of a pre-trained CNN for each pixel is fed into a level set based segmentation algorithm. The approach incorporates the CNN's confidence scores and combines them with neighbourhood and contrast information to achieve a stable segmentation mask. Using the masks, an rPPG is extracted by spatial averaging the green channel and HR is estimated in the frequency domain.

Results

In a demanding dataset, featuring 44 subjects, it was possible to estimate the HR from rPPG with an accuracy of 71.2% (using a 5bpm range of acceptance) and MAE of 6.1bpm. Comparable baseline methods, i.e. using a face detector and colour-based skin detection, achieve an accuracy of 65.8% and MAE of 7.1bpm on the same data.

Conclusion

The presented method introduces a segmentation concept, which is capable of improving HR estimation for rPPG. Further improvements are expected when combining the segmentation method with colour channel processing, e.g. CHROM, which will be evaluated in the future.
The method also features the potential to be transferred to other segmentation tasks by exchanging the weights of the pretrained CNN model.

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Evidential Segmentation of Iliac Stenoses: A Case Study on Modeling Expert Variability

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Introduction

The delineation of stenosis extent in digital subtraction angiography (DSA) images is inherently subjective and exhibits considerable inter-observer variability. As a result, deterministic segmentation approaches fail to capture the ambiguity present for example in clinical decision-making, particularly for stent planning.

Methods

We propose an uncertainty-aware segmentation framework based on evidential deep learning (EDL). The presented EDL U-Net is trained on ambiguously labeled DSA images from iliac artery stenoses using a tailored loss function that incorporates multiple expert annotations. The model predicts a pixel-wise Beta distribution and is trained via a Beta-Binomial likelihood, enabling joint estimation of segmentation and aleatoric uncertainty while explicitly modeling inter-observer variability. The approach is evaluated in a leave-one-out cross-validation on a multicenter dataset comprising 106 cases and compared to standard U-Net baselines with identical architecture and training setup.

Results

The proposed method outperforms the baseline U-Nets by 0.09 to 0.17 in soft Dice, achieving a score of 0.83±0.13. In addition to improved segmentation performance, the EDL U-Net provides well-calibrated uncertainty estimates, reflected by a low Brier score of 0.027±0.015 and an area under the risk-coverage curve (AURC) of 0.040±0.040. Selective prediction based on certainty thresholds further improves segmentation quality up to 0.86±0.17 at 86%±5% coverage, demonstrating the practical utility of the uncertainty information.

Conclusion

This proof-of-concept study demonstrates that EDL-based segmentation can effectively model annotation ambiguity and provide meaningful uncertainty estimates. By leveraging a Beta-Binomial formulation, the proposed approach explicitly captures inter-observer variability and has the potential to support clinical decision-making, for example in confidence-aware stent planning, motivating further validation on larger datasets and integration into clinical workflows.

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Quality Control Method for Raw Materials Using Radiofrequency Measurement Methods

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Introduction

For the detection of blood glucose by electrochemical test strips, the quality of the gold foil involved is of utmost importance. To ensure the desired characteristics of the final product and reliability of the outcomes a new RF-based measurement method is presented.

Methods

For the measurements, test strips from series production are used, which have been marked as either poor or good during the production process. The test strips consist of a plastic (Melinex®, PET, DuPont) substrate with a gold coating (20 nm gold foil). The strips were analyzed using a measurement chamber extracted from a handheld device; this chamber featured integrated contact pins that provided a reliable electrical interface with the gold-coated electrodes of the strip. For the experiment the gold foil is used as a transmitting antenna while a reference antenna is used as a receiving antenna. A Vector-Network-Analyzer is then used to assess the spectrum of the frequency response in a range of 1 MHz to 2.1 GHz, allowing different gold foil properties to be compared with each other. The return loss ratio in dB is recorded and used for evaluation. Reproducibility was demonstrated through measurements of 8 ‘bad’ and 5 ‘good’ test strips.

Results

After the frequency sweep, two areas of the spectrum were identified for evaluation: a) around the resonance frequency of 1.3 GHz and b) between 100 and 400 MHz. In the range from 100 to 400 MHz, the median signal difference between ‘good’ and ‘bad’ test strips is 0.3 dB, while at the frequency of 1.3 GHz the difference is 2 dB.

Conclusion

The method represents a simple way to perform quality control of test strips already during the production process. Poor qualities of gold foils can thus be directly sorted out, enhancing production quality, ultimately benefiting patients through better measurement accuracy.

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Radiofrequency-Based Drop Detection for Sample Localization in Handheld Point-of-Care Devices

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Introduction

Accurate sample positioning is critical for the reliability of optical Point-of-Care diagnostics, as misplacement can cause measurement errors or test invalidations. This study evaluates the integration of radiofrequency antennas within a handheld device to provide real-time, non-contact localization of blood samples within a microfluidic test strip.

Methods

Experiments were conducted using a handheld device with eight camera positions for monitoring fluid flow, focusing specifically on three camera positions (C4, C6 and C8) that cover the sensing area where the strip's reagents are located. To establish a baseline, measurements were first performed on an empty test strip containing no sample. Subsequently, samples including plasma and blood with varying hematocrit levels (20%, 40%, 70%) with a volume of 25 µL were introduced into the strips. Using a Vector-Network-Analyzer, frequency sweeps to capture resonant frequency (Hz) and signal magnitude (dB) were performed as the fluid front advanced through these positions.

Results

Experimental data demonstrates a high sensitivity to sample position. For all samples, a clear shift in resonance frequency and magnitude was observed as the sample progressed from the initial point C4 toward the final zone at C8. The resonant frequency decreased as the sample reached the specific positions, with the lowest point of the curve shifting from approximately 108 MHz for the empty strip to approximately 105 MHz at C8, while the magnitude increased by approximately 2 dB. Further analysis revealed that varying hematocrit levels produce distinct electromagnetic signatures.

Conclusion

By capturing distinct frequency and dB shifts at the analyzed positions, the system electronically validates sample presence. While the additional finding of hematocrit-dependent signatures suggests a path for blood characterization, this requires further research due to the identified mechanical dependencies within this study. This dual-modal approach enhances diagnostic precision by providing a secondary layer of verification to traditional optical measurement techniques.

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An Explainable, Demographic-Aware ECG Transformer for Atrial Fibrillation Detection

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Introduction

Cardiovascular diseases (CVDs) are the leading cause of premature death worldwide, and demographic ageing is projected to significantly increase their incidence in the coming decade. Deep learning models have demonstrated strong performance in electrocardiogram (ECG)-based CVD detection, but face the challenge of systematic variation across individual patients. Patient-specific information, a cornerstone of precision medicine, may help models account for this variability, yet its integration into ECG analysis remains underexplored.

Methods

We developed a hybrid convolutional neural network-transformer architecture with cross-attention-based metadata conditioning for atrial fibrillation (AF) detection from 10-s Einthoven lead II ECGs, trained on a large class-balanced dataset, including recordings from 77,261 patients, as well as diagnostic labels and demographics, namely age, sex, ethnicity, and 13 risk factors for AF. Four model configurations were obtained by combining the metadata attributes and each model was trained in a 5-fold cross-validation grid search for hyperparameter optimization. In a post-hoc explainability analysis, metadata contributions were quantified through ablation-based decomposition, and ECG segment attributions through guided Grad-CAM and attention flow.

Results

All configurations achieved F1 scores between 96.7% and 96.8% on the held-out test set and between 92.7% and 93.4% on an independent multi-source dataset. The contribution analysis revealed that age was the dominant demographic feature, followed by the risk factors, while sex and ethnicity showed negligible contribution. QRS complexes and fibrillatory T-Q baseline were found to be the most relevant segments for the classification by each model.

Conclusion

Despite minimal differences across configurations, our model achieved competitive performance in AF detection on a large dataset. Explainability analysis revealed age as the only demographically relevant feature, while the most highlighted ECG segments aligned with clinical features of AF. These results establish an interpretable baseline for future patient-specific adaptive systems and inform the responsible integration of demographic data in clinical ECG analysis.

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A Software-Framework for Automated Sensor Characterization and Benchmarking

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Introduction

The growing diversity of highly sensitive magnetic field sensors demands systematic methods for quantitative characterization and comparison. Current approaches typically rely on manual signal parameter extraction, are tool-specific, and lack comparability across sensor technologies. Key parameters include gain, offset, amplitude and frequency stability, signal shifts as a function of frequency and amplitude, directivity, and delays in multi-axis and multi-unit systems. Manual extraction is time-consuming, inconsistent, and not scalable, necessitating an automated software framework.

Methods

The software framework operates on recorded measurement data. During data acquisition, a low-noise current source applies a predefined sequence of test signals, typically sinusoidal waveforms at defined frequencies and amplitudes, to the device under test via well-characterized coils.
Based on an analysis “configuration file”, the python-based framework automatically maps each segment of the recorded data to its corresponding test condition. Signal parameters such as amplitude, frequency, and offset are extracted per channel by fitting a parametric sinusoidal model using least-squares optimization. A modular data loader supports proprietary data formats, and the architecture is designed for straightforward extension with additional fitting models.

Results

The system is currently deployed using data acquired in the BMSR-2.1 magnetically shielded room at Physikalisch-Technische Bundesanstalt Berlin, in conjunction with the dedicated test bench (DALAC). The framework has been validated across datasets from a variety of magnetic field sensors (SQUID, Fluxgate, SERF-OPM, etc.). Systematic cross-validation against MATLAB and DIAdem confirms consistent parameter extraction. The automated pipeline substantially reduces analysis time while ensuring reproducible, user-independent results across sensor types and measurement scenarios.

Conclusion

The software framework provides a robust and extensible solution for sensor characterization and benchmarking across magnetometer technologies. By enabling automated, reproducible and comparable parameter extraction, it supports the consistent performance evaluation in biomagnetometry and related fields. Future work will focus on open-source release and the integration of additional data formats and analysis models.

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Activity Recognition from Smart Insole Sensor Data Using a Circular Dilated CNN

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Introduction

Smart insoles equipped with pressure sensors, accelerometers, and gyroscopes offer a non-intrusive means of monitoring human gait and posture. We present an activity classification system based on a circular dilated convolutional neural network (CDCNN) that processes multi-modal time-series data from such insoles. STEP-Insole Dataset from Kaggle is used in this work.

Methods

CDCNN and XGBoost are implemented are compared on testset. Models operate on 160-frame windows with 24 channels (18 pressure, 3 accelerometer, 3 gyroscope axes).

Results

The class distribution is approximately balanced: standing (5,559 samples); walking (5,401 samples); sitting (5,066 samples); tandem (5,043 samples). CDCNN achieves 86.42% test accuracy in a subject-independent evaluation on a four-class task (Standing, Walking, Sitting, Tandem), compared with 87.83% for an extreme gradient-boosted tree (XGBoost) model. Permutation feature importance indicates that which sensor channel contribute more to model decision making.

Conclusion

We presented a CDCNN-based activity recognition pipeline for smart insole data that fuses pressure and inertial modalities. On a challenging subject-independent split (no subject overlap between train, validation, and test sets), the model achieves 86.42% test accuracy with a simple, interpretable architecture and performs competitively against an XGBoost model (87.83%). Permutation feature importance reveals the distribution of contributions made by various sensors to the classification process. The proposed approach has potential applications in areas such as smart insole design, health monitoring, and rehabilitation.

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Force-reduction of alginate-coated cochlear implant electrode in porcine specimens

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Introduction

Cochlear implant surgery focuses on atraumatic insertion to preserve residual hearing. Coating electrode arrays (EAs) with a lubricating alginate hydrogel reduces insertion forces. Previous dip coating approaches have suffered from inconsistent thickness and droplet formation on the array tip. To overcome these limitations, a membrane-based coating method was developed and investigated in a cochlea model and porcine cochlear specimens.

Methods

EAs were coated using a semi-permeable membrane and a 3D printed crimp to restrict total coating thickness below 0.8 mm. Following insertions in an artificial cochlea model *ex vivo* insertion experiments were conducted on 10 porcine specimens using an automated linear insertion test bench with both uncoated and coated EAs. Insertion forces were continuously measured, and microscopic imaging, 2D CBCT, and µCT scans were used to evaluate coating thickness, insertion depth, and scala tympani geometry.

Results

All electrodes were coated successfully below the 0.8 mm target thickness. The initial mean coating of 0.47 mm ± 0.15 mm decreased to 0.38 mm ± 0.15 mm after four insertions. Insertions into the artificial cochlea model yielded significant force reductions of more than 60%. In porcine cochlear specimens, the coating produced measurable but non-significant reductions in peak force (5.3 mN ± 7.0 mN) and insertion work (15.5 µJ ± 16.9 µJ).

Conclusion

The proposed coating method achieves consistent and complete alginate coverage. While force reductions in porcine cochleae were limited by anatomical constraints, the overall trend supports the coating’s potential to mitigate insertion friction. Studies in human temporal bones are expected to provide a more definitive evaluation of its clinical potential.

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Tuning Magnetoelectric Sensors for Medical Applications

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Introduction

Magnetoelectric (ME) sensors are promising candidates for medical magnetic field measurements because they enable compact and low-cost detection of weak magnetic signals without cryogenic cooling. Our current work addresses different ME sensor concepts for applications such as magnetocardiography, movement analysis, and localization. This contribution gives an overview of two complementary sensor platforms, the converse magnetoelectric sensor and the bulk-micromachined (BMM) sensors, and discusses how tailored magnetostrictive layer systems support their application-specific optimization.

Methods

For the sensor design Iron Cobalt Silicon Boron (FeCoSiB) is used as a magnetostrictive material. The focus is on sputter deposited magnetostrictive multilayers, to pin and control the the magnetic operation point and state. By creating an exchange bias stack of Ta/Cu/MnIr/FeCoSiB or FeCoSiB/NiFe/MnIr/Ta the sensors can be operated fully passively and the magnetic state of the FeCoSiB layer is fixed in a well defined single magnetic domain state, minimizing domain wall motion and thus minimizing noise. The exchange bias is introduced by annealing in a DC field post deposition or by directly performing the deposition in a DC magnetic field. Selected examples from cardiologic and motion-related applications are used to illustrate the biomedical relevance.

Results

Recent results show that the sensor performance is strongly governed by the design of the magnetostrictive layer system. New converse ME sensors utilizing exchange bias multilayers based on repeated Ta/Cu/MnIr/FeCoSiB stacks promote flux closure states and significantly reduce magnetic noise, resulting in a limit of detection (LoD) of 8 $pT/Hz^{0.5}$ at 10 Hz. For the BMM sensors, optimization of the functional layer stack established a reproducible miniaturized platform that is compatible with sensor-array concepts. In particular, frequency tuning provides a route to reducing cross-talk between adjacent sensors.

Conclusion

These examples show that tuning of magnetostrictive multilayers is a key strategy for improving ME sensor performance. Tailored layer stack and exchange bias designs enable low-noise operation, miniaturization, and application specific adaptation, thereby advancing converse ME and BMM sensors towards medical use.

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A look into clinical guidelines for AF detection in clinical and home setting

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Introduction

Atrial fibrillation (AF) remains the most common sustained arrhythmia and is frequently underdiagnosed due to its intermittent and often asymptomatic nature. The 2024 European Society of Cardiology (ESC) guidelines emphasize early detection as a cornerstone of AF management within the AF-CARE pathway, highlighting systematic screening and continuous reassessment as essential components of care. Recent European Heart Rhythm Association (EHRA) consensus statements on digital health and artificial intelligence (AI) further underline the transformative potential of multimodal data and wearable technologies for AF detection beyond traditional clinical settings.

Methods

This work reviews current ESC and EHRA guideline recommendations and consensus documents regarding AF detection strategies in both clinical and home environments. Particular focus is placed on screening approaches (opportunistic vs. systematic), device-based detection (electrocardiogram (ECG), photoplethysmography), and the integration of AI-driven algorithms for signal analysis and risk prediction.

Results

AF guidelines recommend opportunistic screening in patients ≥65 years and systematic screening in high-risk populations, supported by ECG confirmation of AF diagnosis. In clinical settings, continuous monitoring via Holter or implantable devices improves detection of subclinical AF. In parallel, consensus documents highlights the growing role of wearable and mobile health technologies enabling large-scale, home-based monitoring. AI-based algorithms enhance detection accuracy, enable analysis of multimodal datasets, and may allow early prediction of AF onset. Importantly, guideline documents stress the need for clinical validation, interpretability, and integration into clinical workflows to ensure safe implementation.

Conclusion

Current ESC and EHRA guidelines and consensus recommendations support a paradigm shift from episodic, clinic-based AF detection towards patient-centered monitoring. While AI offers substantial opportunities to improve early detection and prevention, robust validation, regulatory oversight, and guideline-conform integration remain critical to translate these innovations into clinical benefit.

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