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Introducing a FHIR-Based Toolset for Analyzing Nursing-Related Data

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Abstract. Data analytics is a promising strategy to improve both the decision-making of nursing management and supporting nursing research, often constrained by the lack of standardized data sets. The HL7© Fast Healthcare Interoperability Resources (FHIR) standard offers a structured approach to addressing this issue, yet accessible software solutions for nursing-related FHIR data analysis are limited. This paper introduces an open-design framework to facilitate data-driven innovations in nursing research and practice, based on current developments in the German healthcare sector, such as the development of nursing-related FHIR specifications and the telematics infrastructure for secure data exchange. We present software implementations developed within this work for secure data exchange (Kommunikation im Medizinwesen Care) and the evaluation and visualization of nursing-related FHIR resources (FHIR QR Vis and FHIR Nursing Dashboard). The feasibility of this approach was validated through two case studies at a German nursing home and a university hospital, demonstrating its potential to enhance data-driven decision-making and workflow optimization in nursing.

Keywords. Nursing Informatics, FHIR, Data Analytics

1. Introduction

The nursing sector faces the challenge of optimizing workflows while ensuring high-quality care. Data analysis can play a crucial role in this process, both at the institutional level for process optimization and in nursing science for generating new insights [1,2]. However, a major obstacle is the lack of large-scale, standardized, and comparable secondary data. The Fast Healthcare Interoperability Resources (FHIR) standard offers a potential solution by providing a unified data structure. In Germany, specific FHIR profiles for nursing have been developed, enabling the potential targeted analysis of nursing-related data [3-5]. As the adoption of the specifications grows, freely available

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software solutions for processing and analyzing nursing-related FHIR data are not available.

In this paper, we present an open-source toolset designed to facilitate the analysis of FHIR-based nursing data, supporting data-driven innovations in nursing. We define the underlying requirements for these and present the results of our implementation and their use in different studies.

2. Methods

The goal of this work is to enable healthcare and nursing facilities or researchers in the field of nursing to gain insights from data, regardless of their size or financial resources. Additionally, current developments in the German healthcare system, such as the spread of the FHIR standard and the connection of facilities via the German healthcare network telematics infrastructure [6], should be taken into account.

2.1. Architectural Framework

This toolset builds on a previously developed architectural framework designed to support the analysis of nursing data within a facility using the FHIR standard [7]. It enables the collection of harmonized nursing datasets from diverse data sources for analysis purposes while covering the areas of data import and transformation (known as ETL - Extract, Transform, Load), storage and modeling, and visualization and analysis. We extended this framework by adding the feature of secure interinstitutional exchange of harmonized data sets between different FHIR servers (see Figure 1).

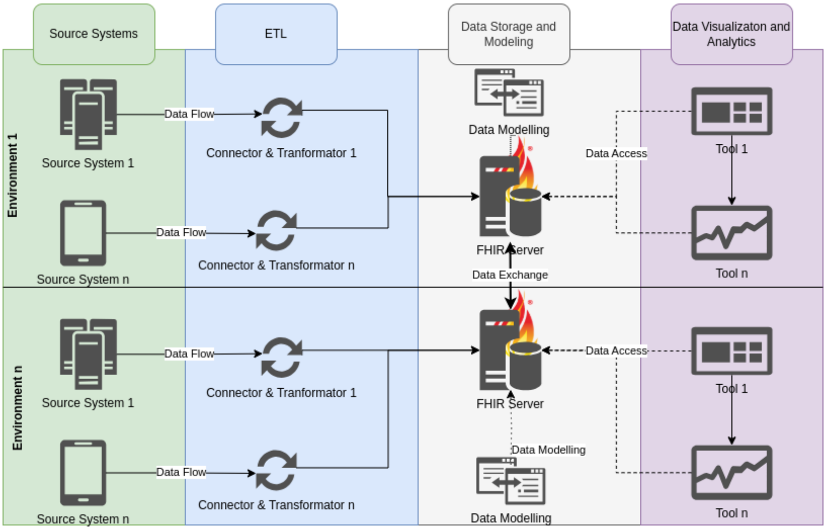

Figure 1. Extended architecture framework.

2.2. FHIR Specifications

To enable the joint storage of information from various data sources and to build the analytics tools, a standardized and harmonized data model is needed. We use the FHIR communication standard, which has become the state of the art for intra- and inter-institutional data exchange in the healthcare sector. In Germany, several developments have also affected the field of nursing. The Gematik GmbH, the operator of the German healthcare network infrastructure, is defining mandatory interface descriptions that have to be supported by hospital (ISiK) and nursing information systems (ISIP). These profiles specify, among others, patient and organizational basic information or diagnosis-related information [3,4]. Furthermore, the German Association of Statutory Health Insurance Physicians (KBV) and mio42 GmbH are developing so-called medical information objects (MIO), which are self-contained specifications that represent the contents of the electronic patient record. In this context, a first nursing information object PIO ULB (care transaction record) was also published, which contains the necessary nursing information for transferring a patient to another facility [5].

3. Results

We have carried out an implementation based on the framework shown above and used it for conducting two studies. Several FHIR servers have been accessible as open-source plug-and-play solutions (e.g. HAPI FHIR Server) [8]. Other universally usable software components were developed for data exchange and analysis.

3.1. Software Implementations

Based on the requirements, the following software components were developed within this work and made available under the open-source principle:
KIMCare: KIM Care is a toolset to transfer files via the German Telematik-Infrastruktur (TI), the secure German infrastructure for the health care system. It is based on the tool Apache Nifi and features so-called processors that enable to send and retrieve files using the KIM component of the TI, its primary mail client. Available from: https://github.com/frankkramer-lab/KIMCare
FHIR QR Vis: FHIR QR Vis is a client-based web application prototype for interactive FHIR Questionnaire Response (QR), the FHIR resource for clinical questionnaires, analysis, and visualization. It enables non-technical users to customize a data filtering mechanism to create conditional one- and two-dimensional charts. Available from: https://github.com/frankkramer-lab/FHIR-QR-Explorer [9]
FHIR Nursing Dashboard: FHIR Nursing Dashboard is a web application that allows users to view and interact with nursing-related FHIR resources. The dashboard features general patient-related information (e.g. stay at the facility, admissions/dismissions, age, gender) as well as treatment-related information (e.g. medical diagnosis, nursing measures performed, respiration) on an organizational as well as on ward level. The data can be filtered by the user to perform statistical analysis. The tool is based on a mix of the nursing-related German FHIR specification standards ISiP/ISiK [3,4] and the PIO ULB [5] and supports resources that are valid against the specifications. Available from: https://github.com/frankkramer-lab/fhir-nursing-dashboard

3.2. Case Studies

Based on our implementations, two real world case studies in different settings were conducted using the developed components:

Case Study 1 - Employee Satisfaction at a German Nursing Home: The system was deployed at a German nursing home to support a study to determine employee satisfaction in different areas and identify potential for improvement. The pseudonymized data of two periodically performed employee satisfaction surveys, 37 participated in the first and 31 in the second, was transformed into QuestionnaireResponse resources and stored on a FHIR server. The tool FHIR QR Vis was used to process the results of the respective surveys and to compare them with each other. The management afterward used the results to perform several measurements.
Case Study 2 - Analysis of Nursing-related Data in a Hospital Setting: Two years of anonymized patient data from four wards of a German university hospital was imported into our system for analysis and potential optimization purposes. The data set consisted of demographic data, movement data, diagnoses, performed nursing measures, and respiratory support. After exporting from the local hospital information system, the data was mapped and transformed into a mix of profiles of German nursing-related FHIR specifications (ISiP/ISiK and PIO ULB) [3,4,5] and stored on a FHIR server. The tool FHIR nursing dashboard was used to perform basic statistic evaluations about differences in patient profiles. Furthermore, the data was used to train a predictive model for workload forecasting and develop an optimization model for intelligent shift scheduling.

4. Discussion

The approach presented in this paper provides opportunities to gain insights from their data for the management of healthcare and nursing facilities as well as nursing researchers, regardless of their size or financial resources. We base our developments on the FHIR standard and its recent developments in the area of nursing, to overcome institutional and system-wide barriers, especially since it can be assumed that these specifications will become more widespread, leading to more systems supporting interfaces and mappings to the FHIR specification. While the deployment of the software components can be done without further programming skills, the tools might also provide a basis that could be extended, e.g. by supporting additional FHIR profiles and resources. Furthermore, our open architecture design also enables to add of additional software components to when needed, e.g. tools that feature an interface to a FHIR server like Power BI to perform additional analyses [10]. Additionally, the concept presented here serves only as a technical foundation. Control concepts, such as access or user management, are not covered and must be developed separately.

By being used in two nursing-related studies, we demonstrated the feasibility of our approach in different real-world settings. However, in order to successfully process data sets, the source systems need to feature corresponding interfaces for data export.

5. Conclusions

In this paper, we presented an open-source and platform-independent toolset designed to enable nursing facilities and researchers in nursing to gain insights from their data. We introduced our architectural framework which is based on current trends in the healthcare sector, particularly the spread of the FHIR standard and the connection of facilities via the German healthcare network telematics infrastructure. The software implementations, that were developed within this work helping with the secure exchange of data and enabling the visualization, analysis, and interaction with nursing-related FHIR resources, were presented. As published under the open-source principle, these tools can also be used as a basis that can be extended, e.g. by adding support for additional FHIR profiles and resources. Furthermore, the open design approach of the presented framework allows the integration of additional software components.

We have demonstrated the feasibility of our approach by applying it in two different case studies. This involved conducting a survey in a nursing home and analyzing secondary data in an inpatient setting at a university hospital.

Our findings highlight the potential of our toolset to support data-driven insights in nursing research and practice, while its open and extensible design enables future extensions.

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