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User-Centered Design of ALERT-ITS: An ICU Bed Forecasting Monitoring System

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Abstract. Intensive care units must proactively plan for adequate resource availability to ensure timely patient care, reducing wait times and improving satisfaction. Access to short-term bed demand forecasts and real-time capacity assessments enables hospital decision-makers to make informed, data-driven decisions. A monitoring system that forecasts bed capacity based on environmental factors can significantly enhance resource management. This paper focuses on the iterative User-Centered Design (UCD) process, with particular emphasis on the design methodology and iterative optimization of its user interface. The presented UCD approach explores how healthcare professionals envision the interface for a bed capacity forecasting system. An initial prototype, developed from preliminary research, was evaluated by twelve specialists, including healthcare professionals, senior nursing staff, and IT specialists, through three interviews. These discussions led to categorized functions and key insights. The early incorporation of diverse user feedback facilitated the creation of a user-friendly interface, enhancing the system's ability to present bed capacity forecasts and support clinical decision-making.

Keywords. Monitoring system, User-Centered Design, User Experience

1. Introduction

Intensive care unit (ICU) capacity planning is crucial to optimize resource allocation and improve patient outcomes. In particular, a mismatch between bed supply and demand, along with corresponding clinical staffing needs, can adversely affect key performance indicators such as waiting times, quality of care, patient and staff satisfaction, and increase the rate of accidents. However, an oversupply of hospital beds can lead to unnecessary costs and waste of resources, as unoccupied beds still need to be maintained and staffed [1,2].

The ALERT-ITS monitoring system (MS) provides a solution for forecasting and effectively managing the demand for intensive care beds based on weather and climate conditions. Key aspects of the MS include its intuitiveness and its UCD [3], which focuses on creating the system based on the needs of the user [4]. The UCD approach supports the development of usable systems, enabling efficient complex data visualization and facilitating system integration into daily clinical practice [5]. This study aims to document the UCD development process for the ALERT-ITS MS, with a particular focus on the design and evaluation of its user interface (UI), as envisioned by ICU clinicians and nursing management.

2. Methods

The entire development of the MS was based on a UCD approach, following the principles outlined in ISO 9241-210:2010 [6]. This process involved iteratively developing prototypes according to system requirements identified through initial interviews. At each stage of development, participants provided feedback through contextual interviews. This feedback was systematically analyzed and used to refine the prototypes, ensuring that each iteration advanced the design closer to the users' needs and expectations.

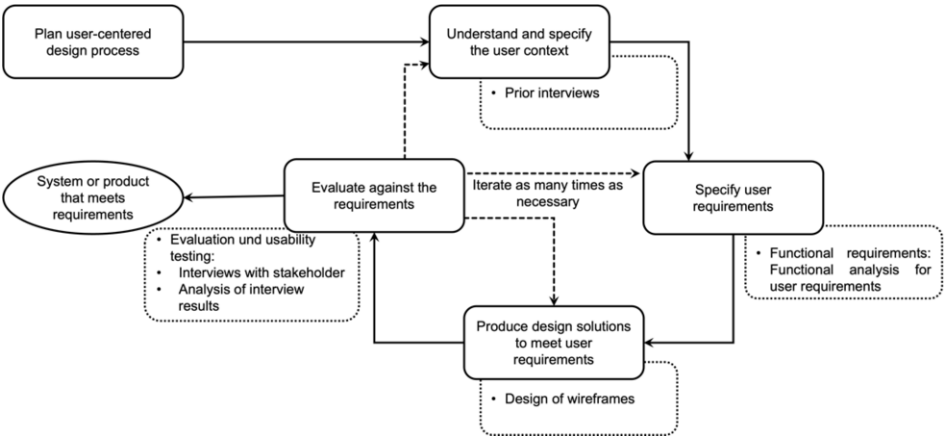

Figure 1. Review of Applied UCD Methods.

2.1 Understanding and specifying the user requirements

Clinicians at Augsburg University Hospital were interviewed to understand their expectations for the ALERT-ITS MS for forecasting ICU bed needs. Their feedback guided the design, which utilized the Functional Information Requirements (FIRs) method to convert objectives into user-specific requirements.

2.2 Conception of an initial user-centered design

Prototypes, including low-fidelity (Lo-Fi), high-fidelity (Hi-Fi) wireframes and a Click Dummy, were created for the ALERT-ITS MS using the Figma [7] prototyping tool. The prototypes were developed as a series of layouts.

2.3 Interviews with stakeholders

We conducted three stakeholder interviews: reviewing the Lo-Fi, Hi-Fi wireframes and Click Dummy. Participants were briefed on the content and objectives prior to each interview. The online video-interviews, conducted in German by an interviewer and a note-taker, lasted 30 to 60 minutes and were based on a structured agenda, including a project overview and a focused discussion [8]. Open-ended questions gathered detailed use case insights. The Click Dummy interview included a usability test based on four tasks with different scopes and difficulty levels.

2.4 Analysis of interview results

All of the interviews were documented, including the observations taken by the interviewers such as difficulties encountered and efficiency of the task completion. A qualitative content analysis of the interviews with clinicians provided detailed insights into their preferences, which were addressed in the further development of the wireframes and the prototype.

3. Results

3.1 Prior Interviews with healthcare professionals and Functional Information Requirements

The interviews revealed that clinicians prioritize a simple design and customization options in UI development. These insights, supported by the study results, suggest that challenges in information visualization and data entry can be addressed through simplified interfaces.

The UCD process for developing the ALERT-ITS MS began with initial research and requirements gathering. Nine preliminary interviews defined core functions, and a functional requirements analysis identified and prioritized 11 key features based on feasibility, time, and resources (see Figure 2).

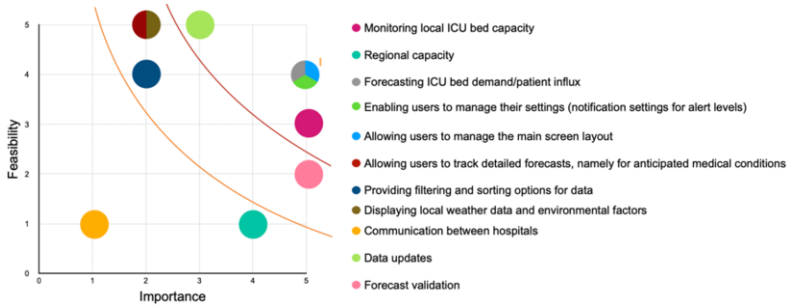

Figure 2. Functional requirements for ALERT-ITS MS.

The identified functions were categorized into three groups: essential and feasible, less relevant but feasible with additional effort, and those either irrelevant or difficult to implement within the project's time and resource constraints. Function importance was determined by the frequency they were mentioned by interviewees.

3.2 User Interface MS Design

In the early design phase, Lo-Fi wireframes with customizable widgets were developed to enable user personalization of MS main screen (Figure 3a). Following the validation of these wireframes, Hi-Fi wireframes were created incorporating user feedback (Figure 3b). Subsequently, an interactive prototype, referred to as a Click Dummy, was constructed to evaluate usability and navigation (Figure 3c).

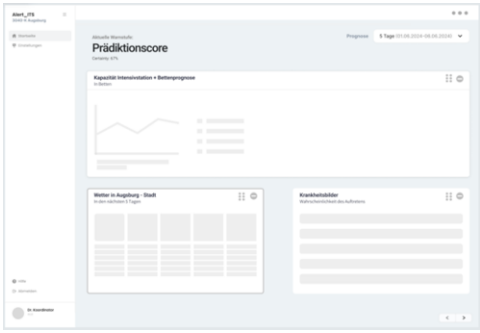

Figure 3a. Lo-Fi Wireframes.

Figure 3b. Hi-Fi-Wireframes.

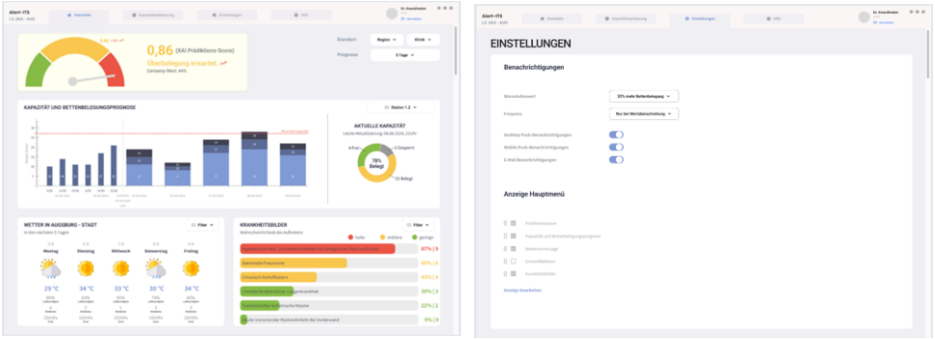

Figure 3c. Click Dummy Prototype.

3.3 Results of the interviews

Feedback from three stakeholder interviews highlighted the need for a user-friendly interface with simplified content and effective graphics. Lo-Fi wireframe feedback suggested adding features like drag-and-drop placement (67%), medical condition filters (33%), regional capacity data entry, and a capacity trend chart. Hi-Fi wireframe feedback emphasized enhancing the bed availability display, with 78% proposing a graphical representation of different bed types (blocked, occupied, and available). Additional recommendations included station-specific views, clearer capacity exceedance indicators, and customization options, such as color palette selection for individuals with color vision deficiencies. All respondents rated the Click Dummy prototype as good to excellent, especially appreciating its customization options. Design specifications, included in this feedback, were provided to the development team for implementation.

4. Discussion

This article demonstrates the effectiveness of the UCD approach in developing a UI for ALERT-ITS MS. Insights gained from user interviews, wireframes, and Click Dummy prototypes led to significant design improvements, including enhanced visibility of bed capacity and the addition of forecast scenarios with color coding. The approach,

involving 12 participants, aligns with similar studies and has been validated by positive usability feedback. Future work focuses on ongoing user feedback and iterative design refinements to ensure the system continually meets user needs. Once the development is complete, the entire system will undergo a comprehensive evaluation to assess its effectiveness and user acceptance.

5. Conclusions

In this study, we meticulously documented each step of the UCD process for the ALERT-ITS MS over the past six months and examined how ICU clinicians envisioned its UI. Early user involvement in the design phase provided valuable insights, leading to the development of a UI tailored to ICU clinicians' needs. The design process prioritized user expectations, resulting in a UI with simplified interfaces, adjustable widgets, intuitive data entry and filtering tools. Effective visualizations enhanced the interpretation of forecasts and bed capacity. Usability studies with target users provided critical feedback, leading to refinements that better aligned with user's mental models. The positive evaluation results highlight the success of the UCD process. Future work will involve an eight-month evaluation at Augsburg University Hospital to assess the systems effectiveness and user acceptance, ensuring it meets the practical requirements of ICU management.

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