

Towards Adaptive User Interfaces: A Model-Driven Approach for mHealth Applications Targeting Chronic Disease

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I. INTRODUCTION

The reclassification of previously fatal diseases and the ageing of the population have contributed to the prevalence of chronic diseases [1]. *Self-management* is crucial in managing chronic diseases [1], [2]. mHealth interventions have the potential to promote self-management by improving medication adherence and facilitating self-tracking capabilities [3]. However, researches show that those who could benefit the most from mHealth solutions tend to use them the least [4]. In order to scale up the deployment of mHealth applications, especially for patients with chronic diseases, it is necessary to design user-friendly systems that cater to the diverse needs of users [4]. However, several challenges must be considered in achieving this goal. First, chronic disease is a highly *heterogeneous disease* affecting patients in different ways (i.e., triggers, symptoms, severity varied) [5]. Therefore, patients may have diverse needs regarding self-management. Second, the **user interface (UI)** design should take into account the fact that *the phases of chronic disease change over time* [6]. Numerous chronic diseases either deteriorate over time if left untreated, while others may improve with proper care and management [7]. Furthermore, chronic diseases are often comorbid with other medical and/or psychopathological disorders, adding complexity to their management [6]. Third, chronic disease is typically *long-lasting, often spanning a person's lifetime* [8]. Therefore, it is crucial for mHealth technologies to maintain user engagement and motivation in the long run.

To cater to the variability, **Adaptive User Interfaces (AUIs)** have emerged as a potential solution. AUIs aim to enhance the interaction between users and UI by adapting to their current goals, needs and preferences [6]. Despite the growing interest in utilising AUIs to promote healthy behaviour and self-management in chronic disease-related apps [9], existing applications often employ a *one-size-fits-all* design strategy, overlooking individual user characteristics and interaction history.

The **Model-Driven Approach (MDA)** is adopted for developing tools supporting AUIs development, which offers sig-

nificant advantages over traditional development and toolkit-based methods [10]. It provides enhanced *traceability* through tracking and documenting UI adaptations [11], technology independence by encompassing a wide range of existing technologies and considering future advancements [12], and the ability to perform checks on the adaptive behaviour of the generated AUIs [13]. Thus, this project adopts the MDA to adapt the UI to various contexts of use. The overarching question of this project is “*How can the utilisation of MDA contribute to adapting the UI for diverse user groups with chronic diseases*”. In the subsequent section of this paper, I discuss various research projects in the healthcare domain that explore AUIs (Section II). Afterwards, I provide an overview of my current progress, including the findings from a systematic review of AUI research in the chronic disease domain and preliminary results regarding end users’ understanding and expectations of AUIs (Section III). Subsequently, I outline my key future work planned for this project (Section IV) and conclude with final remarks (Section V).

II. STATE OF THE ART

Prior research in the healthcare domain has predominantly focused on studying AUIs issues among health professionals [14]–[16]. For example, Greenwood, Nealon and Marshall [14] introduced a novel approach utilising reactive agents to deliver AUIs for medical decision support in diabetes treatment. This approach dynamically displays data based on individual clinicians’ choices and preferences. Vogt and Meier [15] presented a framework for AUIs in specific scenarios, such as smart hospital service. Similarly, Alnanih, Radhakrishnan and Ormandjieva [16] proposed a model that separates context acquisition from utilisation in a hospital environment to improve the usability of technology and the workflow productivity of healthcare staff.

Despite some exploration into patient-focused AUIs, the existing studies tend to focus on a particular adaptive component or specific aspects of patient management. For example, Shakshuki, Reid and Sheltami [17] proposed an architecture for AUIs that specifically caters to patient monitoring, with

a strong emphasis on adapting health-related information. Similarly, Frohlich et al. [18] developed a context-aware monitoring approach for digital homes, specifically focusing on external sensors that monitor physiological parameters. Yuan and Herbert [19] designed a fuzzy-logic-based context model for offering personalised healthcare services to chronically ill patients, adapting technology to fit the daily activities of these patients. However, their focus lies primarily on the prediction of potential health issues and prevention measures based on user data, rather than adapting the UI to accommodate the specific needs, preferences, and context of individual users. However, there is a noticeable research gap when it comes to AUIs for chronic disease-related applications, indicating the need for further investigation in this area.

III. CURRENT PROGRESS

A. Current state of the art in the use of AUIs in chronic disease domain

In the initial phase of the research, I conducted a **Systematic Literature Review (SLR)** focused on AUIs for chronic disease-related applications [20]. This review categorises various sources of adaptation data, data collection techniques, adaptive strategies, adaptation actors, and adaptive elements utilised in different applications. Moreover, a list of key research issues was compiled to guide future investigations in advancing AUI development and utilisation in the context of chronic diseases. These include inquiries about preferred levels of automation for different applications or adaptive elements, as well as strategies to govern user involvement throughout the adaptation process. This list also serves as a guide for the upcoming research endeavours of this project.

B. Adaptive user interface user study

Utilising the literature synthesis from my SLR [20], I have created an AUI prototype that integrates multiple adaptation types, including presentation adaptation, content adaptation, and behaviour adaptation. *Presentation adaptation* involves adjusting interface elements such as colour, object positioning, and font size to optimise the user experience. *Content adaptation* focuses on modifying the text, semantic content, images, or explanatory inscriptions to adapt the content level of the interface. *Behaviour adaptation*, on the other hand, is characterised by its complexity as it can involve both content and presentation adaptation, often necessitating multiple steps to accomplish. Further details on the prototype can be found in [21]. Using this prototype, I conducted a large-scale user study comprising a quantitative survey, focus groups and interviews. The survey focused on collecting data on participants' preferences regarding adaptive elements and their desired methods for collecting and adapting user data. I conducted focus groups and interviews to gain detailed insights into the specific needs related to different types of adaptation. These qualitative research techniques allow for gathering in-depth information from participants and further enrich our understanding of their requirements and expectations.

IV. FUTURE WORK

A. Analysis and study of the AUIs in chronic disease domain

In the ongoing PhD research, I am analysing the qualitative and quantitative data to gain insights into user preferences regarding adaptive elements for mHealth applications designed to support individuals with chronic diseases. The qualitative analysis also enables a more profound grasp of the nuances, patterns, and recurring themes associated with various adaptation types, all of which stem from the user's experiences and perspectives.

B. Design and implementation of a framework for generating AUIs

The research seeks to utilise MDA for constructing a framework that automates the generation of AUIs, helping software developers in creating AUIs for chronic disease-related applications. This framework will include the integration of a graphical modelling tool, leveraging the capabilities of Sirius as a supportive development tool. The foundation of the framework lies in the creation of a meta-model encompassing key concepts from various sources, such as available devices, user-generated information, and adaptation settings which will be defined by the developer. This approach will effectively mitigate the complexity inherent in AUIs development through the modelling and visualisation of complex health-related scenarios while eliminating the burden of handling intricate implementation details.

C. Evaluating from the technical and human perspectives

To evaluate the practical feasibility of the proposed framework, a series of evaluations will be conducted during the development of chronic disease-related applications with AUIs. We will first test the efficiency of some example adaptations. Then, the perspectives of developers regarding the generality and flexibility of the AUIs generation approach will be considered. Additionally, a user study will be conducted to assess the specific AUIs solutions for individuals with particular chronic diseases. We will employ surveys and interviews to collect feedback regarding users' interactions with the initial and an adapted version of the same interface. Longitudinal studies can be conducted to observe user engagement and the evolution of user behaviour resulting from the integration of AUIs.

V. CONCLUSION REMARKS

The increasing prevalence of chronic diseases and the importance of self-management highlight the need for user-friendly mHealth systems. In my PhD project, I will study how to use MDA to address this challenge and how MDA can aid the generation of AUIs in a more effective and efficient manner.

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