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Model-Driven Dementia Prevention and Intervention Platform

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Abstract. Most types of dementia, including Alzheimer's disease, are not curable. However, there are risk factors, such as obesity or hypertension, that can promote the development of dementia. Holistic treatment of these risk factors can prevent the onset of dementia or delay it in its early stages. To support individualized treatment of risk factors in dementia, this paper presents a model-driven digital platform. It enables monitoring of biomarkers using smart devices from the internet of medical things (IoMT) for the target group. The collected data from such devices can be used to optimize and adjust treatment in a patient in the loop manner. To this end, providers such as Google Fit and Withings have been connected to the platform as example data sources. To achieve treatment and monitoring data interoperability with existing medical systems, internationally accepted standards such as FHIR are used. The configuration and control of the personalized treatment processes are achieved using a self-developed domain-specific language. For this language, an associated diagram editor was implemented, which allows the management of the treatment processes through graphical models. This graphical representation should help treatment providers to understand and manage these processes more easily. To investigate this hypothesis, a usability study was conducted with twelve participants. We were able to show that such graphical representations provide advantages in clarity in reviewing the system, but lack in easy set-up (compared to wizard-style systems).

Keywords. model-driven intervention planning, internet of medical things, digital prevention, treatment platform, precision care, Alzheimer's disease, IoMT, FHIR

1. Introduction and Motivation

Currently, dementia is not curable, and treatments are aimed at improving the quality of life of those affected, for example, by treating certain symptoms with medication [1]. Therefore, the prevention of dementia is of particular interest. The most common form of dementia, Alzheimer's disease, is favored by modifiable risk factors. These include treatable diseases such as diabetes and lifestyle-related factors such as an unhealthy diet, lack of physical activity, or sleep disturbances [2]. Personalized interventions can help to preserve the mental abilities of people at-risk or, in the early stages of dementia, delay the onset and progression of the disease. This involves combining different treatment approaches based on individual risk factors, such as nutritional counseling, exercise therapy, or drug treatment [3]. Initial success in decreasing the risk for the development

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of dementia was achieved in the FINGER study [4]. In this study, people at increased risk of dementia were treated individually over two years with nutrition therapy, exercise therapy, and memory training [5]. This treatment showed promise to maintain or improve cognitive function. One challenge here is that the treatments for prevention or intervention in dementia take place over several years and require continuous adaptation to, and monitoring of, the beneficiary individual's state of health and needs. Our previous studies indicated that medical professionals are willing to use digital tools to support this treatment process [6]. Nevertheless, from an ethical point of view, the potential for surveillance and discrimination due to the misuse of such a platform is seen as a threat. On the other hand, the increasing spread of technologies, such as smart fitness wristbands, indicates a greater willingness among the population to use health-related data for themselves.

2. Methods and Definition of Research Questions

Our work aims to develop a model-driven Internet of Medical Things (IoMT) platform to support personalized mHealth applications for dementia prevention and intervention. Besides a mobile application, IoMT devices, such as wearables, will be integrated into the treatment process to monitor individuals' progress, digital biomarkers, and risk factors. IoMT-based personalized treatment may involve the combination of different treatment approaches as well as objectified feedback using multiple heterogeneous devices with different characteristics and sensors. Accordingly, the treatment process is multi-layered and variable. Therefore, the medical professional shall use models to manage and configure the treatment processes. These models should graphically represent and thus facilitate the understanding of the processes as well as the handling of the system for the medical professional. Graphical models are already being used on the Internet of Things (IoT) field to allow non-technical users, e.g. to configure data pipelines to process IoT data streams. In the software development domain, models are used to document and improve understanding of software systems. Model-driven software development uses models of systems for the automatic generation of program code. Here Domain Specific Languages (DSL) are used to express the elements and problems of a domain, thus, a limited knowledge area [7]. To facilitate the use of a platform for medical professionals, a DSL for modeling IoMT-based personalized treatment processes with a focus on holistic dementia prevention is presented in this work. The DSL is useable to specify, manage, and configure the IoMT-supported treatment processes. As a procedure for developing these artifacts, we chose the Design Science Research Method (DSRM) by Peffers et al. [8]. This is broken down within a process into the six steps of problem identification and motivation, definition of goals for the solution, design and development of the solution artifact, demonstration of the solution artifact, evaluation of effectiveness and efficiency, and communication. This enables a systematic development of artifacts for an identified problem, as well as their subsequent evaluation based on the findings of literature research and the deduction of requirements of such a platform. Therein, the following questions are addressed:

1. How must a DSL be designed to specify an IoMT-supported treatment process?
2. How can models be created using the DSL in a model-driven software platform?

3. Results

Addressing risk factors has been shown as an iterative process. Initially, a diagnosis is made by a medical professional. During this process, an individual is examined for risk factors such as lack of exercise, obesity, or chronic diseases like high blood pressure. Based on these risk factors, the medical professional then decides on appropriate interventions to reduce these risk factors. For example, increasing physical activity through sports therapy can manage a lack of exercise. To objectively record the treatment progress, the individual's treatment or risk factors are continuously monitored. The medical professional selects suitable IoMT devices and questionnaires and issues them to the individual. These artifacts then collect the required health data. Based on this data, the medical professional can continuously adjust and improve treatment or identify new risk factors. For this purpose, our DSL requires at least one concrete syntax to represent the elements of this abstract syntax. In our platform, it is implemented in the form of textual forms and graphical diagrams. Therefore, a treatment plan's elements are e.g., represented in a diagram. The structure of a treatment plan diagram is shown in Fig. 1. Treated risk factors, interventions, and challenges used in the process, as well as devices, questionnaires, and notifications to remind the individual, should be represented here as nodes. To build the relationship between the nodes and to compose the treatment plan, these nodes shall be connected by edges (arrows). A connection from a risk factor to an intervention means that the connected intervention treats the risk factor. Interventions are connected to so-called Challenges, each of which is a component of the intervention. The outgoing edges of a challenge describe which Devices or Questionnaires are used for monitoring as part of the challenge and which Reminder for that challenge have been created for the individual.

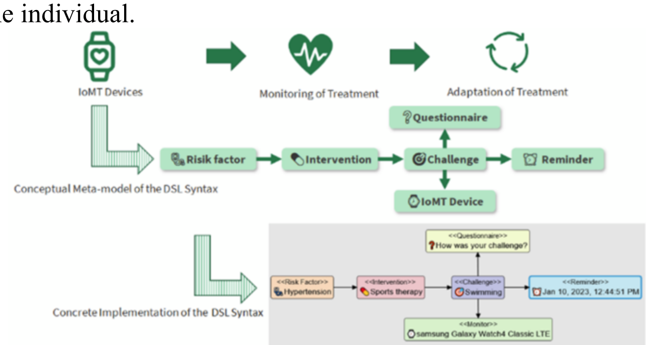

Figure 1. The design steps of the DSL are shown in three abstraction levels. On the top, the overall treatment process is displayed. In the middle, a conceptual representation of the DSL is presented. At the bottom, our system implementation is shown.

A system architecture shown in Fig. 2 was designed to use this DSL within the context of a digital dementia prevention and intervention platform. An Angular-based web application for medical professionals is implemented to interact with the platform [9]. This allows them to view and manage the treated individuals. The JSONForms framework displays and manages elements such as individuals, treatment plans, devices, and the elements in the settings tab [10]. The *Treatment Service* handles the management of individuals, their diagnosis, and treatment. This service was implemented based on technologies of the Eclipse Modelling Framework (EMF) [11]. The Eclipse Graphical Server Language Platform (GLSP) was used to implement the diagram editor for treatment plans [12]. This enables the development of web-based diagram editors consisting of a client and an associated server. The GLSP client was integrated into the

Angular web application and the GLSP server into the Treatment Service. The *Monitoring Service* enables retrieval and collection of monitoring data from individuals' IoMT devices A Nest server was used to implement this service. For data storage, the microservice also uses MongoDB database. To fulfill the requirement of interoperability of the platform with existing medical infrastructure, the Fast Healthcare Interoperability Resources (FHIR) standard was used to persist treatment data [13]. This defines a uniform data format and interfaces for exchanging health data between software systems. For some elements, mapping to FHIR resources is not straightforward. This includes, e.g., additional information on risk factors. There is no suitable resource for these. Therefore, the condition information of a risk factor is bundled in the Basic resource. The Basic resource is used for concepts that are not yet included in the standard. To store information about risk factors, the Basic resource is complemented by its own profile. A separate profile was also defined for other resources of the FHIR standard to adapt them to represent the data of the platform. These profiles define constraints on existing fields of the resource, as well as extensions to the resource. It can be used to persist the data within the FHIR Service. Individuals can eventually interact with medical professionals using a cross-platform mobile application.

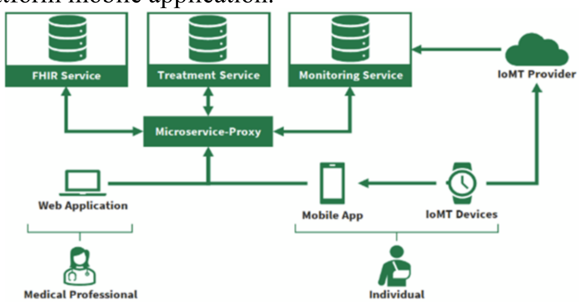

Figure 2. Architecture of the risk factor intervention platform. A microservice proxy and IoMT service providers enable communication between the patient/individual side and the medical professional.

4. Evaluation and Discussion

For the evaluation of the proposed DSL, the platform was checked for meeting all defined requirements. In addition, a usability study was conducted with a 20-minute questionnaire-based survey. In this, a one-sample treatment scenario was to be modeled by the subjects using the developed DSL as well as another variant of the platform that allows treatment to be administered via forms only (wizard-style). A total of 12 subjects participated in the study, ranging from 10 to 25 years of computer experience. For the quantitative assessment of usability, the usage questionnaire by Prümper was used, which is based on ISO 9241-110 standard [14]. Overall, administration via forms performed better than administration via the developed DSL. The results of the user questionnaire showed the advantages of forms over models, especially in terms of ease of learning and conformity to expectations. The model-driven platform, however, performed better in fault tolerance and self-descriptiveness. Ten of the twelve participants also indicated a preference for form-based over model-based management. The primary reason for this is that the latter enables easier use without prior knowledge due to the predefined structure. The advantages of model-based management were located by the participants in the clarity and reviewability of the system. The study could not confirm the hypothesis of improved usability using models, at least for the selected example scenario. The selected scenario was, however, limited by the functional scope of the form-based variant of the platform and the time frame of the evaluation. For the triage and understanding of treatment plans with more elements, the graphical models could nevertheless be advantageous.

5. Conclusion and Future Work

Based on the findings of the literature research and the defined requirements of the platform, a DSL was designed, which supports the management of treatment plans and the configuration of the monitoring. For this purpose, the syntax of the DSL was designed to create models for the planning and monitoring of treatments. Furthermore, the treatment plan can also be used to configure the monitoring of the treatment. The individual's equipment and questionnaires can be selected and added to the treatment plan. For devices, it is also possible to select which parameters, such as activity or sleep, are to be recorded. A transformation rule was developed that maps these models to corresponding FHIR resources. In the future, these FHIR resources will be retrieved and displayed by the individual's mobile application. Therein, the individual should be able to display an overview of the active treatment plans and their challenges, i.e., goals and tasks to be completed. We want to deliver reminders to the individual via the app in the form of notifications so that they are reminded of their challenges and interventions. This work presented a DSL and data representation, the cornerstone for an overall system capable of dementia risk management and treatment. We are confident in delivering and evaluating user-centered mobile applications soon.

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