Development of eHealth Applications Applying the eHix Framework

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***Abstract*—This paper presents, as part of the Hightech@home project, the development of eHealth applications applying the eHix framework. The eHix framework is presented together with comparable approaches. Then, a development method based on the Value Proposition, the User Requirements, the Technology Scan and the Design cells of the eHix framework is described. Following a case-based approach, this development method was applied to design eHealth applications intended to support clients and client guides of an organization caring for people with intellectual disabilities. This resulted in a design of an alarm system augmented with video communication and sensor technology. The method is considered suitable for small-scale development processes with a high degree of client customization, although it was recognized that the resulting applications represented a more general concept.**

Keywords- eHealth; development framework; requirements analysis; user-centred design.

I. INTRODUCTION

Despite numerous promising eHealth initiatives it has not gone unnoticed that many of the implemented systems did not survive beyond the pilot phase [1][2]. A participatory development process involving stakeholders, such as patients' associations, government officials, insurers, and decision-makers [3][4], preferably embedded within a business-model approach [5], has been advocated to improve the development and implementation of eHealth. In such an approach, application design based on an investigation of end-user requirements [6] plays an important role. In this paper, requirements elicitation and design of eHealth applications in cooperation with the intended users will be presented.

The eHealth development was carried out in association with Frion as part of the Hightech@home-project [7]. Frion is an organization in the Dutch province of Overijssel that supports some 950 people with intellectual disabilities. More specifically, eHealth applications were considered for both an intramural and an extramural department.

This paper is organized as follows. In Section II, existing approaches for the development of eHealth will be discussed including the eHix framework [5]. This approach, which is being developed by the Research group IT Innovations in Health Care, has been adopted as the basic framework for this study. In Section III, the method applied for requirements elicitation and design are presented, followed by the results achieved in Section IV. Finally, in Section V, the paper is completed with a discussion, a conclusion, and a description of future work.

II. BACKGROUND

In this section, the eHix framework will be discussed together with related work.

A. The eHix framework

The *eHealth innovation Matrix* (eHix) is intended as a tool to achieve successful implementations of eHealth innovations [1][5]. In this approach, the business model domains of the STOF method [8] are utilized, namely:

- the Service domain describing the service offering, its added value, and the market segment in view.
- the Technology domain describing the technology necessary to realize this service.
- the Organization domain describing the network of parties which together will provide the service.
- the Financial domain describing, amongst other things, the way in which these parties will generate revenues from the service offering.

To these four domains five phases, which describe the innovation process, are added:

- the Inventory phase, in which needs and conditions of the users of the new service are explored, as well as what is necessary to realize and maintain it.
- the Design & Development phase, in which the intend service is realized.
- the Experimental phase, in which the newly created service is tested, typically in laboratory conditions.
- the Pilot phase, in which the service is tested under realistic conditions, typically involving end users.
- the Implementation phase, in which the service is launched once it is considered feasible.

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The four domains and five phases together form a matrix with 20 cells as depicted in Figure 1. A cell describes the steps and choices for a specific domain and phase. The accompanying website [9] contains information and tools for that purpose. Because in this paper requirements elicitation and design are considered, it is only necessary to focus on the four cells in the upper-left corner of the matrix:

- the Value-Proposition cell comprising aspects such as the envisaged end users, their needs, and the value the new service will offer them.
- the User-Requirements cell comprising aspects such as e-readiness and the elicitation of requirements for the service, fulfilling the needs of the end users.
- the Technology-Scan cell containing a scan to investigate the available technology for realizing the intended service.
- the Design cell comprising the aspects of the application's design, such as the architecture and the development method.

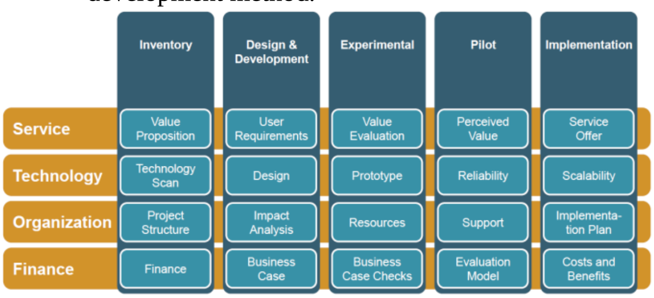

Figure 1. The eHix, comprising twenty cells

B. *Related work*

In this section, related work will be discussed, not only to demonstrate similarities and differences with the framework of choice, but also to present useful notions from the literature which will be applied in Section III.

1) *Technical Action Research*

The design-science approach presented in [10] does not start with a general problem for which an artefact is then designed, but at the opposite end with the design of the artefact, which is iteratively improved. To distinguish this artefact-driven approach from a problem-driven one it is called *technical action research* (TAR).

The notion of an engineering cycle for the development of a useful artefact (e.g., an eHealth application; it should be noted that the artefact concept is taken broadly by the authors: "Artifacts may consist of software or hardware, or they may be conceptual entities such as methods and techniques or business processes.") plays a central role in Technical Action Research. This cycle consists of a Problem Investigation task, comparable to the Inventory phase of the eHix, followed by an Artefact Design task comparable to the Design & Development phase. The engineering cycle presented in [10] does not explicitly contain a counterpart for the Experimental phase, although it is recognized that the artefact should be tested first under idealized circumstances in a laboratory. It does, however, contain a Design Validation task resembling the Pilot phase, followed by an Implementation task, in which the artefact is transferred to the economy. The results of the following Implementation Evaluation may lead to new questions for a next Problem Investigation, thus closing the cycle.

The Design Validation task may be carried out by performing one or more pilot studies. Each of these studies again contains all the steps of the engineering cycle.

2) *The CeHRes Roadmap*

The CeHRes Roadmap is designed for planning, coordination, and execution of eHealth development in which stakeholder participation is of vital importance. Ideally, at the outset a multidisciplinary team is formed which carries out research and development in five main phases. In the Context Inquiry phase problems, end users, and stakeholders are identified. In the subsequent Value Specification phase, values of stakeholders are identified and user requirements are defined. Then, in the Design phase, technology (including prototyping and business modelling) is developed, preferably in a joint effort by the design team, prospected users and stakeholders. Next, the technology is launched in the Operationalization phase, after which it is evaluated in a final Summative Evaluation phase (preceding phases are evaluated formatively). This last phase, comparable to TAR's Implementation Evaluation, complements the eHix phases.

A requirements development approach, embedded in the CeHRes Roadmap, is treated in [11][12]. This approach again consists of five phases coinciding with the first three phases mentioned above. Again the process starts with forming a multidisciplinary team deciding on the goals of the eHealth technology. After this Preparation phase requirements development passes through an End User and Stakeholder Identification phase. In the subsequent Requirements Elicitation phase stakeholders are consulted to determine what the application should do and how it should be implemented. After a Requirements Analysis phase a design document is eventually created in the final Requirements Communication phase.

3) *User-centered design*

The importance of user involvement, pointed out in [11] [13], is fundamental in User-centred design (UCD). In [14] eHealth applications are designed applying UCD together with a conceptual model for the analysis of interactions between agents. Here, the design process comprises four phases: Analysis, Design, Implementation, and Evaluation. In all four phases, medical specialists were involved while patients were consulted in the last three phases.

The development of an eHealth system for fall detection based on end-user centred design is presented in [15]. Not only care takers and elderly and their relatives are involved, but also health professionals and electricians.

In [16], user requirements are investigated using UCD for a tool to stimulate physical activity. A detailed user requirements document was written after three stages: Identification of end users and concepts, Concept development, and Tool (Re)design. To attain this result literature research, expert meetings, and (focus group) interviews were carried out.

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III. METHOD

To develop a concrete method for requirements elicitation and realization of eHealth applications the four cells of the eHix matrix (i.e., Value Proposition, User Requirements, Technology Scan, and Design) were augmented with insights from the studies mentioned above. Following the ideas of Technical Action Research, an artefact-driven approach was adopted taking a limited number of cases as a starting point. The development was carried out by a multidisciplinary team which collaborated closely with users or their representatives from the beginning [11][14]-[16]. In the remainder of this section the main participants in the process will be introduced, after which the steps which were carried out will be discussed.

A. Participants

An overview of the main participants is presented in Table I. Since halfway the project a new Project Manager was appointed, two managers are mentioned in the table. The first five participants are members of the Research group IT Innovations in Health Care, while the next five are employed by the healthcare organization. Participants 7 to 10 possess a long-term experience in guiding clients.

TABLE I. MAIN PARTICIPANTS

No.	Organization	Position	Gender
1	Research Group	Project Manager	F
2	Research Group	Project Manager	F
3	Research Group	Researcher (requirements)	M
4	Research Group	Junior Researcher	F
5	Research Group	Researcher (technical)	M
6	Frion	Operations Director	M
7	Frion	Member team Care and Home Automation	M
8	Frion	Member team Care and Home Automation	M
9	Frion	Client Guide (intramural)	F
10	Frion	Client Guide (extramural)	F
11	TriVici	Consulting engineer #1	M
12	TriVici	Consulting engineer #2	M

Contrary to one of the major principles of UCD no clients could be invited to participate in the user requirements elicitation, because it is unreasonable to expect a significant contribution from the clients in the intramural setting. Observing or interviewing the extramural clients living at home was not only considered an infringement of their privacy but false expectations should also be avoided. However, the clients were represented by experienced employees of Frion (Participants 7 – 10), who expressed the client’s needs to the best of their knowledge.

B. Steps for Value Proposition

Value Proposition started with a kick-off meeting, attended amongst others by the Project Manager and the Operations Director. This led to two interviews with both Client Guides, in which researchers received information about the clients of the care facility. Moreover, eHealth opportunities were explored. The Client Guides were then invited to present concrete cases. Desk research was performed to gain further insight into the target group. Since Technical Action Research is intended as an evaluation tool in the Pilot phase, a problem investigation scheme adopted from [10] was applied to complete the Value Proposition steps.

C. Steps for User Requirements

Based on the concrete cases put forward by the Client Guides, scenarios were written: short stories sketching the situation of the clients. The purpose of the scenarios was not only to verify whether the researcher’s picture of the situation of the clients was correct, but also to present possible solutions. Further, the researchers had the opportunity to carry out observations in the intramural setting. Subsequently, mock-ups were made, which were then reviewed in a focus group interview. Finally, a report summarizing the results was written.

D. Steps for Technology Scan

After determining the criteria for the intended applications, a technology scan was carried out. Additionally, experience with the resulting technology was gained in two preliminary implementations. Based on the outline of the intended applications from the previous investigations, a study of literature was carried out.

E. Steps for Design

Upon entering the design phase it was decided to focus mainly on the extramural cases. Because of the clear outline of the intended applications and a well-developed requirements analysis, the V-model [17] was selected as a development methodology.

IV. RESULTS

Based on four cells of the eHix framework a method to develop an eHealth application was presented in the previous section. In the present section the results obtained are described, again taking the four cells of the eHix matrix as a starting point.

A. Results for Value Proposition

The kick-off meeting and the additional interview showed a need to deploy eHealth technology: in the intramural setting to better ensure the safety of the clients and in the extramural setting to give the clients a sense of security. Moreover, the healthcare organisation wished to set off at a micro level, working closely with (end) users, which corresponded to TAR’s artefact-driven approach.

The invited client guides informed the development team about the living conditions of their clients, the difficulties people with intellectual disabilities face in modern society, and what it meant for them to guide their clients. It was agreed that the guides would come up with specific cases, describing real clients for which they expected eHealth to be promising. In a subsequent interview with the client guide from the intramural setting a case was presented describing a client for whom it is important to know his whereabouts, mostly indoors but also outside. For the extramural situation, two cases were presented: a client who might ask for

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assistance in difficult situations and a client who needed help to get up after a fall, which occurs frequently.

Desk research made clear that in the Netherlands the prevalence of people with intellectual disabilities is estimated to be between 0.7 and 1.4 % [18][19]. This percentage is expected to remain stable in forthcoming years, although the proportion of elderly is expected to increase. Moreover, a trend toward "extramuralisation" is visible [20], which means that fewer people are eligible for admission to a nursing home. This will only increase the need for eHealth to support clients living at home.

The problem investigation scheme mentioned in Section III C listed for example the stakeholders and their goals, such as the increased independence of a client as well as better and more efficient care.

B. Results for User Requirements

Based on the needs which had become clear from the cases presented, scenarios were written. For privacy reasons fictitious names were used for clients, guides and others.

In the intramural case, the scenario depicted the everyday life of the client, sketching a tool helping him to structure his daily activities, while the tool informed his guides about his localisation indoor and outdoor. For the extramural case of the client who would ask for assistance, an incident was described in which the client would be lost driving his microcar. During a video call his guide would manage the situation, reassuring the client, after she had recognized the surroundings. For the other extramural case three scenarios could be formulated, suggesting a solution with a personal alarm, a solution in which a fall was automatically registered after a certain period, and a smartphone application that enabled the exchange of messages via text or simple buttons.

In all three cases, these scenarios appeared to be a good basis for discussion and feedback, although the response differed. In the intramural setting it became clear that the case described was too limited: there appeared to be a broader need for the application of sensors such as bed sensors and nurse call applications. Discussing the extramural case for the client in his microcar, it proved desirable to add Global positioning system (GPS) localisation. In the other extramural case there was a general agreement on the last-mentioned option.

As mentioned before, extramural clients could not be observed at home by the development team for privacy reasons. Instead, their guide asked them about their opinion. This had to be done very carefully to avoid unrealistic expectations. The clients reacted positively. However, the development team did have the opportunity to observe the intramural clients and speak with the client guide's colleagues. This provided a better understanding of the target group, and made clear why the intramural scenario mentioned above was less appropriate. Moreover, it became clear that the required sensors would particularly be used at night, when the clients slept unobserved in a large home with only a single client guide present. Other homes within the organisation are overseen at night from an incident room. Visiting this incident room revealed the important role of audio surveillance.

Elicitation of user requirements was completed by making mock-ups in the form of sketches of the computer screens for the intended applications. These drawings were not intended as a definitive design of the application's user interface, but as a means for further reflection on the required functionality.

The focus group discussing the mock-ups consisted of researchers (requirements and technical), members of the Care and Home automation team and client guides, so that aspects such as usability, e-readiness of users, and technical details could be taken into account.

These requirements elicitation efforts culminated in a report summarizing the considerations made together with a list of concrete requirements. This report was again reviewed within the development team.

C. Results for Technology Scan

The technology scan carried out was partially determined by the agreements that were set out in the Hightech@home project plan. The use of open source software was required [7]. Moreover, WebRTC was chosen at the outset of the project for video and data communication [21]. The open source portal made available by the TriVici Foundation [22] implied the application of the Joomla! content management system [23].

Based, among other things, on this technology two preliminary implementations were realised in order to increase the understanding of the chosen technology. The first implementation focused on WebRTC video and data communication together with the real-time Session Initiation Protocol (SIP). In addition to WebRTC two other approaches for data transport were considered: HTML5 Local Storage and a direct connection between a single-board computer and a server. Building on the results of the first implementation the second rudimentarily realised the connection of sensors to a Joomla! website using the direct-connection approach. After considering a number of data-transmission protocols Message Queue Telemetry Transport (MQTT) was selected.

In their search for devices for the intended applications the development team realized that a smartphone was not only suitable to implement video contact and GPS location, but also added the opportunity of adding a fall detection sensor, using the accelerometer available in many smartphones [24]. An accompanying study of literature for the extramural cases therefore focused on four themes: (a) personal alarm [25][26], because clients would seek contact with their guides in case of an emergency or in a difficult situation, (b) video communication [27][28], which was expected to be a more effective means to reassure clients compared to audio contact, (c) fall detection [24][29]-[31], aimed at client who fall frequently, and (d) GPS localisation [32][33] to determine the location of clients in need of help. This study made clear that, besides technical aspects, attention should also be paid to issues such as privacy, acceptance, ease of use, autonomy of users and wishes of other stakeholders. It could further be noticed that the development of fall sensors receives much attention in the literature. Literature studied regarding the intramural setting showed that commonly used nurse call systems may be augmented with additional information, making the systems context aware [34].

D. *Results for Design*

Although at the time of writing the design, realization and testing of the intended applications were not completed, a sketch of the application, as depicted in Figure 2 can be presented. On the left of the figure, the device for the client is visible, equipped with an alarm button, fall detection and/or GPS functionality. The Internet connects the client application with devices for the client's guides together with functionality for administration and logging. A storage and processing unit stores logging data and generates the web pages of the TriVici portal.

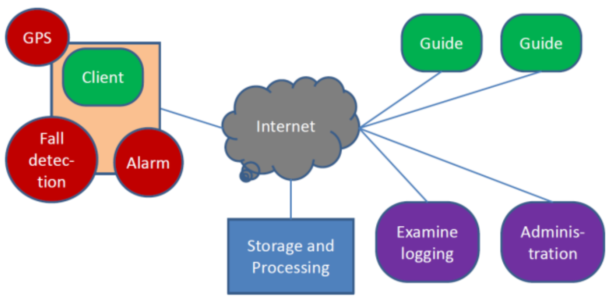

Figure 2. Sketch of the intended application(s)

The design of Figure 2 may be considered as an expansion of the well-known personal alarm with sensors as well as video instead of audio communication. Note that other sensors could be applied as well. In this concept the guide will be better informed about conditions of her clients (including the possibility of an automatically generated alarm, e.g., in the case of a fall) and has better means of communication at her disposal, compared to traditional personal alarm systems.

V. DISCUSSION AND CONLUSION

In the previous sections, the development of eHealth applications to support clients and client guides of an organization entrusted with the care of people with intellectual disabilities has been sketched. This resulted in an alarm system augmented with video communication and sensor technology.

The development process, carried out by a multidisciplinary team, was based on a few well-documented but anonymous cases put forward by the client guides. The development process followed the relevant cells of the eHix framework and included written scenarios and mock-ups.

A. *Discussion*

Although the actual clients were described in the scenarios, unfortunately it was not possible to interview them directly, which in a user-centred approach is undesirable. They were, however, represented by their guides, who know them well, but only after a pilot it will become clear whether the applications are suitable for them.

It may further be noticed that the design is based on only a small number of cases, contrary, for example, to the development of personas found in [35]. However, the clients considered here often demand a higher degree of customization. In that case the more lightweight approach presented here may be advantageous. Moreover, focusing on concrete cases makes the researchers aware of relevant details. Remarkably, the resulting design was recognized by Frion's employees as a generic concept. Following a case-based method, a generally applicable approach has been derived.

A further characteristic of the specific approach used here is the tight connection of user-requirements elicitation, finding solutions, selecting technology, and design of solutions. We may notice, in other words, a risk of "jumping to solutions" with too little room for the creativity of the design team [11]. Again, a balance should be found between thoroughness and the practical demands of a development process with a high degree of client customization.

Finally, it was found that in the process of co-creation the scenarios and mock-ups proved their value in facilitating the communication between members of the multidisciplinary development team.

B. *Conclusion and future work*

Based on the experiences described, it may be concluded that a practicable development approach for eHealth applications with a considerable degree of user customization has been presented. Clearly, the design should be completed for the intended applications, and the other cells of the first two phases should be taken into account. Then, in the subsequent Experimental and Pilot phase the usefulness of the result should be established, after which it can be determined whether further implementation will be promising.

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