Adherence to medical recommendations and treatments by elderly patients: USEFIL web services addressing this challenge

Homer Papadopoulos
National Center for Scientific Research, “Demokritos”
homerpap@dat.demokritos.gr

Antonis Korakis
NCSR “Demokritos”
antoniskorakis@dat.demokritos.gr

Abstract

USEFIL is proposing an integrated system which will cope with ageing problem providing advanced, affordable and unobtrusive monitoring and web communication solutions for seniors living independently. Older adults face many challenges to their independence, often related to feeling loneliness, to a decline in mobility or cognition causing for example unintentional medication non-adherence. The “adherence USEFIL system” provides efficient and effective means of increased adherence to medical recommendations and treatments by elderly patients and thus extends the time that older people can live independently in their homes while limiting increases in public expenditure.

This paper describes the design process of the services and apps of the “adherence USEFIL system”. Aim of the paper is to demonstrate the use of the Design Science Research Methodology (DSRM) to design an ICT solution for increasing adherence to medical recommendations and treatments by elderly people. More specifically using the theoretical lens of the Design Science Research Methodology theory the paper presents the necessary steps that have been conducted to design the “adherence USEFIL system”. Results demonstrate that the exploitation of ‘off-the-shelf’ consumer devices readily succeeds in meeting the study’s initial objectives.

1. Introduction

Elderly people face enough challenges to their independence, often related to feeling loneliness, to a decline in mobility or cognitive problems. These challenges cause direct or indirect health problems. For example incorrect use of medications among the elderly because of forgetfulness and confusion are major causes of unintentional medication non-adherence (DeBettengnies et al. 1999).

Non-adherence in medical plans and treatments may result in increased use of medical resources, such as physician visits, unnecessary additional treatments, emergency department visits, and hospital or nursing home admissions. Furthermore there is a risk non-adherence to cause treatment failure.

Technology today is ubiquitous in nearly all age groups. Following the fact that most seniors utilize the Internet via tablets, computer or other mobile devices there is an increasing use of technology to assist with the care of the elderly (Hyysalo, 2004). A major driver for this is to reduce the costs of providing care. Current trends in Personal Health Systems, enabled by the unabated advances in ICT, can greatly contribute to the ‘stay independent’ solution (Stroetman, 2007).

This work describes the design, development and deployment of an adherence ICT system to support independent living of the elderly citizens as long as possible in their home. The system was developed exploiting the resources of the USEFIL platform and architecture which was designed for males and females at an age 65+ years old, with age related disabilities.

The Design Science Research Methodology (DSRM) has been followed in this work (Peffers et al. 2007; Hevner et al. 2004). DSRM provides a framework that is well suited to the creation of artefacts in the Information Systems arena while in parallel it helps researches to legitimize their research using understood and accepted processes.

The rest of the paper is structured following the main activities of the DSRM methodology. Section II reports on the problem identification and motivation, Section III presents the definition of the objectives for a solution, Section IV describes the design and development where we describe the elements of the adherence USEFIL system, Section V discusses the demonstration and evaluation and Section VI concludes the activity of Communication which is, partly happening in the writing of this paper. Finally Section VII discusses and concludes the paper.

2. PROBLEM IDENTIFICATION AND MOTIVATION
Studies Design-Centered Approach

The major problem that has been identified concerns the ageing population and the services and technologies we can develop to extend the independent living. One of the problem we identified is that as we age, we tend to live with more chronic illnesses and seem to require more daily medications. Thus older persons with chronic diseases and conditions benefit the most from taking medications, and risk the most from failing to take them properly. It’s obvious that among older adults the consequences of medication non-adherence may be more serious and less easily resolved than in other age groups (Hammarlund et al., 1985).

Given the fact that now seniors are actively engaged on the Internet it makes sense for medical professionals to use smart devices to assist patients with non-adherence behavior. Within the USEFIL project we addressed a narrower research question: if it’s possible to use the latest developments in consumer electronics—smart TV sets, smart watches, tablets and smart phones—to create an ubiquitous adherence system for assisting elderly people to adhere to their medical plans and thus extend their independent living. This question triggered a design- and development-centered approach building on the USEFIL platform of an adherence to medical plans system that enables the information flow in an ubiquitous way.

This design science research artifact was to be deployed across three different country pilots. The design-science paradigm seeks to extend the boundaries of human capabilities by creating new and innovative artifacts (Hevner et al. 2004). In the design-science paradigm, knowledge and understanding of a problem domain and its solution are achieved in the building and application of the designed artifact. However, designing useful artifacts is complex due to the need for creative advances in domain areas in which existing theory is often insufficient. The design process of the adherence USEFIL system following the Design- and Development-Centered approach building of the DSRM methodology is shown in Figure 1.

Figure 1. DSRM process for the adherence USEFIL system

Problem Identification and Motivation

The life expectancy in the EU as in other developed countries is continuously increasing and the proportion of elderly citizens in the population as well as the total number of seniors living alone is growing (Cannuscio et al. 2003). Older adults face many challenges to their independence, often related to chronic physical health conditions, to feeling loneliness, to a decline in mobility or cognition. These conditions generate behavioral problems to the elderly people such as non-adherence in medical plans and medication causing further health problems and burden in health systems. For example more than 10% of older adult hospital admissions may be due to non-adherence with medication regimens while non-adherence costs the US health care system $100 billion per year (Vermiere et al., 2001). Similar to the above Sokol found that for a number of chronic medical conditions—diabetes, hypertension, hypercholesterolemia, and congestive heart failure—higher rates of medication adherence were associated with lower rates of hospitalization and a reduction in total medical costs (Sokol et al., 2005).

Non-adherence with medical plans and medication can be classified as intentional, often related to the need to avoid drug-related adverse effects (Hughes, 2004; Fernando et al., 2006) or unintentional related to cognitive or visionary impairment (van Eijken et al., 2003), poor cognition (Gray et al., 2001) or cognitive decline, forgetfulness and confusion (DeBettengnies et al. 1990; Svarstad et al. 1999). More specifically older adults with impaired cognition, cognitive decline or memory problems may have difficulty understanding how to take their medications, forget to take a dose, or take too much (Krueger et al., 2005; Osterberg and Blaschke, 2005).
Furthermore, because older adults often suffer from multiple comorbidities and thus use more medications than other age groups, medication nonadherence can have drastic deleterious health effects on the elderly (Hughes 2004). Therefore, finding potential areas for interventions to help improve this process should be a top priority. The identified barriers that hinder an older adult from adequately adhering to prescribed medications and medical plans that the adherence USEFIL system will cope with concern poly-pharmacy, cognitive confusion and forgetfulness. Current trends in Personal Health Systems, enabled by the unabated advances in Information and Communication Technologies (ICT) can greatly contribute to the design and development of effective adherence systems. These adherence to medical plans and medication assistive living systems must be flexible and customizable as the needs of elders change and must diffuse the information in such a way that will help end users cope with their cognitive impairment and forgetfulness. Designers of such systems should develop tools for helping people to stay longer in house based on realistic costs, risks, and benefits.

3. DEFINING OBJECTIVES OF THE SOLUTION

The following objectives have been identified during the development of the USEFIL concept:

- To develop integrate off the self commercial products like Smart TV, smart watch, tablet and others into a simplified operational complete adherence system providing ease of use applications and services to the end users.
- To develop an adherence system that its installation will not require retrofitting of the residence of the elderly people
- To develop an adherence system being able to diffuse information to the end users anytime anywhere
- To evaluate the proposed adherence system in terms of the effectiveness of support in user adherence behaviour
- To evaluate the proposed platform in terms of user acceptance and to demonstrate the efficacy of the proposed system to solve the problem by controlling and managing the flow of information within the house in order to diffuse information to the end users anytime anywhere and monitor their adherence to the predefined medical plans.

4. ADHERENCE USEFIL SYSTEM DESIGN AND DEVELOPMENT

The design of the adherence USEFIL system was based on well-defined needs and objectives. Following the Design-Centered Approach we did not want to develop this system from scratch but we preferred to exploit and use the high-level architecture of the USEFIL platform. This adherence application was built on the top of the USEFIL core infrastructure and has the ability to offer value services to elderly people, carers, doctors and familiares to offer quality services for the control and monitoring of the adherence behavior of the elderly people.

4.1 Overview

The main USEFIL platform components that were exploited for the adherence system are:

- A wrist-worn device able to be connected in the web
- A tablet PC to act as one the end-user interaction device.
- A Web-enabled TV as the main end-user interaction device and the main gateway towards external USEFIL services.
- Calendar and Messaging servers. The messaging service beyond the information diffusion will allow elderly, carers and relatives to have an open communication channel through the Web devices to interact with each other. Therapists and doctors’ communication will encourage the interaction, the adherence and proper delivery of treatments while closing the loop of health care. This will increase elderly’s adherence to medical recommendations and treatments.
- Relevant applications that exploited the web services of the USEFIL platform

The architecture of the adherence USEFIL system consists of three main servers which are replicated to another three external identical servers for failover, backup and disaster recovery. The USEFIL system follows the three tier systems architecture, separating the system to the database tier hosted on Ubuntu server, the API tier hosted on Windows server and the Presentational layer which deploys all the user interfaces hosted on CentOS server. The Davical Calendar Server and the XMPP Server are also hosted in the same server as shown in the following Figure.
The design of the adherence USEFIL system consists of the following modules:

4.2 Calendar Server
The USEFIL Calendar Service is using a Calendar Server. It is a calendar management and scheduling system. It allows recording and managing timed events and tasks and it supports multiple users. The Calendar service is intended, first of all, for recording and reminding of treatments, such as medications and exercises, but can also be used for other, e.g. social, purposes.

All the user’s appointments, reminders and other scheduled events are saved in the Calendar Server Database. The connection with the database is achieved only via web services for security reasons.

4.3 XMPP (Extensible Messaging and Presence Protocol) Server
An XMPP Server is used for the implementation of the adherence USEFIL Communication Service. The purpose of this service is to provide a communication link between users of the system. It supports instant messaging and notification sending. The instant messaging function allows users to send messages in real time to their friends. It also supports offline messaging: user can send messages to offline contacts, the messages will be displayed as soon as the contact becomes online. Notifications are displayed in the applications, providing useful information to the user in a quick and direct way. All the data that XMPP Server needs are saved in its Database.

4.4 Databases
The adherence USEFIL system consists of four databases:

1) USEFIL Global DB is an off-house database server storing data on a number of elderly users. It is ‘global’ in the sense of being the single one for the whole USEFIL system deployment. The database server also provides all the necessary functions for storing, retrieving, updating and maintenance of system’s data as well as all the necessary mechanisms for data integrity.

2) Calendar database is responsible for storing all data relative to the calendar service. All user’s reminders, medication reminders, appointments data are stored and retrieved from the calendar database.

3) XMPP messaging database holds all the information concerned for the messaging service.

4) Redis database is used to store and retrieve the messaging and notification history (XMPP messaging).

Direct access to the databases is forbidden and it is feasible only via secured web services.

4.5 Web Services
Due to security considerations, all databases are not accessible for other components of the system, except for Server Web API service. Therefore, Server Web API provides a single controlled access point to the database. Server Web API is also responsible for user registration between the Calendar, the Messaging and the USEFIL portal services. Using the registration method on the Server Web API, a user automatically gets registered in all the above mentioned USEFIL services. Then the user providing the same credentials can login in all the services available. Server Web Application Programming Interface (API) consists of a set of Web Services, typically one per Global DB table. Every Web Service defines a number of functions (operations) that clients can execute by sending a SOAP message.

4.6 Applications relevant to adherence service

TV Application
The role of the application is to provide users, registered in the system an easy way to use all the system’s provided services. There are two different interfaces, one for the elderly people and one for the Health Staff. The services that are provided through the application include
communicating with other users (friends) through a chat service, viewing the medical history and current status, visualizing health data, exercising through physical training service and cognitive training.

In particular, the application uses the calendar service to display user’s appointments, reminders and other scheduled events. It also displays notifications about medications or doctor appointments. The user or his doctor can add new events or reminders in user’s calendar. It also supports viewing the medical history and current medical status. The user can view diseases and treatments that are added by the Health professional staff. It also visualizes the health data of the users (data regarding person’s blood pressure, heart rate, glucose, weight, steps taken, calories burned etc.). The user can also view information, medical or not, about other system users as long as they are friends and have the appropriate access rights. Communication between them is available too. The instant messaging function uses the XMPP Server and it allows users to send messages in real time. The user gets a notification whenever a new chat message arrives.

Inside the application, the registered doctors can create questionnaires and prescribe them to the elderly people to be filled at a specific date and time. The answers are available for further analysis and evaluation.

Finally, a useful service is the emergency service. Users can configure their emergency contacts and contact them automatically and directly with an SMS or mail, in case of an emergency.

Special care was given in designing the application’s interface. It is a user interface which makes the operation easy, efficient, and enjoyable especially for elderly people.

The most important feature of the adherence USEFIL System that aims to provide efficient and effective means of increased adherence to medical recommendations and treatments by elderly patients, is the notifications service. It’s a service that shows important information to the elderly persons in an easy and direct way. There are four kinds of notifications:

- Reminder Notification
- New Medication Prescription Notification
- Medication Reminder Notification
- New Chat Message Notification

**Reminder Notification**

The elderly person can use the Calendar Service to add new reminders to his personal calendar. A new record is created in the calendar database. The Calendar Database is checked every 10 minutes for upcoming reminders in the next few minutes. When a reminder is found, the XMPP Server is used to send a notification to the corresponding user. The XMPP Server takes the message and sends it to all the applications (TV, pc, tablet, SmartWatch), where it is displayed and informs the elderly about the upcoming event. The reminder could be also created by the elderly’s doctor and could be an appointment or a medical recommendation regarding the elderly’s health status.

**New Medication Prescription Notification**

The elderly’s doctor can add medications to the patients, through the web application. Whenever this happens, a record is saved in the database and also a new notification is created and sent to the user’s account through the XMPP Server. The user is informed and can confirm when the treatment starts.

**Medication Reminder Notification**

As soon as an elderly starts a medication treatment, after the doctor has prescribed it, a new record is created in the Calendar Server Database that contains all the medications that the user will take during the treatment. The Database is checked for upcoming medications every 10 minutes. When a medication is found, a notification is created and sent to the corresponding user, through the XMPP Server. The notification message is displayed in all the user’s applications (TV, pc, tablet, SmartWatch) and contains information like the medicine name, the dosage and the medication time. This notification is very important as it prevents the elderly persons from taking incorrect medications or incorrect dosages, because of forgetfulness and confusion.

**New Chat Message Notification**

During the time the elderly uses the USEFIL System application, the Communication Service is active. The user is available for chatting with other users. Whenever a new chat message arrives from an elderly’s friend, a new notification popups in the applications (TV, pc, tablet, SmartWatch) informing the user and redirecting to the chat room as shown in Figure 3.
The idea behind the notifications service is rather simple. All the notifications are sent through the XMPP Server as a normal chat message would be sent, but displayed in a different way. The reminders Notifications are created from the Calendar Service, while the other notifications are created from the applications. For keeping a notifications history, all notifications, when created, are also sent in Redis where they are saved for easy and quick retrieval.

5. DEMONSTRATION AND EVALUATION
During the development of the application prototypes the adherence USEFIL system artifact was validated. More specifically pre-trials have been set up with real users / healthy individuals in the lab installations in order to apply iteration cycles between development tasks and user feedback.

In order to fully evaluate, improve and validate the whole USEFIL system, pilot studies are planned in three participating institution countries: Greece, Israel and the UK. Within these trials the adherence USEFIL system will be evaluated.

But beyond that further validation trials will be applied in the area of Athens evaluating mainly the adherence system. These trials will demonstrate the efficacy of the proposed system to solve the problem by controlling and managing the flow of information within the home environment in order to diffuse information to the end users anytime anywhere and monitor their adherence to the predefined medical plans.

For these pilot studies more specific clinical protocols that can be used to observe and measure how well the adherence USEFIL system supports elderly people have been designed. The pilot studies are planned for the final year of the project which is 2015.

6. COMMUNICATION AND CONTRIBUTION
The communication activities were conducted by all USEFIL partners because they were well-connected with European technological platforms and market and because of their expertise on exploitation and disseminations activities. Scholarly and popular communication of system functions has been conducted via the project Website www.usefil.eu and the Websites of the partners. Manuscripts relating to the adherence USEFIL system and applications have been published in academic journals, academic conference proceedings, professional outlets, workshops and exhibitions.

The communication strategy created a large awareness of the adherence USEFIL application.

7. Conclusion
The motivation behind the adherence USEFIL system is to diffuse information within 'off-the-shelf' consumer devices providing thus support to the elderly in their daily living. The system aims at improving the adherence behavior against the medical plans and medication of the elderly suffering from chronic diseases, cognitive decline and depression due to age.

The adherence USEFIL system goes beyond the current similar products and applications by bringing together, using USEFIL integrated system, a number of different technologies and common 'off-the-shelf' consumer devices that will provide information to the end user through many modalities.

Aim of the paper is to give an overview of the design process of the adherence USEFIL system. We have shown that the integration and exploitation of 'off-the-shelf' consumer devices along with internet services can form the basis of a low cost, minimally intrusive artifact which can be used to send ubiquitous information to help the elderly people to adhere to the medical plans.

8. ACKNOWLEDGEMENTS
The “USEFIL: An Unobtrusive Smart Environments for Independent Living” project (www.usefil.eu) is under a funding scheme of Small or medium scale focused research project (STREP) by FP7-ICT-2011-7. The partners of
USEFIL are: National Center for Scientific Research “Demokritos” (Greece), VTT Technical Research Center (Finland), University of Bremen (Germany), University of Warwick (UK), Aristotle University of Thessaloniki (Greece), Fraunhofer Heinrich Hertz Institute (Germany), Maccabi Healthcare (Israel), and TP Vision (Belgium).

9. References