

Self-serve ICT-based Health Monitoring to Support Active Ageing

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Abstract: Today, the healthcare monitoring is not limited to take place in primary care facilities simply due to deployment of ICT. However, to support an ICT-based health monitoring, proper health parameters, sensor devices, data communications, approaches, methods and their combination are still open challenges. This paper presents a self-serve ICT-based health monitoring system to support active ageing by assisting seniors to participate in regular monitoring of elderly's health condition. Here, the main objective is to facilitate a number of healthcare services to enable good health outcomes of healthy active living. Therefore, the proposed approach is identified and constructed three different kinds of healthcare services: 1) real time feedback generation service, 2) historical summary calculation service and 3) recommendation generation service. These services are implemented considering a number of health parameters, such as, 1) blood pressure, 2) blood glucose, 3) medication compliance, 4) weight monitoring, 5) physical activity, 6) pulse monitoring etc. The services are evaluated in Spain and Slovenia through 2 prototypical systems, i.e. year2prototype (Y2P) and year3prototype (Y3P) by 46 subjects (40 for Y2P and 6 for Y3P). The evaluation results show the necessity and competence of the proposed healthcare services. In addition, the prototypical system (i.e. Y3P) is found very much accepted and useful by most of the users.

1 INTRODUCTION

With the advent of relatively easy to acquire digital health sensors and the communication infrastructure, health monitoring at home is becoming increasingly popular. Such solutions present benefits for healthcare providers by enabling a more frequent and continuous monitoring of patients. Of equal importance are the benefits to the primary users, e.g. residents who are able to be aware of their own health parameters and their trends. An important question to be considered in parallel to technological development is how to interface the information obtained from the system to the users who may have little technical or medical expertise.

This paper presents an iterative and user centred design approach to develop an ICT health monitoring system for use at home. The system

integrates a number of off-the-shelf sensors into a larger Ambient Assisted Living (AAL) framework. Focus in this paper is put on the integration of the various sensor components and the presentation of information via services to the end users. Such services include summaries of health parameters, indication of trends and notifications of deviations. To validate the proposed approach, user evaluations have been performed in two countries with a selected group of elderly users. The work performed in this paper is part of a larger project called SAAPHO, whose aim is to integrate health, social and security services seamlessly in the same architecture. This paper focuses only on the health services, their design, and evaluation. The evaluation results show the necessity and competence of the proposed healthcare services. In addition, the prototypical system (i.e. Y3P) is found very much accepted and useful by most of the users.

2 RELATED WORK

SOPRANO (Soprano, 2014) project aims to develop smart ICT-based assisted living services with easy to use interfaces for older people. PERSONA (Persona, 2014) aimed at advancing the paradigm of Ambient Intelligence (Aarts, 2004) for the development of sustainable and affordable solutions for the independent living of elderly. Many other research projects address the need of older people independent living through promotion of active ageing (Czaja, 2005) and healthy habits. AMICA (Crespo et al, 2010) tries to emulate the medical consultation at home: auscultation and interview. CCE (Hanák et al, 2012) is a dementia solution, which comprises of connectivity between the different physical components, sensors, medication dispenser, server, and Net TV. The H@H system (Health@Home, 2014) gathers the wearable sensors data, which continuously monitor patients' physio-pathological cardiovascular and respiratory parameters. The HELP (Claas et al, 2012) project proposes solutions to improve the quality of life of Parkinson's disease patients based on: a body sensor and actuator network and home devices to monitor the health parameters (e.g. blood pressure) and body activity (e.g. to detect gait, absence of movement). Another project IS-ACTIVE (Ruxandra et al, 2011) emphasizes the role of the home as care environment, by providing real-time support to patients. PAMAP is another healthcare system (Hendebly et al, 2010), which comprises information acquisition and management. Other mentionable AAL projects, which are currently dealing with healthcare systems, are: REMOTE, ELF@Home, Dalia, and eCAALIX that aim to be assistant systems for daily life of elderly (Catalogue of Projects, 2014). The authors in (Pantelopoulous and Bourbakis, 2010; Alemdar and Ersoy, 2010; Banaee et al, 2013) present reviews in the research and development of the wearable sensor systems in health monitoring. According to these reviews, most of the works are focusing on sensor devices and communication protocols, i.e. low-cost, energy-efficient ad hoc deployment of multi-modal sensors and Bluetooth, Zigbee, Wi-Fi, GPRS and 3G network communications. Similarly, authors in (Jovanov et al, 2005; Nee et al, 2008; Varshney, 2007) present their research on homecare monitoring where they have shown how to receive sensor measurements and represent these measurements on a computer or mobile device. Moreover, in (Pansiot et al, 2007; Ahmed et al, 2013a; Ahmed et al, 2013b; Ahmed et al, 2013c; Ahmed et al, 2012) the authors

presented remote health monitoring systems for elderly using wireless sensor devices. SAAPHO aims for an ICT based healthcare solution where the proposed services are essentially designed based on the feedback obtained from the elderly and intended for daily use.

3 THE ICT-BASED HEALTH MONITORING SYSTEM

The proposed approach has identified the healthcare services mainly in three different kinds of facilities for each parameter: 1) real time feedback generation service, 2) historical summary calculation service and 3) recommendation generation service. The goal of the *Real Time Feedback Generation Service* is to provide a feedback message based on sensor readings in real time.

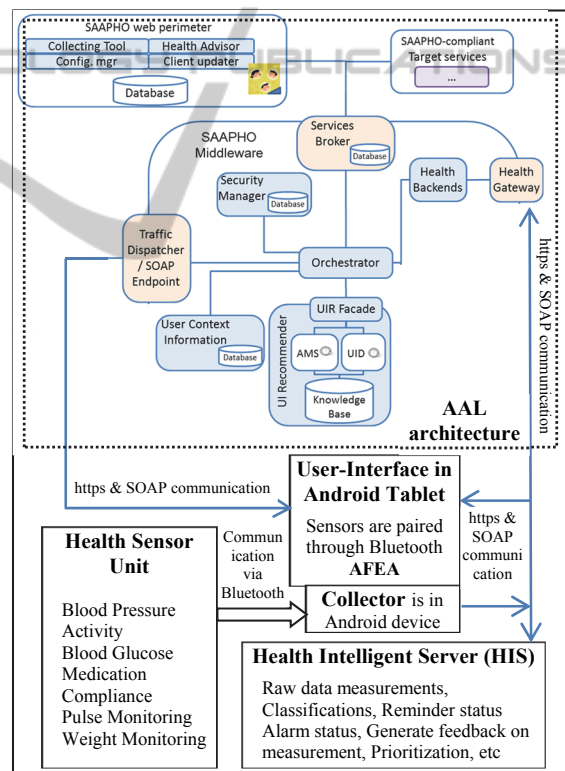


Figure 1: Architecture of the ICT-based health monitoring system.

Here, a rule-based classification method is applied to classify the measurements. For example, a blood pressure measurement 142/92 mmHg could be classified as "High blood pressure" and/or BMI 26.1 by measuring user's weight¹ could be classified

“Overweighed”. A set of rules used in the classification method is mainly collected from the literature study (MCMS, 2014; eCAP, 2014; Culhane et al, 2005; Alberti et al, 1998; Understanding blood pressure, 2014; Why exercise, 2014; Deurenberg et al, 1991), which is further validated through healthcare practitioners. The *historical summary calculation service* calculates historical summary on a daily and weekly basis. The goal of this service is to provide to the user a possibility to see and compare the summary in a graph for a specific range of dates. In order to calculate the summary, the service will use raw data measurements and the classification. This service mainly considers the frequency of classes and the number of total measurements. For example, in order to monitor medication compliance it calculates “total number of medication is taken”, “total number of medications”, and “total number of medications are skipped”.

The main objective of the Recommendation Generation Service is to generate a recommendation including reminder and alarm based on user’s historical summary and raw data measurements. Eight different kinds of recommendations are implemented: 1) *Devices_Not_Used* is generated if there is not any received measurement over one week duration, 2) *Medications_skipped* is generated if the number of medications skipped and the number of medication that should be taken in a day is equal, 3) *Out_Of_Normal_Range* is generated if 70% of the measurements classes are outside the normal range considering a week, 4) *Fluctuation* is generated if the measurements over a week show fluctuation in more than 70% of the cases, 5) *Weight_Loss* is generated if the current weight is less than 3 kg comparing to the previous weight (3 months ago), 6) *Weight_Increased/Weight_Decreased* is generated considering one month measurements and a calculated slope value, 7) *Activity_Increased/Activity_Decreased* is generated considering one week measurements and a calculated slope value, 8) A monthly summary is generated based on the raw measurements where statistical features i.e. maximum, minimum, average and standard deviation for each week are calculated. The detail about the healthcare services can be found in (Ahmed et al, 2014). The architecture of the proposed ICT-based health monitoring system is presented in Figure 1.

As it can be seen from Figure 1, the architecture is divided into two parts, i.e. the AAL (Ambient Assisted Living) and the rest. The AAL architecture

(presented in chapter 3.1) is used as a core framework of the proposed ICT-based health monitoring system. Here, AAL architecture is connected with the rest of the components of the health system via the user interface and the *Health Gateway*. The *Health Sensor Unit* contains of six health’s related preventive parameters recommended from the user requirements stage. Different commercial Bluetooth sensor devices were acquired to provide those parameters, for example, the blood pressure and weight monitoring devices are collected from a third party vendor OMRON² and BeneCheck³ and others are in-house products provided by the partner IZM⁴ which are under development. These sensor devices are paired with an android tablet device where it runs the *User-Interface* and the *Collector*. The *Collector* receives health measurements using Bluetooth Classic and Low Energy (BLE) communication from the sensor devices upon user request through the *User-Interface*. The *Collector* is based on native Java source code, which is in general the main programming language for Android devices. *Adaptive Front-End Application (AFE)* is the main module in the user interface (UI) application, which is in charge of handling the user interactions and of presenting the information in a way indicated by the AAL architecture. The interaction of the user with the *UI* involves, in some cases, requests for information to the *TD (Traffic Dispatcher)* for obtaining all the information requested by the user or needed by the device for presenting a correct interface for the specific user. As soon as the *Collector* receives the measurements it transfers them to the *Health Gateway* through https protocol and SOAP web service communication. The measurements are sent as a zip file including timestamps, battery and some other related information. The *User-Interface* developed to be delivered through Android tablets given their low cost, portability, direct interaction and ease of use. The *Health Gateway* mainly conveys the messages among the *Collector*, *Health Intelligent Server (HIS)* and *Middleware*. It classifies the measurements, calculates priority, asks the *HIS* for the message ID and finally forwards the data to the *Middleware* through *Health Backend* (presented in chapter 3.1). The *HIS* stores all the raw measurements and generates message ID for the communication. It also calculates daily and weekly historical summary and stores them in a MySQL database. The user has a direct access to *HIS* to see the historical summary through the *User-Interface*. *HIS* also generates recommendation in weekly basis based on historical

summary and raw data measurements. The generated recommendations are sent to the user through Health Gateway, Health Backend and Middleware.

3.1 AAL (Ambient Assisted Living) Architecture

The main objective of the AAL (Ambient Assisted Living) architecture throughout the SAAPHO project is to be accessible, adaptable, context-aware, interoperable, ubiquitous, scalable, and to be able to answer the requests of the *User-Interface* and of the health connected to it in an efficient way. With the collected ones that were published in (Doménech et al, 2013), architecture was designed based on the INREDIS architecture (INREDIS, 2014) and on the reference architecture of universal (UNIVERSAAL, 2014).

Traffic Dispatcher (TD) takes the requests of the user formalized by the *AFEA* about different types of information and obtains the response from the AAL architecture. These requests could be: login/logout of the user, obtain adaptations, obtain messages of the different services connected to SAAPHO or obtain URLs of external services. Among all of them, those relevant for the health services are the following:

- Obtain messages related to health. These messages are stored in the *TD* after they are received from the AAL architecture (sent by the *User Interface Recommender* or by the *Health Gateway*) and until *AFEA* asks for them and indicate to the *TD* that they have been shown to the user.
- Obtain the URL of the *Health Gateway*. This is useful to the *AFEA* to know where it has to send the measures taken by the *Collector* in the user's device.
- Obtain URLs with information of healthy habits. While the previous request of URLs is done by the *AFEA*, the user does this request.

User Interface Recommender (UIR) indicates the way in which the information should be presented to the user through the *User-Interface*, sends messages with generic recommendations, recommendations related to the services connected to the AAL architecture, or recommendations of new direct accesses to social tools. This component has a database that contains the information that could be useful for the generation of recommendations of information to be shown to the user and the information about the appearance of the interface (Character size, symbols used, font type, background

colour...) that the user selected in the Settings section of the *User-Interface*. In relation to the health services, the *UIR* stores the recommendations send by the *Health Gateway*, and they are used for generating recommendations for promoting active and healthy ageing considering the historical list of recommendations of the user. For example, the *UIR* can send a congratulation message when the level of a specific parameter is good during a period of time or send general advices for having a healthy life. Together with the generation of recommendations, the *UIR* is also in charge of creating the textual messages that are included in the health messages to be presented to the user in a suitable way. For this, the *UIR* studies the type of message, the gender, the language and the name of the user, and creates the text adapted to these characteristics. This text will be included in all the messages received from the *Health Gateway*. This component and the *AFEA* component are the *UI Model* and the *User Interaction Management* modules of universAAL (Sala et al, 2013)

Services Broker (SB) hosts a registry of descriptions of the services inside the AAL architecture but also of other services that could be useful for the users. Together with the storage of the information of these services, the *SB* also allows to link the user with them when he/she requests for a type of information (for example, online health newspaper), such as the *SB* makes a search of a specific service that satisfies the topics indicated by the user and that is more suitable for the profile of the user. This makes the platform accessible from a cognitive point of view, because the user, for example, does not need to know the name of the newspaper; he/she just says that he/she wants to read sport news. To do this, the *Services Broker* has also a database of users and their profiles and the searches done by them. This database is constantly updated with the new searches of the users and with new entries of services in the catalogue. The functionality of the *Context Management* and of the *Service Management* in universAAL is included in the *SB* (Sala et al, 2013).

The *Orchestrator* is the module in charge of abstracting all the dependencies among all the other modules of the architecture. This module redirects the communication from one module to another, decoupling each module from the rest, making the modules independent from each other.

Security Manager (SM) controls the access of the users and gateways to the system generating SessionIDs. To do that, it has a cyphered database with the information of the user, it generates

SessionIDs, and controls that the SessionIDs used in the AAL architecture are correct, cutting the sending of information when a wrong behaviour, or an incorrect SessionID, is detected. This involves four main different functionalities:

- User registration in the system. When a new user wants to use SAAPHO, his/her data will be stored in the *SM* database. The SAAPHO user identifier used by the architecture is the *UUID (Universally Unique Identifier)*, which guarantees that the user is identified in a unique way by any component in the platform but also out of the AAL architecture.
- User login. Each time that the user wants to use SAAPHO he/she will have to log into the *User-Interface*. This process involves the sending of the username and password to the *SM* and the generation of the sessionID if the data was right.
- Health Gateway registration. This process is similar to the previous one, but in this case the gateways are the components that send the parameters to be validated by the *SM* for obtaining the sessionID, and the parameter sent is a registration token.
- Validation of sessionIDs and userIDs.

Health Backend (HB) is connected to the *Health Gateway*, and it is in charge of prioritizing the information sent by the gateway and transmitting it to the user through the AAL architecture. The prioritization of the messages sent by the gateway is a function based on the priorities of the provided measures and the priority of the users; and the load balancing of the requests of the users to have a safe and efficient communication. The main operations in the *HB* are:

- Registration of the gateway in the AAL architecture. If the gateway is in the *SM*, the backend looks for a backend of the type of the gateway that wants to be registered with space to handle the load of a new gateway, and if there isn't any, a new backend of that type is created internally and in a transparent way for the gateway, that always sends the information to the same backend.
- Deregistration of the gateway. The backend frees up the space associated to that gateway and the sessionID of that gateway is closed.
- Forwarding of the real feedback and recommendations coming from the *Health Gateway*. When a new message is received in the *HB*, it is sent to the *Orchestrator* to be sent to the *UIR* for creating the textual message

through which the real feedback or the recommendation is presented to the user in the *UI*, and after that to the *TD* to be shown to the user.

4 EVALUATION

In order to assess the usability, accessibility, applicability, impact and user satisfaction, as well as detecting areas for improvement, the health monitoring system was evaluated using two different prototypes resulting of the second and third year of the SAAPHO project. The second year prototype (Year2Prototype) provided a complete vision of SAAPHO, including the *User-Interface*, but of limited functionality. The final and third year prototype (Year3Prototype) contained the full pack of functionalities, services and devices of the system.

4.1 Year2prototype (Y2P)

The prototype considered two health parameters (i.e. blood pressure and activity monitoring) with a part of healthcare services (i.e. real-time feedback generation and historical summary calculation). The aim of this evaluation is to test a prototype, which is very similar in functionality and appearance to the final one. The tasks related to health carried out by each end user were:

Task 1: Logging into the SAAPHO Platform with own Login data.

Task 2: Setting the preferred volume and text size.

Task 3: Checking the historical summary information of blood pressure.

Task 4: Measuring the blood pressure and reading the results.

Task 5: Checking the physical activity results.

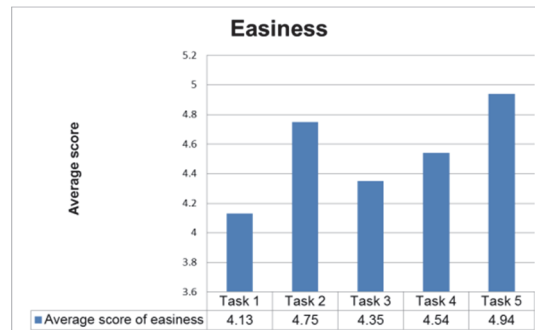


Figure 2: Average scores for easiness.

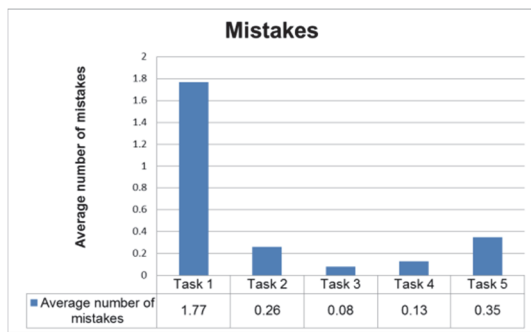


Figure 3: Average number of mistakes.

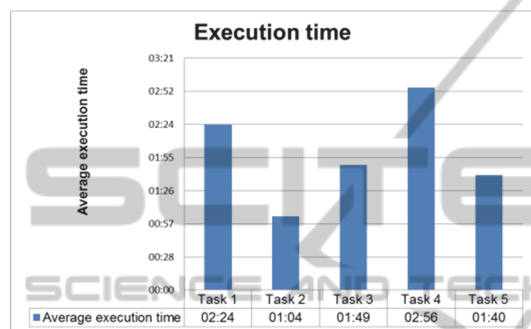


Figure 4: Average execution time.

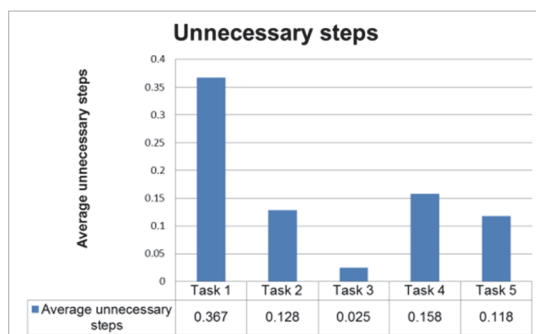


Figure 5: Average unnecessary steps.

20 users in Slovenia, and 20 users in Spain performed the tests. Each test took about one hour and a half, and the tests were conducted one by one, with a professional guiding the session, while a video camera recorded all the user interaction with the system. After the user carried out the complete set of tasks, he had to respond to a questionnaire that covered mostly the usability and applicability issues. Afterwards, every video was reviewed and analysed, so that every task for every user was documented as far as execution time, use patterns, etc. Four principles were considered for the main analysis: 1) user-rated easiness 2) number of mistakes 3) execution time and 4) unnecessary steps. The figures below present the average values for different tasks.

As it can be seen from figures 2 to 5, the SAAPHO platform was considered as being easy to use as most of the scores were above 4 on a 1 to 5 scale (i.e. Figure 52). Task 1 (Login to SAAPHO) was deemed the most difficult, this is probably explained, because it was the first task, where users had the first contact with the keyboard layout, but still many users complained about difficulties with most things related to text input. Similarly, Task 1 (Login to SAAPHO) had the highest number of mistakes; again, users had difficulties dealing with typing in text boxes (switching between fields was one of the major difficulties). System stability and performance also played a role in these cases. The summary of the health related tasks considering all four principles are presented in Table 1.

Table 1: Summary of the health related tasks.

Health Related Tasks	No. of Mistakes	User Easiness	Time	Unnecessary Steps
Task 3: Check Blood Pressure history	0.078	4.35	01:49	0.025
Task 4: Measure Blood Pressure	0.128	4.54	02:56	0.158
Task 5: Activity monitor	0.353	4.94	01:40	0.118

Most users commented on the health aspects of the SAAPHO platform as the one section they found the most interesting, even if only two sensors were used in Y2P testing (activity monitor and blood pressure monitor). Also, usability of the two health tasks of the system were deemed as very good, although the layout of the blood pressure history charts made the score a bit lower (hard to read and understand because of too much data and therefore text was too small on some charts).

4.2 Year3Prototype (Y3P)

The year3prototype considered most of the healthcare parameters (i.e. blood pressure, blood glucose, pulse monitoring and weight monitoring) and services defined in section 3. The composition of the trial formed by six participants from Spain (n=3) and Slovenia (n=3). They were invited to use the SAAPHO platform at their own home at least during a month. The mean age of the 3 participants in Spain was 69.3 (SD: 9.9); 66-72 years and the mean age of the 3 participants in Slovenia was 65.7 (SD: 9.9); 60-74 years. Regarding the gender both in Spain and Slovenia, 66.6% of the participants were women (n=2) and 33.3% were men (n=1). 100% of participants had experience using computers. 66.6%

had experience in using tablet PC and all of them had Internet at home.

Table 2: Summary of the health related questionnaire.

Healthcare services	Questionnaire
Real-time feedback generation	Q1. How do you like the feedback messages Q2. How useful is the SAAPHO measurement's classification Q3. Any Comments on feedback messages
Historical summary	Q4. How useful are the feedback charts Q5. Any Comments on feedback Charts Q6. How useful are the Daily-wise historical summary charts Q7. How useful are the Weekly-wise historical summary charts Q8. How useful are the raw data/historical summary charts based on a selected date range Q9. Any Comments on Historical Summary Charts
Recommendation	Q10. How do you like the recommendation messages on "Devices_Not_Used" Q11. How do you like the recommendation messages on "Out_Of_Normal_Range" Q12. How do you like the recommendation messages on "Weight_Loss" Q13. How do you like the recommendation messages on "Weight_Increase/Weight_Deceased" Q14. How do you like the recommendation messages on "Activity_Increase/Activity_Deceased" Q15. Any Comments on Textual Recommendation messages

Each participant was equipped with a tablet running the SAAPHO platform in the Y3P version. They had to conduct several tasks in order to familiarize themselves with the system and to know all possibilities that SAAPHO offers. Researchers contacted them frequently in order to check their experience. First 3 days of monitoring, users had to perform some specified tasks prepared by SAAPHO in order to familiarize with the system.

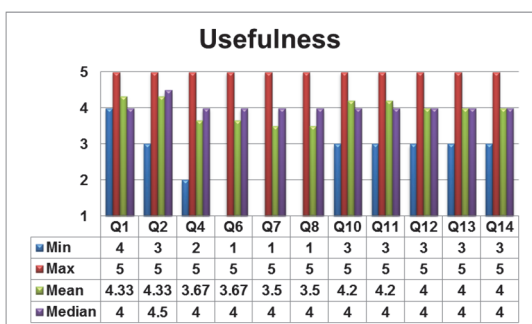


Figure 6: Statistical analysis on the score of usefulness.

After the 4th day the users were supposed to have enough knowledge of the system to be able to work

autonomously and they experimented with the system by themselves. After completing the 4 weeks of testing, a set of questionnaires' was provided to the users in order to evaluate the usefulness of the proposed healthcare services. The questionnaires were divided into three parts. User's answers were collected both in textual form and as evaluations (a 1 to 5 scale). The Table 2 presents a summary of the health related questionnaire.

As it can be seen from the figure 6, most of the questions have the answer 5 as maximum score and for average and median are around 4. However, the minimum scores are very low i.e. 1 or 2. The reason behind this is that one of the participants had problems with sensor devices and Bluetooth connections and thus was not able to access the functionality of the system properly.

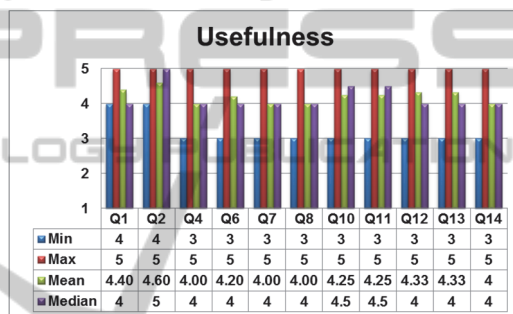


Figure 7: Statistical analysis on the score of usefulness after removing the outlier.

If the evaluation of this participant is considered as outlier and removed from the analysis then the result could be improved as presented in Figure 7. Here, the figure shows that the minimum score is 3 or 4 and the median of the some questions is 4.5 or 5. User's comments on the healthcare services are summarized and presented in Table 3.

As it can be seen from the evaluation result, the healthcare services through the prototypical system were acceptable by most of users both in Spain and in Slovenia. Here, all participants would recommend the proposed ICT-based health monitoring system to another older person since they considered it very easy and useful in relation to the offered services. Nevertheless, one of them mentioned again the users that could benefit the most from it: older people living alone or with his/her partner or caregiver; having health problems and/or mobility difficulties; without cognitive problems; living in an old building without lifts.

Table 3: Summary of the comments on healthcare services.

Healthcare services	Positive comments on the services	Others comments
Real-time feedback generation	The feedback messages are excellent. The feedback messages are useful for quick information and a general feeling. Very practical and clear	I did not receive notifications about activity.
Historical summary	The changes in blood pressure and weight values are very welcome for the health evaluation. The changes in blood pressure and weight values are interesting. Charts were very transparent. Very practical and clear. By choosing the date range it is easier for me to determine the time that interests me and the health status at that time.	In relation to Weight, I would like to have more information about the ideal weight. In relation to BP, data are difficult to interpret.
Recommendation	Textual Recommendation messages were excellent. Recommendations were understandable and correct. To recommend contacting with the doctor in case of not having good health results is a good idea.	Information received is not clear. I am not able to judge as I very rarely or almost never received the health recommendation messages.

4 CONCLUSIONS

This paper presents architecture of an ICT-based health monitoring system, which allows for information services connected to a number of wireless health sensors. The article also describes the integration of this system into a much wider and extended AAL architecture (i.e. SAAPHO) that aims to provide active aging to the elderly in their homes. The paper has complemented the technological aspects with user evaluation conducted in two countries. The aim of this work has been to investigate how users interact with monitoring system at home, how well they are able to take the measurements, and how well they are able to negotiate through the various menus and options. The aim of the paper has also been to evaluate whether there was a perceived usefulness of the system. Overall, the impression of the system has been positive provided that there is relative ease in operating the physical sensors. The level of detail of the information has been deemed sufficient and the textual recommendations were highly appreciated. Both objective and subjective measures were used for the evaluation. Future work will focus on

longitudinal evaluations deployed in larger user groups. Also, cross-cultural differences between the user groups will be studied when larger samples sizes are used.

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REFERENCES

- Aarts, E., 2004, Ambient Intelligence: A Multimedia Perspective. *IEEE Multimedia*, 11, 12-19.
- Ahmed M. U.; Banaee H.; Loutfi A.; Rafael-Palou, X., 2014. Intelligent Healthcare Services to Support Health Monitoring of Elderly, Accepted in the International Conference on IoT Technologies for HealthCare, HealthyIoT, at Rome, Italy.
- Ahmed, M.U.; Banaee, H.; Loutfi, A., 2013a. Health monitoring for elderly: An application using case-based reasoning and cluster analysis. *ISRN Artif. Intell.*, 2013, 380239.
- Ahmed, M. U.; Loutfi, A., 2013b. Physical Activity Identification using Supervised Machine Learning and based on Pulse Rate, *Advanced Computer Science & Application*, 4.
- Ahmed, M. U.; Loutfi, A.; 2013c. Physical activity classification for elderly based on pulse rate, in Proceedings of the 10th International Conference on Wearable Micro and Nano Technologies for Personalized Health.
- Ahmed, M. U.; Islam A. M.; A Loutfi.; 2012. A case-based patient identification system using pulse oximeter and a personalized health profile, in Proceedings of the Health Sciences at 20th International Conference on Case-Based Reasoning, Eds., Springer, Lyon, France, September 2012.
- Alberti, K.G.M.M., Zimmet, P.Z., 1998. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus. Report of a WHO Consultation. *Journal of Diabetic Medicine*, 15, 539-553.
- Alemdar, H., Ersoy, C., 2010. Wireless sensor networks for healthcare: A survey. *The International Journal of Computer and Telecommunications Networking*, 54, 2688-2710.
- Banaee, H., Ahmed, M.U., Loutfi, A., 2013. Data Mining

- for Wearable Sensors in Health Monitoring Systems: A Review of Recent Trends and Challenges. *Sensors*, 13, 17472-17500.
- Catalogue of Projects 2013, Ambient Assisted Living Joint Programme (AAL JP), Available online: http://www.aal-europe.eu/wp-content/uploads/2013/09/AALCatalogue2013_Final.pdf, (accessed on October 2014).
- Claas, A., Albert, S., Jordi, R. S., Simon, H., Alejandro, R. M., 2012. HELP: Optimizing Treatment of Parkinson's Disease Patients. *In proceeding of 3rd International Conference on the Elderly and New Technologies*.
- Crespo, M., Sánchez, D., Crespo, F., Astorga, S., León, A., 2010. Collaborative Dialogue Agent for COPD Self-management in AMICA: A First Insight. *Advances in Intelligent and Soft Computing*, 70, 75-80.
- Culhane, K. M., O'Connor, M., Lyons, D., Lyons, G. M., 2005. Accelerometers in rehabilitation medicine for older adults. *Academic Journal of Age Ageing*, 34, 556-60.
- Czaja, S. J., 2005. The Impact of Aging on Access to Technology. *SIGACCESS Access. Comput*, 83, 7-11.
- Deurenberg P, Weststrate J.A., Seidell J.C., 1991. Body mass index as a measure of body fatness: age- and sex-specific prediction formulas. *Br J Nutr*; 65(2):105-14.
- Doménech, S., Rivero, J., Coll-Planas, L., Sainz, F.J., Reissner, A., Miralles, F., 2013. Involving older people in the design of an innovative technological system promoting active aging: the SAAPHO project. *Journal of Accessibility and Design for All*, 3, 13-27.
- eCAP monitor for bottled medications, Information Mediar Corporation (IMC), Available online: <http://informationmediary.com/ecap> (accessed on October 2014).
- Hanák, P., Kiss, N., Kovács házy, T., Pataki, B., Salamon, M., Seres, Cs., Tóth, Cs., Varga, J., 2012. System Architecture for Home Health and Patient Activity Monitoring. *5th European Conference of the International Federation for Medical and Biological Engineering*, pp 945-948.
- Health@Home, Available online: <http://www.aal-europe.eu/projects/healthhome/> (accessed on October 2014).
- Hendeby, G., Bleser, G., Lamprinos, I., Stricker, D., 2010. Healthy Aging using Physical Activity Monitoring. AALIANCE conference, Spain, 11-12, pp. 1-5.
- INREDIS. Available online: <http://www.inredis.es> (accessed on October 2014).
- Jovanov, E., Milenkovic, A., Otto C., de Groen P.C., 2005. A wireless body area network of intelligent motion sensors for computer assisted physical rehabilitation. *J Neuroeng. Rehabil*, 2, 1-10.
- Medication Compliance Monitoring System (MCMS), Cybernet Medical, Available online: <http://www.cybernetmedical.com/index.php/mcms> (accessed on October 2014).
- Nee, O., Hein, A., Gorath, T., Hulsmann, N., Laleci, G.B., Yuksel, M., Olduz, M., Tasyurt, I., Orhan, U., Dogac, A., Fruntelata, A., Ghiorghe, S., Ludwig, R., 2008. SAPHIRE: intelligent healthcare monitoring based on semantic interoperability platform: pilot applications, *Communications, IET* 2008, 2, 192-201.
- Pansiot, J., Stoyanov, D., McIlwraith, D., Lo, B. P., Yang, G. Z., 2007. Ambient and wearable sensor fusion for activity recognition in healthcare monitoring systems. *Proceedings of the 4th International Workshop on Wearable and Implantable Body Sensor Networks (IFBME'07)*, pp. 208-212.
- Pantelopoulos, A., Bourbakis, N.G., 2010. A Survey on Wearable Sensor-Based Systems for Health Monitoring and Prognosis, *Systems, IEEE Transactions on Man, and Cybernetics, Part C: Applications and Reviews*, 40, 1-12.
- Persona Project, Available online: <http://www.aal-persona.org/> (accessed on October 2014).
- Ruxandra, B., Luminita, D., Alina, I., Horatiu, D., Ileana, C., Mihai, B., 2011, *IS-ACTIVE Project in Lab Trial Phase. In Romanian Journal of Physical and Rehabilitation Medicine*, 21, 64-65.
- Sala, P., Tazari, S., Farshchian, B., Furfari, F., 2013. The universAAL Reference Architecture. *universAAL Deliverable D1.3 – E* 2013.
- Soprano Project, Available online: <http://www.soprano-ip.org/> (accessed on October 2014).
- Understanding blood pressure readings. American Heart Association. Available online: http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/AboutHighBloodPressure/Understanding-Blood-Pressure-Readings_UCM_301764_Article.jsp, (accessed on October 2014).
- UNIVERSAAL. Available online: <http://universaal.org/index.php/es/about/about-project-description> (accessed on October 2014).
- Varshney, U., 2007. Pervasive healthcare and wireless health monitoring. *Journal Mobile Networks and Applications*, 12, 113-127.
- Why exercise with a Heart Rate Monitor, Available online: https://zsig.com/content/why_exercise_with_a_heart_rate_monitor_/, (accessed on October 2014).

¹<http://wserver.flc.losrios.edu/~willson/fitns304/handouts/bodyComposition.html>

²<http://www.healthcare.omron.co.jp/bt/english/>

³<http://www.glbiotech.com.tw/productdesc.php?ptid=11>

⁴<http://www.izm.fraunhofer.de/en.html>