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Intelligent Healthcare Services to Support Health Monitoring of Elderly

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Abstract. This paper proposed an approach of intelligent healthcare services to support health monitoring of old people through the project named SAAPHO. Here, definition and architecture of the proposed healthcare services are presented considering six different health parameters such as: 1) physical activity, 2) blood pressure, 3) glucose, 4) medication compliance, 5) pulse monitoring and 6) weight monitoring. The outcome of the proposed services is evaluated in a case study where total 201 subjects from Spain and Slovenia are involved for user requirements analysis considering 1) end users, 2) clinicians, and 3) field study analysis perspectives. The result shows the potentiality and competence of the proposed healthcare services for the users.

1 Introduction

According to WHO, healthy ageing is vital for countries' economic development because of it is one of the three pillars of active ageing [1]. Around two billion people i.e., one out of every four will be older than 60 years in the year 2050 according to [2]. As a consequence there is a need to provide efficient healthcare services to the elderlies. Here, the term 'Healthcare' means diagnosis, treatment and prevention of diseases and illnesses of human beings. Traditionally, a healthcare service is mainly focusing on primary care located at a local community where physician consultations take place for all patients as the 1st visit [3]. However, today, the healthcare services are not limited to take place in primary care facilities simply due to deployment of mobile devices and/or wireless communication. The result is a provision of service that could be accessible to anyone at any time and in anywhere with a good quality [4]. Research also shows that several projects like eCAALYX and HELP are on-going which provide home healthcare for elderly [5]. Similarly, due to the need to have ICT and globalization, several web sites or online based healthcare service providers are available in the market which provide possibilities to monitor health parameters such as blood pressure, blood glucose [9][10], and activity [16][17].

This paper presents the definition and architecture of healthcare service to support a health monitoring of elderly based on several health parameters through a project called SAAPHO[1]. In SAAPHO, six different health parameters have been considered: 1) physical activity, 2) blood pressure, 3) glucose, 4) medication compliance, 5) pulse monitoring and 6) weight monitoring. The project is offering intelligent, intuitive and user-friendly tools using a mobile tactile interface (android based tablet) and wireless sensor devices that will allow and facilitate the home monitoring. The sensor devices for these parameters are wearable and have Bluetooth communication to send raw data measurements in the cloud (i.e. Health Intelligent Server) for further processing. Data transfer is done using https and SOAP web services from the sensors to the cloud and cloud to user-interface. The proposed approach identified and constructed three different kinds of healthcare services for each parameter: 1) *real time feedback generation service*, 2) *historical summary calculation service* and 3) *recommendation generation service*. The *1st service* applies a rule-based reasoning technique on each measurement to generate a text based feedback message. The *2nd service* serve a daily/weekly wise historical summary based on raw measurements and store them into a MySQL database for offline access by the user. The *3rd service* generates reminder, alarm and necessary recommendation provided on a weekly basis. A comparison between a case study of user requirements and the proposed approach is presented where the user requirements are conducted by considering three perspectives namely 1) end users, 2) clinicians, and 3) field study analysis.

2 Definitions and Architecture of the Healthcare Services

The main objective of the healthcare services in SAAPHO is to monitor health parameters of elderly and warn them in time in order to increase their personal independence. Moreover, it also provides recommendations to take necessary steps such as when they should go to healthcare provider or do any physical exercises. For instance, considering a scenario of a healthy user, one might have a blood pressure machine or blood glucose measuring device at home and he/she might use the devices in his/her daily lives. However, the devices only provide some values i.e. 122/82 or 5.7 mmol/L [9] and if someone is technically sound they might have the possibility to use internet and Google and try to interpret the measurement values or need to ask to the health provider directly. At the same time, as soon as someone diagnosed with heart disease or diabetes, a clinician might want to see a historical measurement for a week or a month before they start to use any medication. For example, a diabetes patient often asked by the healthcare provider to use a log book or diary where they can write all the measurements they have taken [10]. Moreover, depending on patient's historical measurements a doctor provides his/her recommendation on food, medication or when they should meet again. Thus, the proposed approach has identified the healthcare services with 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. Here, a rule-based classification

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[1] http://www.saapho-aal.eu/

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 weight[2] could be classified “Overweighed”. A set of rules used in the classification method are mainly collected from the literature study [6][7][8][**9**][11][12][15] which is further validated through healthcare practitioners. For example, rules for blood pressure and medication compliance are presented in Table 1. The rule-based classification scheme is developed in an *Intelligent Health Gateway* (see chapter 2.1 architecture), where as soon as the gateway receives the measurements it classifies them.

Table 1. Rules are used to generate real time feedback for Blood Pressure and, medication compliance Systolic/Diastolic as mmHg.

Health Parameters	Rules to Generate Real Time Feedback
Blood Pressure (BP)	1. If Systolic < 90 or Diastolic < 60 then BP_class = “*Low*” 2. If Systolic is 90 to 119 and Diastolic is 60 to 79 then BP_class = “*Normal*” 3. If Systolic is 120 to 139 or Diastolic is 80 to 89 then BP_class = “*Pre-High*” 4. If Systolic > 140 or Diastolic > 90 then BP_class = “*High*”
Medication	1. If current_device_info != stored_device_info then message = “*wrong pills*” 2. If current_device_info= =stored_device_info and interval_time<60 then message = “*already taken the pill*”

It is crucial to keep and store all measurements especially if someone has diabetes or high blood pressure since this kind of diseases need a proper management in order to keep a healthy lifestyle. A weekly or monthly diary book is often used to keep track of blood glucose measurements and this helps to adjust medicine and food nutrition for a diabetes patient [9] as an example. A similar concept is proposed here in the *Historical Summary Calculation Service*, which means the service will calculate historical summary on a daily and weekly basis. This historical summary information is calculated automatically and stored into the *Health Intelligent Server (HIS)* as presented in chapter 2.1 architecture. A user has a possibility to see a summary in a graph for a specific range of dates. In order to calculate the summary, the service uses raw data measurements and the classification. This service mainly considers frequency of each 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 historical summary calculation service collects the measurements for each individual parameter for user from MySQL health database and starts historical summary calculation on a daily and weekly basis. The automatic scripts for calculating daily and weekly based historical summary are developed using PHP programming language where the script for daily-wise historical summary runs every day at 23:59 and the script for weekly-wise historical summary runs on every Saturday at 23:59 (once a week). After calculating the summary, the information is again saved and stored into the MySQL health database for further use.

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[2] http://wserver.flc.losrios.edu/~willson/fitns304/handouts/bodyComposition.html

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.

1. *Devices_Not_Used*: a reminder message is generated if there is no measurement received over one week duration i.e. the sensor device is not used for a week.
2. *Medications_skipped*: an alarm message is generated if the number of medications skipped and the number of medication that should be taken in a day is equal, i.e. the patient totally skipped taking his/her medication for that day.
3. *Out_Of_Normal_Range*: considering a week, if 70% of the measurements classes are outside the normal range, a recommendation message is generated to "Visit a healthcare provider".
4. *Fluctuation*: if the measurements over a week show fluctuation in more than 70% of the cases, a recommendation message is generated to "Go to a doctor".
5. *Weight_Loss*: the current weight will be compared with the previous weight (3 months ago) and the recommendation is generate "Visit your doctor" while the difference is more than 3 kg.
6. *Weight_Increased*/*Weight_Decreased*: considering one month measurements, a slope value will be calculated. Based on positive/negative slope value the weight increased/decreased recommendation is generated.
7. *Activity_Increased*/*Activity_Decreased*: considering one week measurements, a slope value will be calculated. Based on positive/negative slope value the activity increased/decreased recommendation is generated.
8. A monthly summary is generated based on the raw measurements where statistical features i.e. maximum, minimum, standard deviation, and average for each week is calculated. This information together with the date will be sent to the user via email.

The automatic script for recommendation generation is developed in the *Health Intelligent Server (HIS)* using PHP programming language and they run once in a week, i.e. every Saturday at 23:59. The generated messages are sent to the user according their priority value calculated based on user's age, health parameters and the classification. The monthly summary information and recommendation are also generated automatically once in a month and provide the information to the user's email.

2.1 Architecture of the Healthcare Services

In order to provide an intelligent healthcare service through SAAPHO, several components are considered and integrated. Fig. 1 presents all the components related to the healthcare service and communications between the components. The main components are: 1) sensor devices for healthcare 2) android based user-interface and collector 3) intelligent health gateway 4) health backend including middle-ware and 5) health intelligent server. The *sensor unit* contains six health related sensor devices and the devices are run by battery and communicate via Bluetooth communication. The sensor devices are paired with a Tablet where android operating system is installed. Some sensor devices are just bought from the market and integrated into the system, for example, the blood pressure and weight monitoring devices are collected from a third party vendor OMRON[3] and BeneCheck[4] and others are in-house products provided by the work package partner IZM[5] which are under development. The sensor is sending the data sets via Bluetooth Classic and Bluetooth Low Energy (BTLE) to the collector.

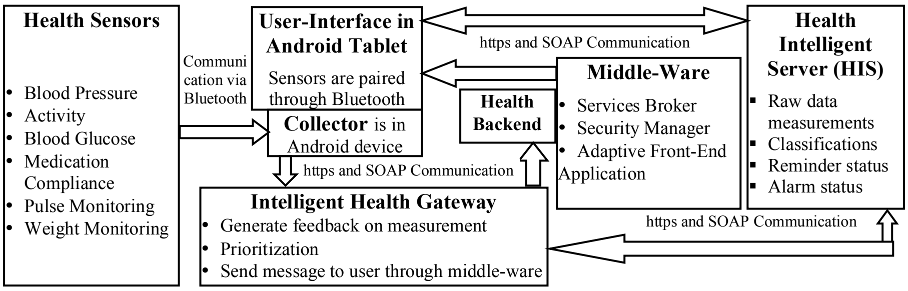

Fig. 1. Communication and components related to the Healthcare

In the Tablet, *user-interface and collector* are running, where the collector receives health measurements using Bluetooth 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. As soon as the collector receives the measurements it transfers them to the *intelligent 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 is developed using JAVA programming language so that it can run in Android 4.0 operating system considering the *Google Nexus 10* device. The *Intelligent Health Gateway* mainly conveys the message among the collector, HIS and middle-ware. It classifies the measurements, calculates priority, asks for message id to the *Health Intelligent Server (HIS)* and finally forwards them to the middle-ware through health backend. The *middle-ware* is a module collected from AAL (Ambient Assisted Living) architecture[6] which includes services broker, security manager, adaptive front-end application and etc. The *health backend* is the entry point of the *middle-ware*, where SessionID and UUID are for each user is generated in security manager. Adaptive Front-End Application (AFEA), is a module in the user's device, which is in charge of handling the interaction of the user with the User Interface and of presenting the information in the way indicated by the AAL architecture. Services Broker (SB) hosts a registry of descriptions of the services inside the AAL architecture but also of services out of it that could be useful for the users [14]. Middle-ware also stores all the service URLs and user ids and communicates with other components using health backend. Middle-ware receives the measurements and generates a textual feedback message based on the measurements and their classification. Finally, the textual message is sent to the user in SAAPHO user-interface. The *health intelligent server (HIS)* stores all the raw measurements and

[3] http://www.healthcare.omron.co.jp/bt/english/

[4] http://www.glbiotech.com.tw/productdesc.php?pdtid=11

[5] http://www.izm.fraunhofer.de/en.html

[6] http://universaal.org/index.php/es/about/about-project-description

generates message id for the communication. It also calculates daily and weekly historical summary and store them in a MySQL database. The user has a direct access to the 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 middle-ware.

3 Evaluations

During the SAAPHO's system design, a *questionnaire* is used to collect the users' needs and preferences. Here, the main goal was to collect the users' requirements to select the technology, devices, to design the components that the system should have, and to define the functionality. Regarding the questionnaires, participants were asked about general requirements for SAAPHO system. Participants also indicated their needs and preferences in monitoring their health (medication, activity and blood pressure). For example: 'How would you like to monitor your medication compliance – e.g. buzzer light…-?'; 'Would you be interested in monitoring your daily physical activity?'. The user requirements presented here considering three perspectives and they are 1) end users, 2) clinicians, and 3) field study analysis. The user requirements have been gathered via a field study conducted in Spain and Slovenia which included a questionnaire with 201 participants followed by 2 focus groups [13]. Below the paper compares the requirements and users viewpoints about the proposed approach i.e. the healthcare services to provide remote health monitoring of elderlies.

According to *end user perspective*, the activity monitoring device should monitor 1st the movement of a user in time stamped and classified them as none, low, medium or high level. 2nd it can also calculate the calorie consumption based on number of step counts and present information in a trending graph on calories/step counts. The blood glucose monitoring could measure blood sugar several times a day and in the case of diagnosed Diabetes it could provide the real time feedback. The blood sugar value could be stored with a time stamp which would then be analyzed to detect the status of diagnosed diabetes. It is important to monitor blood pressure for the elderly, moreover in the case of people who have already experienced high blood pressure. Forgetfulness is one of the leading reasons for medication non-compliance, which could be solved through a reminder system. The medication monitoring tool could track the drug regime and be able to raise alarms when not being followed properly and/or also reminding if the medicine was taken. Using the pulse monitoring tool, one could know whether the intensity of the physical activity was too high, exceeding the threshold value (especially with more strenuous exercises, like walking uphill, running, cycling). Regularly weight monitoring is also interesting and could be used once in a week and some recommendation is necessary when the weight is lost. Moreover and very important is the ease of use, affordability and ease of carrying the device on a person's body. The users would prefer a wearable sensor during training and read results later at home.

According to *clinical perspective*, glucose monitoring should be used by the individuals diagnosed from Type 2 Diabetes to monitor their blood glucose and typically these types of patients measure their blood glucose at least once a day. Activity monitoring could promote physical activity and enhance healthy ageing. Considering the pulse monitoring, it could be useful to detect heart rate during exercise as proxy of exercise intensity and provide information if the intensity of exercise they do is right or too demanding for them. In medication monitoring, the treatment plan of medication should be adjusted on a weekly basis mainly by the patients themselves and a formal or informal career. Depending on specified times (i.e. morning, midday, night, before sleep) a reminder could be generated and presented. Blood pressure is very important to measure for the older persons who are diagnosed with Hypertension (high blood pressure), as they typically need frequent monitoring. Similarly, checking weight is also valuable; it will help to adjust daily meal. Moreover, all the monitoring systems could facilitate self-management and communication with health professionals. That means the results could be presented very clearly and could display the trends and comparison with reference values. In order to facilitate communication with healthcare professionals, data could be transferred to the healthcare center and be read by clinicians, but also the older person could present them personally in his/her smartphone or tablet PC to the healthcare provider (if no e-health system is available).

According to the *field study analysis and results*, the activity monitoring should calculate both the step count and calorie burn and be presented in trending graphs (calorie, weight, step counts). Presenting data graphically could be done using some summary bar graph where the accumulated (weekly or monthly) duration of non-walking activities are shown together with bars for the step count and calories for the same period. Concerning the blood glucose monitoring, the diabetes patients require a direct feedback on glucose value both when at home and on the go. Regarding the blood pressure monitoring, users would typically take a reading once a week and add comments to blood pressure readings like, “gym”, “measured when feeling unwell” etc. to facilitate interpretation in the context. The user would like to have reminders for their medication however, the length of the so called “reminder cancel window” has to be adjustable as it depends on the type of medication. On the sensor side, the reminder signal should be both buzzer and light, the reminder function should continue as long as the cap is left off. Considering the pulse monitoring, the sensor should alarm in real-time during training especially when the pulse is too high.

4 Conclusions

This paper has provided a description of the definition of the healthcare services and their design in the context of the SAAPHO project. Specific emphasis has been placed on detailing the different type of services and health parameters that will be used in the project. The paper has also provided a comparison of these services against the perspective of the end-users and the healthcare professionals. The aim of this paper has been to share the design of the healthcare services so that other similar efforts can take part in the specific values and rules that have been used within the context of the project. Future work will evaluate this first version of the services in a controlled field trial.

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