Applications of pervasive computing and mobile services in health care

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Abstract. The massive penetration of mobile devices into the everyday life's actions was made possible by the tremendous growth in the emerging computation paradigm called pervasive computing. This approach envisions a conglomeration of small smart devices as sensors, signal conditioners, wearable computers, mobile phones, tablets, notebook computers, hand-held devices etc. seamlessly integrated and scattered in the environment, according to IoT concept. Pervasive health care focuses explicitly on the use of pervasive computing technology for developing tools and procedures that put the patient at the center of the health care process. From a technological stand point, it includes remote monitoring, remote consultation, and assistive technologies. The main focus in this paper is presentation of our approach in design of these complex distributed systems as a part of improved patient's conditions for living

Keywords: Pervasive computing, mobile devices, SOA, Health Pal system

1. Introduction

Life expectancy today tend to increase in many places around the world. The number of chronic diseases increasing all the time and they have to be address as earliest as is possible, in order to ensure optimal treatment. One example is that the difference in cost between well-monitored and badly monitored diabetic patients is reported to be 2000 per year. Many attempt are made in this direction proposing some models for improvement healthcare systems despite of decreasing the number of medical practitioners in some areas [1]. The demands for medical advice grow because the people become aware of the importance of the health conscious, but they do not want to spend more time at health centers or hospitals. This fact lead to increasing overall cost for healthcare [2].

One of the possible solutions for improvement of patient's health care is to set up health and patient management systems that provide continuous monitoring of some vital signs, allowing ubiquitous medical treatment and advise patients at minimum cost. Continuous monitoring is required to obtain a better understanding of the key medical variables by increasing the measuring frequency. Thus, trends

and historical data can allow more accurate analysis of abnormal values. Today, telemedicine enables permanent access to medical knowledge and reduces the cost due to improved efficiency [3, 4]. It also increases patients' quality of life since people feel safer and their lives become more independent from stationary treatment. The concept tends to be some kind of ambient assisted living [5, 6] helped by the cloud concept, with purpose to send some data to some e-health providers in order to increase the patient control [7, 8] by the medical practitioner in distance.

As computing technology is in a state of continuous evolution, there is a many new emerging trends that can change the healthcare systems [9]. One of them as the state of the art computing paradigm is called pervasive computing, that envisions a conglomeration of small smart devices as sensors, signal conditioners, wearable computers, tablets, mobile phones, notebook computers etc. seamlessly integrated and scattered in the environment. The ultimate goal is to provide some exciting possibilities in the health care sector neither for diagnostic equipment [10] as well as communication devices.

Pervasive health care focuses mainly on the use of pervasive computing technology for developing tools and procedures that put the patient "at the center" of the health care process. From a technological view, it includes remote monitoring, remote consultation, and assistive technologies. This provides exciting possibilities in the health care sector neither for diagnostic equipment or communication devices [11]. Contemporary telemedicine systems have sufficiently advanced so as to relay the medical data over large distances within a reasonable delay. Attempts are being made to develop intelligent wearable computers that can perform a primary diagnosis and are the part of a concept Internet of Things [12, 13].

This paper explains our approach in designing a system named "Health Pal"-information system that uses ubiquitous devices and provide constant monitoring of patients vital signs as temperature and heart rate in a critical postoperative period after they've being sent to home care. The number of selected vital signs, measured by different appliances and connected to the mobile systems is not limited, so they do not overload the proposed concept.

The first section of the paper analyze the proposed Health Pal System. After that, Health Pal module for mobile device are analyzed taking into consideration detailed use case diagrams for different scenarios in the application. The next section provides analysis of the service module of the Health Pal application with use cases of all scenarios envisioned. The fourth section explains Inpatient care module that have to provide the representation of the data received from sensors for medical staff alert. Fifth section provide some clarification of SOA Health Pal System design taking into consideration deployment diagram and sequence diagram for the system. Conclusion remarks highlights some point of the proposed Health Pal system and some proposal for improvements.

2. Health Pal System Analysis

A pictorial overview of the pervasive health care scenario is given on Fig 1. The requirements for this kind of system are the following: accurate and timely notification of the medical staff for the trend and the most recent condition of the patient by reading its vital signs. The medical staff should get the readings in the appropriate easy readable format, taking into consideration the level of importance, attached to them. This system have to empower the medical staff to convey messages to the patients with different severity, depending on their most recent condition. Having in mind the sensitivity of this data, the system should have a high level of security and preserve the privacy of each patient. It should be open also for third party systems (i.e. emergency care notification, research institutes etc.) that might require this kind of data and enhance the medical care provided to the patient.

These requirements can be implemented using distributed system and service oriented design approach, enabling greater flexibility platform wise as well as device wise. It have to provide also decoupling of all different parts in the system. In this solution, the patient's temperature and heart rate as well as its location are monitored. The other vital signs as ECG, blood pressure and respiratory flow are not taken into consideration because of sensor availability issues.

The Health Pal system consists of three separate application modules and a sensor module consisted of body temperature sensor and a heart rate sensor. The first module is an application for a mobile device or tablet that will gather and send sensor's data readings to the other parts of the system. The second module is service oriented application (SOA) that gather the data, process and send it to the medical staff or third party users. The third module is an application used by medical staff in order to get the processed data and allow feedback messages to be sent to the patients according to their most recent condition.

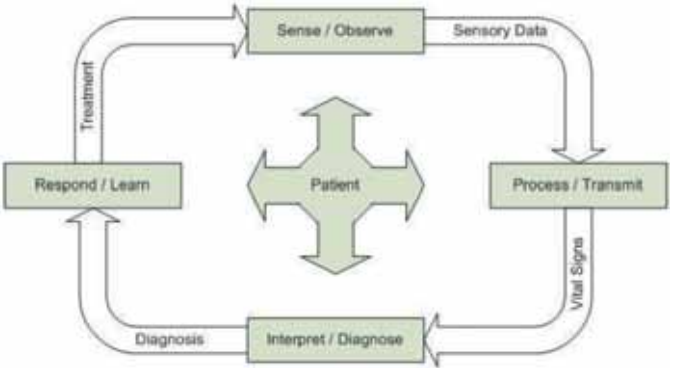

Fig. 1 Pervasive health care scenario

3. Health Pal Module for Mobile Devices (HPMMD)

HPMMD module provides sampling the sensor values and send them to the service application. It should also give an appropriate notation as sound and visual notifications to the patient when feedback message from the doctor is received. It's very important when an abnormal reading from the sensors occurs and application sends a prompt notification through the system to the medical staff. Having this in mind it can be conclude that the application needs to have easily configurable set of values that the sensor readings will be compared against (normal body temperature and heart rate). The sampling times as well as data sending times should be also configurable so the application can be flexible to different medical cases with various examination needs, flexible to the network capabilities that they send the data through. Another requirement in this kind of application is that, together with the sensor readings, it also sends the actual position of the patient with purpose if there is life threatening situation, the medical staff can promptly send an emergency vehicle to the place where the patient is located. Fig. 2 shows a detailed use case diagram for the possible scenarios in the application.

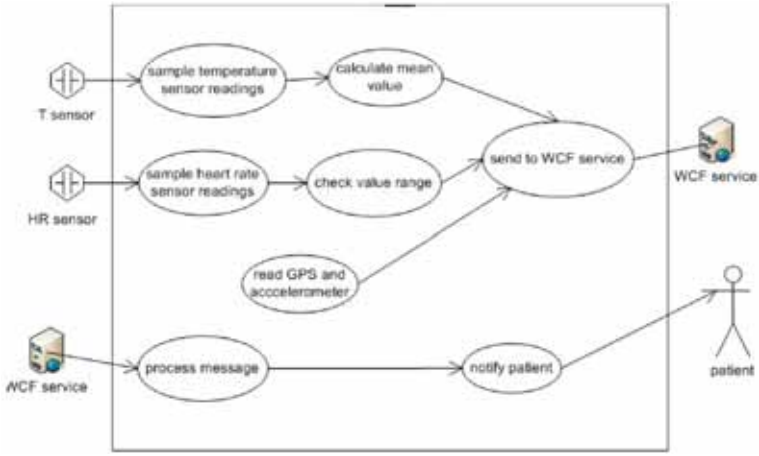

Fig. 2 Detailed use case diagram for mobile application

- **sample temperature sensor readings** – get the value shown from the sensor in one minute intervals
- **calculate mean value** – calculate mean value of all temperature readings in one preconfigured sending interval
- **sample heart rate sensor readings** – get the value shown from the heart rate sensor in one minute intervals
- **check value range** – compare the heart rate reading against the preconfigured "normal heart rate" value range. In case the current value is out of this range the system should be notified

- **read GPS and accelerometer** – get the current global position reading from the internal GPS in the mobile phone or tablet and the accelerometer reading to show patients position and movement
- **send to WCF service -** create a package with all the information (temperature, heart rate, position and movement) and send it to the WCF service for further processing
- **process message –** when a return message is received its importance indicator should be checked
- **notify patient –** depending on the message's importance the patient is notified with a visual, sound or both signals and the message is displayed

Not every sensor reading is sent because of the fact that may cause an information overload since neither the temperature nor the heart rate, in normal conditions are expected to fluctuate much. Instead mean values in a predefined period of time are sent through the system if the values are in the "normal range" and the current readings are sent if any of the parameters are out of this range.

In order to ensure a consistent and reliable data through the system this application send test signals between every batch of sensor data. If there is a network or processor failure in any part of the system it can be detected in a timely manner and the patient will not be left unmonitored for a longer period of time. These test messages (signals) should be sent twice in between two consecutive data batches and an error will be raised if two consecutive test messages are not propagated through the system. Test messages will be sent in point of time t which equation is shown below:

$$t = nT/3+\alpha \quad (1)$$

n = 1,2.. – signal number
T – interval for sending sensor data batches
α – provisional time difference

4. Analysis of the Service Module of Health Pal System (SMHPS)

SMHPS module is the central part of the whole system. It handles all communications between the various applications and provides data for all of them. That kind of interoperability requires a flexible and platform independent application. The module receives the data packages sent by mobile device, processing and storing data into database. It also notifies the appropriate medical staff about the latest patient's condition. If there is life threatening readings from the sensors, the application should immediately communicate with the emergency service. All depersonalized data from patients that give a consent to share their

information, have to be available to accredited research institutions. Having these entire requirements in mind, the conclusion is that the best scenario is to build application as SOA with possibility to communicate across different platforms. The best way to achieve that kind of interoperability is if SOAP messages are used.

Fig. 3 shows the detailed use case diagram for this and all scenarios envisioned.

- **read data** – get the data package passed from mobile device and read its contents
- **check value range** – compare the passed data points with a predefined set of "normal values". The predefined set of "normal values" should be individual for every patient and configurable by the medical staff at will
- **notify emergency** – if a data point that shows a life threatening situation for the patient is received, emergency service should be notified with all information available (patient information, latest sensor readings and position)
- **send message to medical staff** – a notification with appropriate data and importance attached to it are sent to the medical staff. The importance depends on the information in the latest data package received
- **update database** – the latest data is inserted into the database
- **convey doctor's message to patient** – the message sent from the doctor or the medical staff is sent to the appropriate mobile application to notify the patient if he/she need to take some actions according to his/hers latest readings
- **3rd party users** – these users (i.e. research institutions, patients etc.) after they've been given appropriate credentials can log in to the system and ask for information. After the database is searched they get the data.

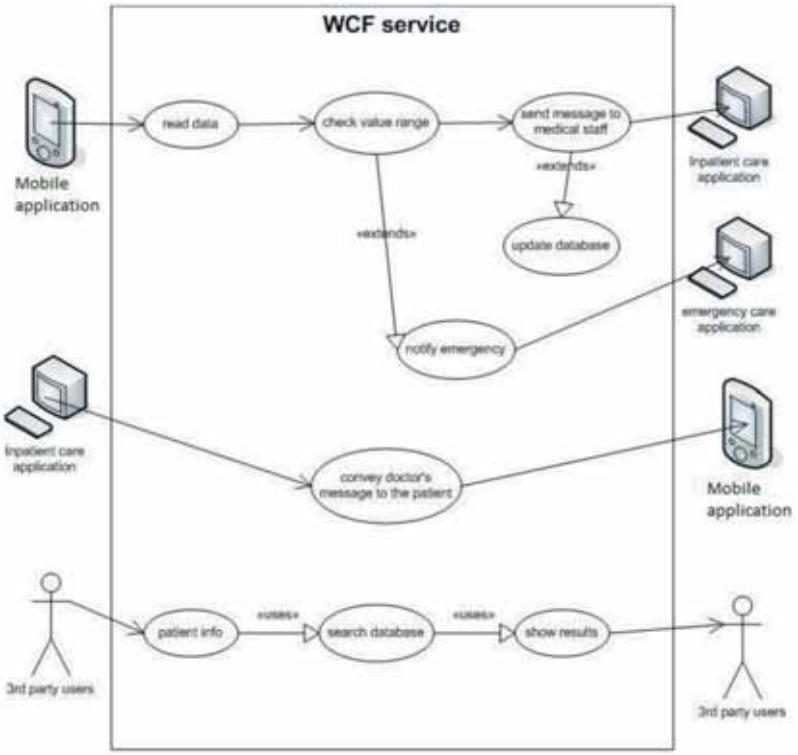

Fig. 3 Detailed use case for the service application

4. Health Pal Inpatient Care Module (HPICM)

HPICM provides visual representation of data received through the sensors and prompts notifications. It provides an interface for the medical staff enabling them to send messages to the patients and configure the "normal" values and sampling times. Notifications about patients' data can be sent to this application or to a designated member of the medical staff through different means (i.e. SMS, MMS, email etc.)

Fig. 4 shows a detailed use case diagram of this application and is explained in detail below.

- **get notification message** – receive message from the service containing patients' data
- **notify medical staff according to severity** – depending on the importance level of the received message send a notification to a member or multiple members of the medical staff assigned to the appropriate patient. This message can be visual on screen message, SMS, MMS,

email or voice message depending on the importance with a proper representation of the data.

- **send message to the patient** – through an interface members of the medical staff should be able to send a message to the patient regarding his/hers latest condition and advise him/her on which further actions to take

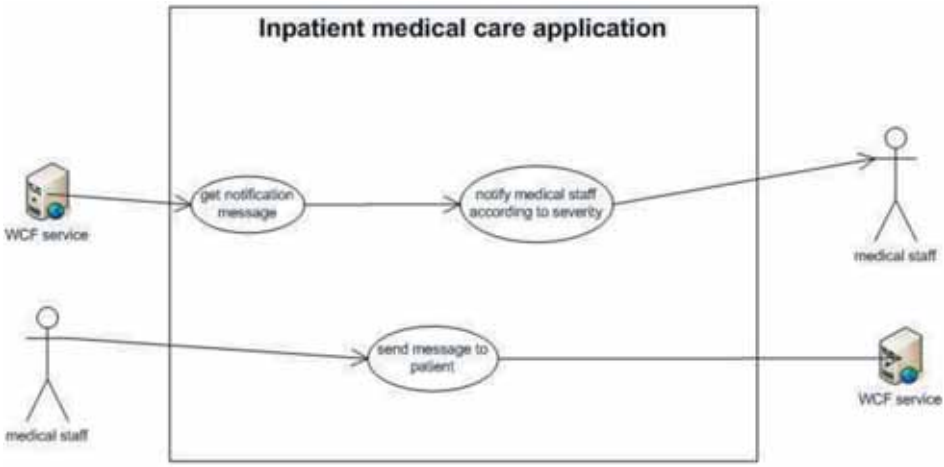

Fig. 4 Detailed use case diagram of inpatient application

HPICM is a terminal application designed specifically for this purpose or a part of an already existing application. Having in mind that this paper focuses on a system that is designed to deal with patients that are in their postoperative period, we can assume that they've already been into the medical facility and are in some shape or form present in its system. With that assumption we can consider this application to be a part of already existing application as an added functionality. It will be referred as an inpatient care application[1].

4. Health Pal System design

Health Pal is a distributed system with service oriented architecture. The system is consisted of number of appliances with temperature and heart rate sensors, connected to mobile devices, a web service and a number of working stations with running applications or entire systems that have to use these information. Sensor are connected through Bluetooth to mobile devices. Mobile applications gather sensor readings process and send them to the web service through the Internet. The web service is responsible for feeding information to the other parts of the

[1] inpatient care application is a common term used for in-house applications used by medical facilities for keeping track of patients' information

system. It can send messages to some working stations in the medical facilities through MMS, SMS or email. It can also communicate to other applications through SOAP messages regardless of the platform and programming language that they are built on. The deployment diagram of the whole system is shown on Fig. 5.

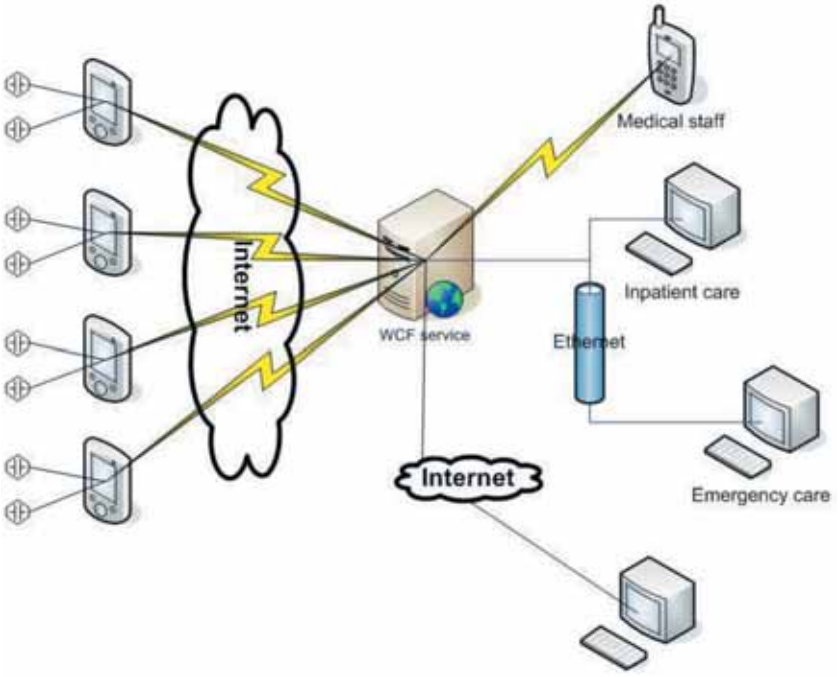

Fig. 5 Deployment diagram of the whole system

The information flowing through the system is very sensitive and private so a high level of security is implemented.

The sequence diagram on Fig. 6 shows the relationships and data flow through the system. As it's portrayed the sensor values are asynchronously read through the time, to insure continuous monitoring of the patient. These readings are spaced in 1 minute intervals for both types of sensors, body temperature and heart rate. In normal circumstances both of these vital signs shouldn't change a lot in very short periods of time so sending every single reading through the system can cause a lot of unnecessary information to be delivered to the medical staff and a lot of network traffic. That is why the mobile applications have a configuration option for the sending intervals. For this purpose, the time interval can be preconfigured in 30 minutes, calculating the mean value of all readings and then creates a message that have to be sent to the web service. This message contains the mean heart rate and body temperature in the last 30 minutes, the

current position and the accelerometer reading. Every reading from the sensors is compared to the "normal values" range which is also configurable to reflect the needs of every individual patient. This configuration option is available to the medical staff to change it remotely, flexible to every change of patient's condition. If a read value is out of this "normal" range, either heart rate of temperature, a message with only the current readings and GPS position is sent to the web service. This ensures a prompt notification to the system if the patient is experiencing problems. Right after this notification is sent to mobile application, it does one more sampling to ensure that the last readings are consistent and it's not just a temporary malfunction from the sensors. If a malfunction is discovered (the readings are normal again) a cancelation of the previous alert is sent.

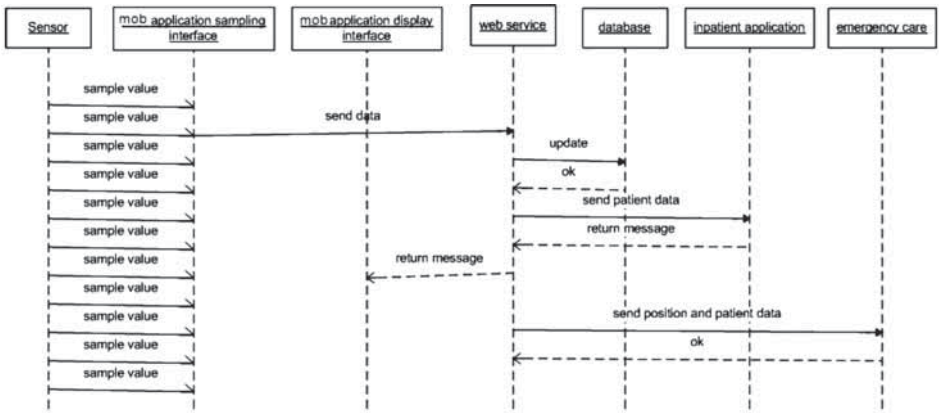

Fig. 6 Sequence diagram for the Health Pal system

When the web service receives the data through one of its methods checks the values against the "normal" range to determine if it is an emergency situation, just a minor offset from the "normal" values or everything is fine with the patient. The values are saved into database for monitoring purposes. If emergency readings are received, the web service sends a notification to an emergency care center with the appropriate information. This notification contains patient's personal data, GPS position for easier tracking and latest vital signs readings. If in the meantime the web service receives an alert cancelation from the mobile application, is also sent to the emergency care center, flagged in database as bad data for maintenance purposes. The whole package of patient's data is also sent to the inpatient application as a notification of the medical staff. This web service also provides methods that make this data available for third party users (research institutions, other medical applications etc.). They have to have appropriate credentials to be able to extract data from the system and their access is limited only to the data from the patients that give a consent to share their data for research and some specific purposes.

Other applications and application modules can also use the information and services that the Health Pal web service provides. One typical example is the inpatient care application. This part of the system delivers the notification of the patent's most recent condition to the medical staff. For this purpose the application has different modes of data presentation (graphs, tabular etc.) and different kinds of attracting users' attention (as sound, pop up messages etc.). The notification messages with the highest importance use sound and visual methods to get one's attention and as the severity of the notification declines, the number of used notification methods decrease. This means that if there is no problem with the patient's readings, the medical staff will latter deal with the patient's condition due to the obligations with other patients and administrative work. The application also has an interface for medical staff to send messages to a patient and to inform him/her about his/hers latest condition and what step or measures should be taken. It allows a direct communication with the patient and enhances his/hers confidence. The inpatient care application has an interface that can change the configuration settings to every single mobile application at will. This option allows to the medical staff to change the notification periods and "normal values" range remotely, so every patient can be monitored according to its latest condition and therapy. In this way, if the patients getting better and do not have problems, he/she can be monitored less frequently opposed to the ones that have more difficult recovery and require more frequent monitoring. These changes are also reflected in the web service.

6. Conclusions

The paper considers an aspect of solving some problems connected with improving patients' condition of live with usage of pervasive computing and mobile services in health care services. Having in mind the cost of in-clinic recovery an off-site healing process, cost-effective methods are proposed. The rehabilitation of the patient in the comfort at home has proven as a very productive method for the patients because of the psychological factors. But they still have to be monitored.

This is the reason why the Health Pal system was designed. Its purpose is to provide accurate and convenient monitoring of patient in their post-operative period and reduce the costs in these process. Reduced costs can cause greater availability of the health care to the people and a better health care system in general, connecting data with other health care application and alert system that send information to dedicated medical staff. The model is appropriate also for short (or long) time monitoring of vital signs at home for the peoples with disabilities, elderly people, children and remote patients. Health Pal application uses mobile devices equipped with mobile application and sensors that provide a vital sign data for the patient. The number of possible sensor is not limited on

the mentioned ones. Taking into consideration the Internet of Things concept, the possible medical devices connected through mobile applications, there is increasing trend of their usage in time, decreasing the price of used devices. The medical practitioners embraces the concept and goes toward accepting the concepts of telemedicine and e-health, that have to provide better health care services for the wide range of patient who don't have appropriate health care, especially in the area of lack of medical staff as well as the distance location. For this reason, the application as Health Pal are desirable for medical institutions. The lack of medical staff will increase the usage of such application using pervasive and mobile technology connected with SOA.

References

1. Savoski Z., Savoska S., E-health, Need, Reality or Mith for R.of Macedonia, , in Proceeding of AIIT, Bitola, 5.10.2018, in print
2. Scheffler M. and Hirt E., *Wearable devices for telemedicine applications*, Art of Technology, AG, Zurich, Switzerland; Journal of Telemedicine and Telecare 2005; 11 (Suppl. 1): S1: 00–00
3. Hinckley K., Pierce J., Sinclair M., Horvitz E., Sensing Techniques for Mobile Interaction, Symposium on User Interface Software and Technology Proceedings of the 13th annual ACM symposium on User interface software and technology San Diego, California, United States Pages: 91 - 100, 2000, ISBN:1-58113-212-3
4. TELEPROM-G Access and Delivery of Telehealth Services among Community base sensors, 2017, IEEE Xplore digital library, DOI: 10.1109/FTC.2016.7821779
5. Scott G. Cunningham, Deborah J. Wake, Annalu Waller, Andrew D. Morris, eHealth, Care and Quality of Life, Springer-Verlag Italia, 2014, DOI: 10.1007/978-88-470-5253-6_2
6. Ace Dimitrievski, Eftim Zdravevski, Petre Lameski, Vladimir Trajkovik, "A survey of Ambient Assisted Living systems: challenges and opportunities", 12th IEEE International Conference on Intelligent Computer Communication and Processing, Cluj Napoca, Romania, September 8-10, 2016.
7. Cubo J., Nieto A. and Pimentel E., A Cloud-Based Internet of Things Platform for Ambient Assisted Living, Sensors 2014, (www.mdpi.com/journal/sensors), 14, 14070-14105; doi:10.3390/s140814070
8. Gavrilov G., Jakimovski B., Chorbev I., Trajkovik V., Cloud-Based Electronic Health Record for Health Data Exchange, in Proceeding of AIIT, Bitola, 5.10.2018, in print
9. Pham T., Schneider G., Goose S., A Situated Computing Framework for Mobile and Ubiquitous Multimedia Access using Small Screen and Composite Devices, International Multimedia Conference Proceedings of the eighth ACM international conference on Multimedia Marina del Rey, California, United States Pages: 323 - 331 Year of Publication: 2000 ISBN:1-58113-198-4
10. FDA Approved drugs Products, https://www.accessdata.fda.gov/scripts/cder/daf/, Accessed 10.6.2018
11. Ho J. and Intille S.S.; Using Context-Aware Computing to Reduce the Perceived Burden of Interruptions from Mobile Devices; Conference on Human Factors in Computing Systems Proceedings of the SIGCHI conference on Human factors in computing systems Portland, Oregon, USA SESSION: Interruptions and attention 2: attending to interruptions Pages: 909 - 918 Year of Publication: 2005 ISBN:1-58113-998-5

12. Olivera Kotevska, et al, “Towards a Patient-Centered Collaborative Health Care System Model”, 4th IEEE International Conference on Computer Science and Information Technology (IEEE ICCSIT 2011), Chengdu, China, June 10-12, 2011, pp. 562-566
13. Rahmani A.M. and all, Exploiting smart e-Health gateways at the edge of healthcare Internet-of-Things: A fog computing approach, Future Generation Computer Systems, Volume 78, Part 2, January 2018, Pages 641-658, https://doi.org/10.1016/j.future.2017.02.014