Intelligent Mobile Health Monitoring System (IMHMS)

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Abstract. Health monitoring is repeatedly mentioned as one of the main application areas for Pervasive computing. Mobile Health Care is the integration of mobile computing and health monitoring. It is the application of mobile computing technologies for improving communication among patients, physicians, and other health care workers. As mobile devices have become an inseparable part of our life it can integrate health care more seamlessly to our everyday life. It enables the delivery of accurate medical information anytime anywhere by means of mobile devices. Recent technological advances in sensors, low-power integrated circuits, and wireless communications have enabled the design of low-cost, miniature, lightweight and intelligent bio-sensor nodes. These nodes, capable of sensing, processing, and communicating one or more vital signs, can be seamlessly integrated into wireless personal or body area networks for mobile health monitoring. In this paper we present Intelligent Mobile Health Monitoring System (IMHMS), which can provide medical feedback to the patients through mobile devices based on the biomedical and environmental data collected by deployed sensors.

Keywords: Mobile Health care, Health Monitoring System, Intelligent Medical Server.

1 Introduction

Pervasive computing is the concept that incorporates computation in our working and living environment in such a way so that the interaction between human and computational devices such as mobile devices or computers becomes extremely natural and the user can get multiple types of data in a totally transparent manner. The potential for pervasive computing is evident in almost every aspect of our lives including the hospital, emergency and critical situations, industry, education, or the hostile battlefield. The use of this technology in the field of health and wellness is known as pervasive health care. Mobile computing describes a new class of mobile computing devices which are becoming omnipresent in everyday life. Handhelds, phones and manifold embedded systems make information access easily available for everyone from anywhere at any time. We termed the integration of mobile computing to pervasive health care as mobile health care. The goal of mobile health care is to provide health care services to anyone at anytime, overcoming the constraints of place, time and character. Mobile health care takes steps to design, develop and evaluate mobile technologies that help citizens participate more closely in their own health care. In many situations people have medical issues which are known to them but are unwilling or unable to reliably go to a physician. Obesity, high blood pressure, irregular heartbeat, or diabetes is examples of such common health problems. In these cases, people are usually advised to periodically visit their doctors for routine medical checkups. But if we can provide them with a smarter and more personalized means through which they can get medical feedback, it will save their valuable time, satisfy their desire for personal control over their own health, and lower the cost of long term medical care. A number of bio-sensors that monitor vital signs, environmental sensors (temperature, humidity, and light), and a location sensor can all be integrated into a Wearable Wireless Body/Personal Area Network (WBAN/WPAN). This type of networks consisting of inexpensive, lightweight, and miniature sensors can allow long-term, unobtrusive, ambulatory health monitoring with instantaneous feedback to the user about the current health status and real-time or near real-time updates of the user's medical records. Such a system can be used for mobile or computer supervised rehabilitation for various conditions, and even early detection of medical conditions. When integrated into a broader tele-medical system with patients' medical records, it promises a revolution in medical research through data mining of all gathered information. The large amount of collected physiological data will allow quantitative analysis of various conditions and patterns. Researchers will be able to quantify the contribution of each parameter to a given condition and explore synergy between different parameters, if an adequate number of patients are studied in this manner.

In this paper we present a bio-sensor based mobile health monitoring system named as "Intelligent Mobile Health Monitoring System (IMHMS)" that uses the Wearable Wireless Body/Personal Area Network for collecting data from patients, mining the data, intelligently predicts patient's health status and provides feedback to patients through their mobile devices. The patients will participate in the health care process by their mobile devices and thus can access their health information from anywhere any time. Moreover, so far there is no automated medical server used in any of the work related to mobile health care. To maintain the server a large number of specialist are needed for continuous monitoring. The presence of a large number of specialists is not always possible. Moreover in the third world countries like ours specialist without proper knowledge may provide incorrect prescription. That motivates us to work for an intelligent medical server for mobile health care applications that will aid the specialists in the health care. As a large amount of medical data is handled by the server, the server will perform mine and analyze the data. With the result of mining, analysis and suggestions and information provided by the specialists in the critical scenarios the server can learn to provide feedback automatically. Moreover as time grows the server will trained automatically by mining and analyzing data of all the possible health care scenarios and become a real intelligent one. Our main contribution here is the Intelligent Medical Server which is a novel idea in the field of mobile health care. The outline of this paper is as follows: System Architecture of IMHMS is described in Section 2 followed by the evaluation of IMHMS in Section 3. Our future research direction and concluding remarks are in Section 4.

2 System Architecture

IMHMS collects patient's physiological data through the bio-sensors. The data is aggregated in the sensor network and a summary of the collected data is transmitted to a patient's personal computer or cell phone/PDA. These devices forward data to the medical server for analysis. After the data is analyzed, the medical server provides feedback to the patient's personal computer or cell phone/PDA. The patients can take necessary actions depending on the feedback. The IMHMS contains three components. They are: 1. *Wearable Body Sensor Network [WBSN]*, 2. *Patient's Personal Home Server [PPHS]* and 3. *Intelligent Medical Server [IMS]*.

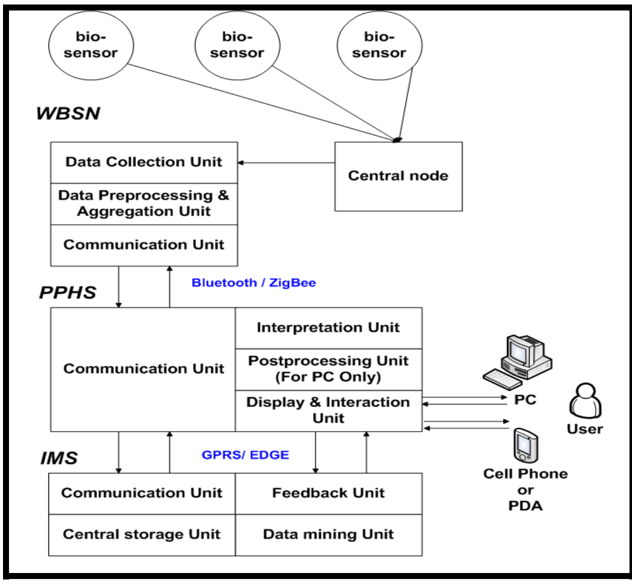


Fig. 1. System Architecture

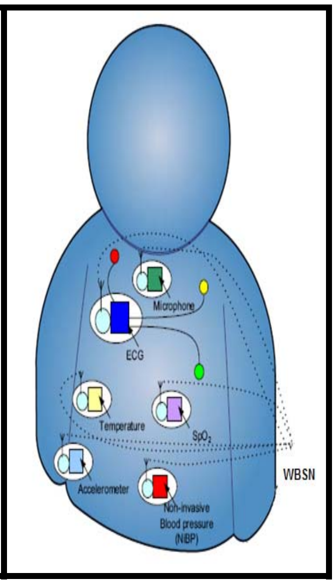


Fig. 2. WBSN

They are described below.

Wearable Body Sensor Network [WBSN]

Wearable Body Sensor Network is formed with the wearable or implantable bio-sensors in patient's body. These sensors collect necessary readings from patient's body. For each organ there will be a group of sensors which will send their readings to the group leader. The group leaders can communicate with each others. They send the aggregated information to the central controller. The central controller is responsible for transmitting patient's data to the personal computer or cell phone/PDA. A recent work suggested that for wireless communication inside the human body, the tissue medium acts as a channel through which the information is sent as electromagnetic (EM) radio frequency (RF). So in WBSN, information is transmitted as electromagnetic (EM) radio frequency (RF) waves. The central controller of the WBSN communicates with the Patients Personal Home Server [PPHS] using any of the three wireless protocols: Bluetooth, WLAN (802.11) or ZigBee. Bluetooth can be used for short range distances between the central controller and PPHS. WLAN can be used to support more distance between them. Now days ZigBee introduces itself as a specialized wireless protocol suitable for pervasive and ubiquitous applications. So ZigBee can be used for the communication too. As we all know that Bluetooth, WLAN and ZigBee have very different characteristics and they should be analyzed for which one makes most sense for use in our system. Currently we are working on it by comparative studies and analysis to choose the best one.

Patient's Personal Home Server [PPHS]

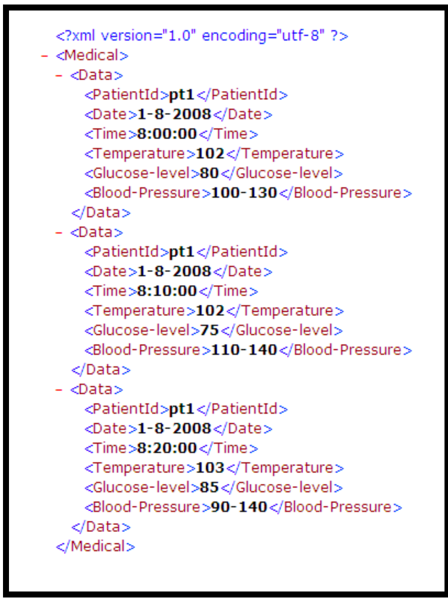
The patient's personal home server can be a personal computer or mobile devices such as cell phone/PDA. We suggest mobile devices because it will be more suitable for the users to use their mobile devices for this purpose. PPHS collects information from the central controller of the WBSN. PPHS sends information to the Intelligent Medical Server [IMS].PPHS contains logics in order to determine whether to send the information to the IMS or not. Personal Computer based PPHS communicates with the IMS using Internet. Mobile devices based PPHS communicates with the IMS using GPRS / Edge / SMS. The best way to implement IMS is by Web Service or Servlet based architecture. The IMS will act as the service provider and the patients PPHS will act as the service requester. By providing these types of architecture, a large number of heterogeneous environments can be supported with security. So personal computer or cell phone/PDA can be connected easily to a single IMS without any problem.

Intelligent Medical Server [IMS]

Intelligent Medical Server [IMS] receives data from all the PPHS. It is the backbone of this entire architecture. It is capable of learning patient specific thresholds. It can learn from previous treatment records of a patient. Whenever a doctor or specialist examines a patient, the examination and treatment results are stored in the central database. IMS mines these data by using state-of-the-art data mining techniques such as neural nets, association rules, decision trees depending on the nature and distribution of the data. After processing the information it provides feedback to the PPHS or informs medical authority in critical situations. PPHS displays the feedback to the patients. Medical authority can take necessary measures. The IMS keeps patient specific records. It can infer any trend of diseases for patient, family even locality. IMS can cope with health variations due to seasonal changes, epidemics etc. IMS is controlled and monitored mainly by specialized physicians. But even a patient can help train IMS by providing information specific to him. After mining the database stored in IMS, important information regarding general health of the people can be obtained. It can help the authority to decide health policies. Large numbers of patients will be connected to the IMS using their PPHS. So security of the patients is a major issue here. So RFID can be used in this purpose. Radio-frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader. So security can be provided by providing RFID tags to each patient. Our main contribution is the Intelligent Medical Server (IMS) which is a novel idea. So we are describing it in more details with possible scenarios below. ***In intensive care units, there are provisions for continuously monitoring patients.*** Their heart rates, temperatures etc. are continuously monitored. But in many cases, patients get well and come back to home from hospital. But the disease may return, he may get infected with a new disease, there may be a sudden attack that may cause his death. So in many cases, patients are released from hospital but still they are strongly advised to be under rest and observation for some period of time (from several days to several months). In these cases, IMHMS can be quite handy. ***Patients of blood pressure frequently get victimized because of sudden change of pressures.*** It cannot be foreseen and also a normal person cannot be kept under medical observation of a doctor or a hospital all days of a year. Blood pressures change suddenly and can be life-treating. Using IMHMS, they can get alerts when their blood pressure just starts to become high or low. ***Patient's data (temperature, heart rate, glucose level, blood pressure etc.) will be frequently measured and sent to PPHS.*** Period of sending (say every 3 min) can be set from the patient in the central controller of WBSN. Normally glucose level will be sent after several days or a week. Heart rates can be sent every minute and temperatures can be sent after half an hour etc. But these can be parameterized to ensure that when a patient is normal, not many readings will be sent so that sensors have a longer life-time. But when the patient is ill, readings will be taken frequently and sent to PPHS. ***PPHS will have some logic to decide whether the information is worthy of sending to IMS***. Say, temperature is in safety range(less than 98F), and then PPHS will not send this info to IMS to save cost for the patient. Again say, glucose level is safe and same as the last several days, then this info also need not be sent. Data must be sent to IMS when there is a change in status (say temperature of the patient goes to 100F from 98F or a patient with severe fever 102F has just got temperature down to 99F). Again if there is a sudden change in blood pressure or glucose level, then this info must be sent to IMS. ***IMS learns patient specific threshold.*** Say the regular body temperature of a patient is 98.2F whereas one person feels feverish if his body temperature is 98.2F. By employing an averaging technique over a relatively long time, IMS can learn these thresholds for patients. However, patients can also give these thresholds as inputs based on directions of their doctors. ***Using IMS, one can view his medical history date wise, event wise etc.*** IMS can perform data mining on a particular patient data to discover important facts. Suppose a person has medium high temperature that starts at evening and lasts till midnight. If this phenomenon continues for several days, IMS will automatically detect this fact and send a message to PPHS saying "You frequently have short-period fever that may be a symptom of a bad disease. Consult doctor immediately". ***Using IMS, one can view his medical history date wise, event wise etc.*** A patient can also enter extra information like he has had chest pain today, or he is frequently vomiting, he has rashes on body etc. in PPHS. In IMS, there will be a set of rules for preliminary prediction of disease. These rules will be pre learnt based on neural network or data mining of existing disease databases that are available over web. Now IMS, with the additional information, will check the rules. If it finds a matching rule, then it will predict the disease and send the message to PPHS. ***The most important fact about IMS is that it can help stop the spread of diseases.*** Whenever it finds that several people from same locality over a small period of time are having the same disease, it will predict that the disease is spreading out in that locality so that authority can take immediate action. Say, when some people of the same area report that they are having high fever, pain over body and rashes, IMS will report this which the doctors can interpret that dengue is breaking out in that area and the authority has a chance to take actions at the very first stage so that epidemic can be avoided.

3 Evaluation

To evaluate IMHMS, we implement a prototype of different components of IMHMS We are working on building WBSN. We consider the data provided by the bio-sensors as a well structured XML file. A sample XML file is shown in Figure 3 where a patient's Temperature, Glucose-level and Blood-pressure are measured continuously over a period of time. Two possible implementations are there for PPHS. It can be implemented in personal computer. While implementing for personal computer, the most suitable communication media between WBSN and PPHS is Bluetooth because of its availability and low cost. The personal computer based PPHS implementation required Bluetooth Server setup in the personal computer. The medical data of the patients will be transferred from WBSN to PPHS through the Bluetooth Server. Then the personal computer based PPHS processes the data and send necessary data to the IMS. But we suggest mobile devices for implementing PPHS because it will be more suitable for the users to use their cell phones or PDA in this purpose. The real mobility of the solution can be provided by mobile devices. We choose J2ME based custom application so that it can be deployed immediately in a large number of available cell phones or PDA available in the market. The J2ME based PPHS automatically collect patient's data from the WBSN and transfer it to the IMS. It is also responsible for displaying results and feedback from the IMS to any specific patients. We implemented the skeleton of the IMS. IMS is built with the Java Servlet based architecture. To connect to the IMS, PPHS requires software to be installed. We implemented a J2ME application that processes the XML file of patient's data using KXML which is an open source XML parser. The application connects to the IMS using GPRS or EDGE. It can connect using SMS also if SMS receiving capable application can be developed in the IMS. Our J2ME application connects to the IMS's Web Servlet by GPRS or EDGE. To implement the SMS based portion the IMS must be interfaced with a number of cell phones or PDA in order to receive SMS from the PPHS and send the feedback to the PPHS as SMS. The flow diagram of the implementation is shown in the Figure 4. The WBSN collects patient data and send the data to the PPHS. PPSH receives the data and processed the data to reduce the transmission of unnecessary data to the IMS. The PPHS communicates with the IMS using GPRS or EDGE. The IMS contains a Data Mining Unit, a Feedback Unit and a central database. The database contains the entire patients' profile, continuous health data and a large set of rules for data mining operations. The Data Mining unit processes the data and returns the feedbacks and results to the Feedback Unit. The feedback unit then sends the data to the corresponding PPHS. Moreover the patient's can login to the IMS using authorized patient-id and password to provide information manually and to view the patient's entire history. Some screenshots of these activities are shown in the figure. Figure 5.1 and 5.2 show the interface in IMS for patients profile information and manual health data submission. Figure 5.3 shows one patient's entire medical history with the feedbacks and results stored in the IMS's central database. Figure 5.4 and 5.5 show the automated health data collection of J2ME based PPHS and display of feedbacks provided by IMS based on the collected data.



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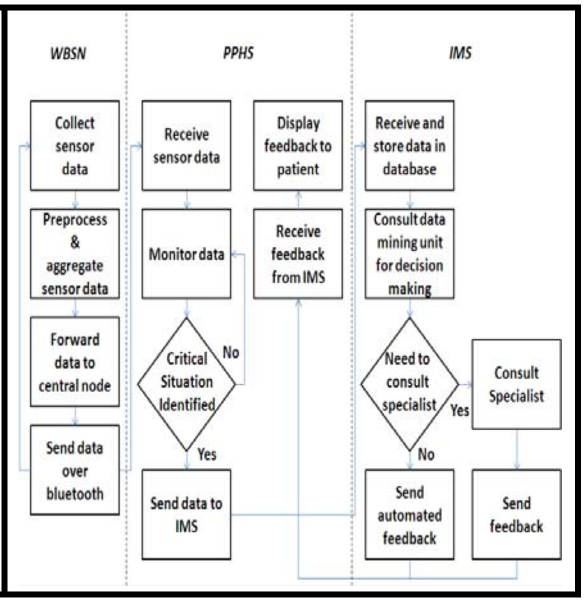

Fig. 3. Patient's Health Data

Fig. 4. Flow Diagram

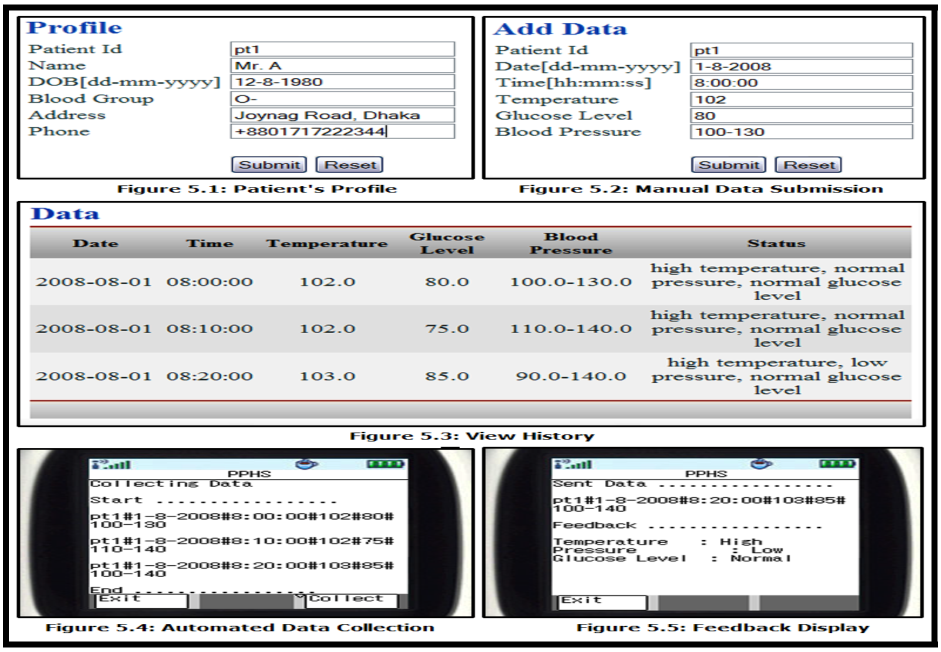

Fig. 5. Screenshots

4 Future Works and Conclusion

The whole system of mobile health care using biosensor network places forward some future works such as finding the most effective mechanism for ensuring security in bio-sensors considering the severe restrictions of memory and energy, representing the collected data in the most informative manner with minimal storage and user interaction, modeling of data so that the system will not represent all the data but only relevant information thus saving memory. These are the generic works that can be done in future in the sector of mobile health care. For IMHMS our vision is much wider. We think of a system where the patients need not to do any actions at all. With the advancement of sensor technologies it is not far enough when the bio-sensors itself can take necessary actions. A patient needed glucose does not need to take it manually rather the bio-sensors can push the glucose to the patient's body depending on the feedback from the IMS. It seems to be impossible to achieve by everybody. But nothing is impossible. Today we imagine of something and see that it is implemented in the near future. But if we stop imagine and thinking then how impossible can be made possible? This paper demonstrates an intelligent system for mobile health monitoring. Smart sensors offer the promise of significant advances in medical treatment. As the world population increases, the demand for such system will only increase. We are implementing the IMHMS to help the individuals as well as the whole humanity. Our goals will be fulfilled if the IMHMS can help a single individual by monitoring his or her health and cautions him to take necessary actions against any upcoming serious diseases.

References

1. S. I. Ahamed, M. M. Haque, K. Stamm, and A. J. Khan. Wellness assistant: A virtual wellness assistant using pervasive computing. ACM Symposium on Applied Computing (SAC), Seoul, Korea, pages 782–787, March 2007.
2. S. K. S. Gupta, S. Lalwani, Y. Prakash, E. Elsharawy, and L. Schwiebert. Towards a propagation model for wireless biomedical applications. IEEE International Conference on Communications (ICC), 3:1993–1997, May 2003.
3. I. Korhonen, R. Lappalainen, T. Tuomisto, T. Koobi, V. Pentikainen, M. Tuomisto, and V. Turjanmaa. Terva: wellness monitoring system. Engineering in Medicine and Biology Society, 20th Annual International Conference of the IEEE, 4(29):1988–1991, Oct 1998.
4. A. Milenkovic, C. Otto, and E. Jovanov. Wireless sensor networks for personal health monitoring: Issues and an implementation. Computer Communications (Special issue: Wireless Sensor Networks: Performance, Reliability, Security, and Beyond), Elsevier, 29(13-14):2521–2533, Oct 2006.
5. J. Parkka, M. van Gils, T. Tuomisto, R. Lappalainen, and I. Korhonen. Wireless wellness monitor for personal weight management. Information Technology Applications in Biomedicine, IEEE EMBS International Conference, pages 83–88, Nov 2000.
6. U. Varshney. Pervasive healthcare and wireless health monitoring. Journal on Mobile Networks and Applications (Special Issue on Pervasive Healthcare), Springer, 12(2-3):111–228, June 2007.