ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 10, October 2015

A Review of Wearable Health Monitoring Systems

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ABSTRACT: In this paper, various wearable health monitoring techniques have been reviewed. A WHMS keeps track of temperature, blood pressure, pulse/heart rate, pulse-oximetry (SPO2) and muscle activity, etc. The system displays these readings in real time on some kind of display. It also keeps track of historical information on an hourly and daily basis. This historical data can be pulled up on the display at the request of the user or sent to a remote server. Various techniques are used to monitor the health like standalone health monitors, wearable sensor, wireless sensor networks, microcontrollers and in the recent years cloud based e-healthcare systems have emerged. Along with these systems we have also discussed the possibilities of using Internet of Things in the field of Healthcare and rehabilitation.

KEYWORDS: Health Monitoring, Wearable Sensors, Wireless Sensor Networks, e-healthcare, Cloud Computing.

I.INTRODUCTION

In this 21st century, technology has grown to limitless extents. It has made human lives more easy and sophisticated. However, from the period of industrial revolution pollution has significantly risen thus making the environmental conditions unhealthy for life. In the turn of events humans have become more prone to different physical and psychological problems. While the aging population is increasing day by day there is a rising demand of healthcare systems in order to encounter the various health related challenges. This paper intends to study and review the various techniques used or under research for such healthcare situations. Wearable health monitoring systems are designed to make the measurements necessary to track different body parameters in a cost effective manner. In WHMS, different parameters like blood pressure, temperature, pulse/heart rate, muscle activity, blood sugar level, oxygen content in blood (SPO2), brain activity, motion, etc are all shown on the LCD or Graphical LCD display. Measurements are taken on request or in a timely manner depending upon the person's health. Programmable alarms are also available in the monitoring systems which indicate out-of-range conditions. Devices have internal memories to save the measured data. Blood Pressure measuring devices have Systolic and Diastolic range indicators. While some blood pressure sensors have pulse indicators on the same device. Some devices have serial port connectivity which permits linking to a PC or laptop for data transfer. Some systems supplied with sensors, an AC adapter, and some AA sized backup batteries. The conventional health monitoring system consisted of individual sensors to measure one health parameter, each connected to a data collection device or recorder. Recent technology advancements has allowed the combination of several sensors into one integrated healthcare system that can be permanently located at one place, or transported to any place where localized healthcare is needed. To reduce the bulky transportation wearable healthcare systems have been developed for individual healthcare, thus making health monitoring simple, easy and cost effective. Cloud computing being the fourth Information Technology revolution has found its way into healthcare. Researchers and organizations are collaboratively working towards the inclusion of cloud based remote healthcare which has yielded some advanced wearable devices as well.

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II. REVIEW OF HEALTH MONITORING TECHNIQUES

A. ***Standalone health monitoring systems.***

Fig. 1 Physiological Health monitoring device showing vital signs used besides the patient bed in hospitals.

Health monitoring is essential in any hospital environment. It gives valuable insight of patient's health to medical and nursing staff. The conventional devices used in this environment are typically pulse monitors, electrocardiography monitors, electromyography monitors, invasive diabetic monitors, breathing rate monitors, invasive and non-invasive blood pressure monitors, body temperature, (SpO2), mixed venous oxygenation (SvO2), cardiac output, intracranial pressure, and airway gas concentrations. Some devices incorporate some of the above sensing devices in one like the one described in [1]. **Fig. 1** shows a physiology health monitoring device usually seen in the hospitals or nursing homes. It is used to monitor vital signs of a patient besides their beds inside hospitals. They are developed with medical and industrial precision standards and show the most accurate sensing values when implemented on a person. However these devices are bulkier and costly. Thus they are rarely used for individual health monitoring outside of the hospitals.

B. ***Wearable health monitoring systems.***

A wearable health monitoring system is the one that can be body worn. In the past decade advancements in silicon technology has led to the rise of smaller microcontroller chips and sensing devices. This led to the development of smaller healthcare devices that were implemented as wearables. Due to their small and compact size, cheap cost wearable health monitors have found their uses in the hospitals as well as homes.

Fig. 2 Wearable watch with pulse rate monitor

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As described earlier in this paper wearable health monitors with different parameters can be seen. Pulse rate measurement has always been an important aspect while determining person's health. For the same reason pulse rate monitors have a longer history than any other wearable health monitor. They have been present for quite a long time. Years of development have transformed them into compact sized wrist bands, watches and recently a ring shaped pulse monitor has been developed which has earned popularity in personal healthcare in a short span of time. A commercially available pulse rate monitoring watch can be seen in **Fig. 2**. Recently a pulse rate sensor based ubiquitous healthcare system was implemented by [2]. The system used wireless 802.11 wireless protocols to communicate with a remote server thus enabling the doctors or nursing staff to view the health parameters of a person remotely.

Fig. 3 Wearable blood pressure monitor with automatic inflation

Blood pressure monitors popularly known as sphygmomanometer were previously bigger in size and consisted of an inflatable cuff, a measuring unit, typically a mercury manometer or aneroid gauge and manually operated inflation mechanisms. Developments in technologies helped creating smaller devices that have automatic inflation mechanism and digital measurement sensors and can be used as and when required. These monitors also have pulse rate measurement sensors. These monitors are more accurate than their predecessors. Wearable blood pressure monitor with automatic inflation usually helpful for personal healthcare is seen in **Fig. 3**. In clinical environments and hospitals this automatic BP monitors have popularized. For their compact sizes and simple functionality this monitors are also being used for personalized healthcare at homes. A PC based management system with Zigbee wireless transmission to wirelessly monitor blood pressure variations was developed by [3]. It consisted of a database and data was represented in graphical format.

Fig. 4 Wearable pulse oximetry (SPO2) monitor

Pulse oximetry sensors or SpO2 monitor is a device to determine person's blood oxygen saturation. It is an important tool that can give insights to respiratory functioning of any individual. A wearable SpO2 monitor can be seen in **Fig. 4**.

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These sensors are widely used in medical environment however these devices are cheaper and smaller and making self-tracking of SpO2 at homes a reality. [4] Implemented a non invasive design of SpO2 sensor for OSA detection that remotely monitored blood oxygen levels and data was transmitted to an android based Smartphone via Bluetooth.

III.WIRELESS SENSOR NETWORKS IN HEALTH MONITORING

Wireless sensor network are the system consisting of the sensor nodes connected wirelessly with a centralised server for data acquisition. Wearable health monitoring systems have been implemented using wireless sensor networks.

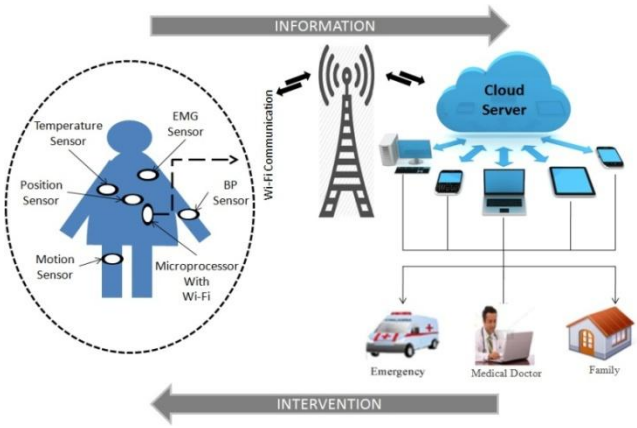

Fig. 5 Representation of wireless sensor networks with data acquisition system.

Wireless sensor networks have been implemented previously using different wireless technologies. A zigbee based wireless sensor network system for healthcare monitoring (RHCMS) was implemented by [5]. It monitored different health parameters in real-time and send this data to online data acquisition system. The system also featured an alert system whenever patient's health parameters deviated from the normal values. [6] Discussed the various available wireless technologies available today like Radio technology, GPRS and Bluetooth that have been used while designing different wireless body area networks. It also describes the uses of Smartphone's in providing healthcare and how they can be used in logging data to remote devices.

Cloud computing has revolutionized the present Information Technology world. The ease of accessing data from any corner in the world has made cloud computing popular with healthcare monitoring systems. **Fig. 5** shows a representation of cloud based healthcare monitoring system. [7] Shows a remote e-healthcare monitoring system using smart devices and wireless sensor networks. It used a processing unit connected to the centralised cloud server through wireless gateway and was able to log the data acquired through different sensors like ECG, pulse rate, temperature etc in real-time. The system notified unevenness in health parameters to the healthcare personals and nursing staff. [8] implemented a similar system consisting of a centralised cloud server with healthcare system to log the data in real-time that can be accessed by anyone having access to the server through an android application.

Internet of things is the most recent technology that is currently in research and development phases. Internet being the worldwide communication gateway was previously accessible by networking devices, PC's or Smart phones. However Internet of things is the implementation of internet with almost anything. In wearable health monitoring devices IoT's can be used to connect human body to the internet so as to remotely monitor various vital body parameters in real-time thus making healthcare simpler and easy. It is still a topic for research and hopefully the implementations will be available for day-to-day healthcare soon.

VI.CONCLUSION

In this paper, the current state in research and development of health-monitoring is reviewed by summarizing and comparing the attributes of the most promising current achievements of several worldwide projects and commercial products. We also reviewed the most important and widely employed bio sensor technologies along with the

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corresponding measured bio signals that are currently in design phase or have already been designed. Wireless networks, Internet of Things and Cloud computing for Medical Applications are becoming a hot topic in the industry. In this deep study paper, we focused our discussion on the benefits of wireless networks for medical applications. We have discussed about how these new Wireless technologies and Cloud Services can be utilized in potential manner to get benefits for the human well being. Thus these technologies help us to design less intrusive Wireless sensor devices, which help us in ensuring human life. After having a study about the Wearable sensor networks, we acquired good knowledge about it. We are planning to implement the ideas whatever we gained from this deep study to contribute to the medical application that could help the whole mankind.

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