International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.3, 2015

RESEARCH ARTICLE

ISSN: 2321-7758

WIRELESS SENSOR BASED HEALTH MONITORING FOR GERIATRIC PERSON

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Article Received:20/05/2015 | Article Revised on:10/06/2015 | Article Accepted on:16/06/2015

ABSTRACT

Human behaviour modelling is one of the biggest challenges in artificial intelligence. Falls are the top causes of unintentional injury and death in the elderly population. The associated costs, coupled with a rapidly growing elderly population, are placing a burden on healthcare systems world-wide that will swiftly become unbearable. To facilitate expeditious emergency care, an artificially intelligent camera-based system had been developed that automatically detects, if a person within the field of view had fallen, in consumer home network. The accelerometer sensor is complemented by other smart sensors such as temperature, pressure sensors all integrated on a single board, recording real time acceleration and ambient environment information. Both acceleration and environment information are first captured by using an analog-to-digital converter. Each sensor is used to identify the human activity and this information is collected, stored based on acquisition. If this measurement exceeds these values, through zigbee protocol the information is transferred to caregivers and then provides solution to patient. In proposed system, while using ambulance the location of patient also be identified.

Keywords —Consumer Home Network, Fall Detection System, Elderly Patient Monitoring, unintentional injury, Zigbee protocol

I. INTRODUCTION

Nowadays, many types of consumer electronics devices have been evolved for home network applications. A consumer home network ordinarily comprises variety of electronic devices, e.g. sensors, actuators, controllers, so that home users can control them in clever and automatic way to upgrade their quality of life. Some emerging technologies to implement a home network include: IEEE 802.11, Ultra Wide Band (UWB), Bluetooth, ZigBee etc. ZigBee is a ***specification*** for a suite of high-level communication protocols used to create ***personal area networks*** built from small, low-power radios. Some typical applications include home automation, home activity detection (like fall detection) and home healthcare, etc. ZigBee has a defined data rate of 250 kbit/s best suited for intermittent data transmissions from a sensor or input device. Abbate et al proposed a smart phone based fall detection system consideration of the acceleration signal produced by fall-like activities of daily life. For the enhancement of wireless sensors and low-power sensor nodes, thanks to many novel approaches have been proposed to solve the problem, as discussed in as Section II. This paper presents enhanced fall detection system for elderly person monitoring through the consumer home network environment is proposed based on smart sensors worn on the body.

In proposed system the patient health is continuously monitored by patient monitoring system the acquired data is transmitted to a centralized PIC server using wireless system. It is commercially implemented to all around the world. Furthermore, the cost of healthcare is highly related to the response and rescue time, and can be greatly reduced by fall detection and delivering signals to the specified operator for immediate solution. It is found that the system can achieve very high accuracy of 97.5%, the sensitivity and specificity are 96.8% and 98.1% respectively. To provide emergency assistance to senior citizens, rehabilitation patients and also provides feedback to notice optimal health status. Wearable sensors continuous health monitoring is a key technology in helping the transition to more practical and affordable healthcare.

The fundamental problem with this system is that when medical emergency happen to the user, they are often unconscious and unable to press an "emergency alert button". There is no product on the market which does not require manual activation of alarm and monitors a user's vital signatures smartly, though research is currently undergoing. This is the novel design goal of the work presented in this paper. The reported device consists of a wrist strap and a finger ring (circuitry). This allows the sensors to be mounted around the wrist, finger and the PIC unit connected via ribbon cable. Kinsella and Phillips found that the population of 65-and-over aged people in the developed countries will approach 20% of total population in the next 20 years. Evidently in serious condition healthcare and maintenance is great consequence in near future. The rest of the paper is organized as follows: Section I gives detailed overview of the paper. Section II describes the system about previous research. Section III describes the system architecture and sensor deployment. Section IV explains fall detection system in detail. Section V illustrates system performance and Section VI concludes this paper.

II. PREVIOUS RESEARCH

Many previous and current research projects use medical sensor networks to identify and track human activities in daily life. In order to monitor, detect and report time-critical events such the urgency of the situation can be evaluated, and co-ordinated in a number of ways and in a timely manner. The reason is that it is very expensive for the base station or the sink node to accumulate information from every sensor node and identify them in a centralized manner. With the purpose to successfully detect falls, there are primarily three types of fall detection methods for elderly people, namely wearable device based methods, Computer Vision-Based Methods, Ambient Based Methods.

A. Wearable Device Based Methods

The present development of the demography of elderly people in the Western world will generate a shortage of caretakers for elderly people in the near future. The new concept of health monitoring is advanced by which health parameters are automatically monitored at home without disturbing daily activities. Wearable based methods often rely on smart sensors with embedded processing. They can be attached to the human body or worn in their garments, clothing or jewellery. For these methods, different sensors (including acceleration sensors, acoustic sensors and floor vibration sensors) are used to capture the sound, vibration, and human body movement information and such information is applied to determine a fall event. Zhang, Ren and Shi proposed HONEY (Home healthcare sentinel system), a three -step detection scheme which consisted of an accelerometer, audio, image and network storage for approximately 390,000 and specifically 40% of the falls were from people over 70 years of age. Bagalà gave an evaluation of accelerometer-based fall detection algorithms on real-world falls. Statistics show that one among three 65-and-over aged person falls on each year. Among these fall events, 56% occur at home and 22% occur near the home. Bai, Wu and Tsai described a system based on a 3-axis accelerometer embedded in a smart phone which had a GPS function for the user. However, due to the high energy consumption of current smart phones, their system could only be active for 40 hours with

44hours in background execution, which means continuation of this system is the most important consequences .

B. Computer Vision-Based Methods

In the past decades, there had been more improvement in computer vision and camera/video and image processing techniques that use real-time movement of the subject, which opens a new branch of methods for fall detection. For computer vision-based fall detection methods, some researchers have gathered information from the captured video and a simple threshold method had been applied to determine whether there is a fall or not; Rougier *et al.* [7] and [8], in these two papers, the head's velocity information and the shape change information were extracted and appropriate thresholds were set manually to differentiate fall and non fall activities.

C. Ambient Based Methods

Ambient based methods usually concentrate on pressure sensors, acoustic sensors or even passive infrared motion sensors, which are usually furnished around caretaker's houses. Popescu developed an acoustic-based fall detection system which used an array of acoustic sensors. Acoustic sensors have been early used in habitat monitoring. In a set of acoustic sensors was used to differentiate between several sound classes such as breaking glass, screams, door sound and human sound. A microphone was placed in each room of the apartment to acquire the location of the sound. Yan addressed the invasive nature of these wearable devices by developing a system that did not necessarily require the user to be wearing a sensor, yet was able to detect the user's location based on observations of interaction with the home-installed sensor network. Video based methods are usually more accurate than wearable based and ambient based methods. However, these systems often suffer from high risk of privacy and the excessive cost implementing cameras.

III. PROPOSED SYSTEM

The block diagram of proposed fall detection system is shown in Fig. 1, whose core structure is based on a This technique presents a system to upgrade existing health monitoring systems in hospitals by providing monitoring capability and gives a better cure. The accelerometer sensor is combined by other smart sensors including temperature and pressure sensors are unified in a single board, recording real time acceleration and ambient environment information. Both acceleration and environment information are fed to an analog-to-digital converter (ADC). Then, the digital signal is transmitted to the MCU for further processing. The heart rate is captured by an IR (Infrared light sensor) and also passed directly to the MCU. The fall detection sensors are linear arrays of electrode condensers fixed on a pre-amplifier board. In order to capture the information of the sound height, the sensor array was placed in the z-axis. The disadvantage of this method was that that only one person was allowed in the vicinity. Besides it holds out a convenient solution to add any custom sensing. The system with a custom interface designed to monitor information in real time.

Micro programmed Controller Unit (MCU).

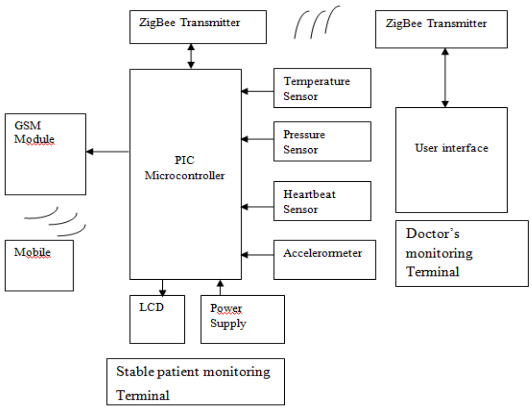

Fig. 1 Block Diagram

A. *System and Sensors*

A multi-functional data acquisition board has been used incorporating temperature, pressure, heart beat sensors. LM35 is a precision IC temperature sensor where change in resistance proportional to the temperature (in ^{o}C). A pressure sensors to measure pressure and heart beat sensors to measure heart rate. Besides, it offered a suitable solution to add any custom sensing application in future research. To detect the impact of accidental falls, a small low power tri-axial accelerometer is used to measure the static acceleration of gravity in tilt-sensing applications. Also, it can measure the dynamic acceleration results from motion, shock or vibration. The specified accelerometer gives output accelerometer will output acceleration in a three axis at every sample point, with units of m/s^2. The output is an analog signal which must be converted by an ADC before sending to the MCU.

B. Controller Unit System

The main component of this system is a MCU with 8 Kb flash memories. It is an intermediate between relatively high performances vs. low-power (2.7-5.5V). This high-density non-volatile memory based MCU equip with an embedded 8-channel, 10-bit ADC, and system produce a highly flexible and cost effective solution to many embedded control applications. Information collected by accelerometer is converted in the chip and send to the wireless communication module along with pulse signals. To detect the acceleration and heart rate more accuracy, the whole house can be divided into several clusters based on the room locations. Each room has a fixed access point for data collection and transmission. The sensor nodes represent the accelerometer or cardio-tachometer, which could be located anywhere in the house. The signal from wireless module can be transmitted directly to base station or through the fixed access point. The system sends information through zigbee to enable communication when it encounters problems of connecting to the base station directly. Some features of MCU are listed below.

- 368 bytes of data Memory (RAM).
- 256 bytes of EEPROM Data Memory.
- 33 inputs or output pins.
- 20 MHz operating speed (200 ns instruction cycle).
- High performance RISC CPU.
- Only 35 simple word instructions
- Timers, 2-16 bit CCP, 2-Serial communication modules.

C. User Interface

The data gathered from a participants body is appended with a unique ID and transmitted to a remote laptop by the wireless receiver with type number of the base station being used. As is shown in Fig. 3, a user interface is designed to display the accelerometer and heart rate signal. The interface can monitor four participants' data at the same time. In each part, data curves are illustrated on upper left and real -time data are shown on the right of the curves. Once the alarm is triggered, a red marked warning will be shown at the bottom left part of the monitors. In order to assure that a caregiver, or relatives, get real-time and accuracy information, the location of the wireless sensor network is significant. Modern wireless sensor networks have been highly normalized by ZigBee, but they cannot efficiently handle the specific tasks due to the constrained environment. In order to do so, the wireless communication stack in the wireless sensor network needs to be optimized so many sensor nodes need to be put in one base station. There is a use of 16x2 characters LCD. This will be connected to microcontroller. The job of LCD will be to display all the system generated messages coming from the controller. LCD will provide interactive user interface. Every sensor node can be freely configured as a master or slave. Considering ZigBee transmission power, propagation does not reliably pass through modern construction walls to the base station therefore the base station usually does not receive the signal transmitted from a neighbouring room.

IV. LEVELS OF OPERATION

The proposed enhanced fall detection method is based on three common changes which happen during accidental falls: impact magnitude, trunk angle, after-event heart rate. Hence, a triple-threshold for the previously fall related even tin chronological order is proposed in this paper. A flowchart of the proposed method is .An initiatory estimation of the body movement can be obtained from the Signal Magnitude Vector (SMV) defined as:

$$SMV = \sqrt{Acc_x{}^2 + Acc_y{}^2 + Ac} \quad (1)$$

Since the direction of possible falls cannot be predicted, it is inappropriate to use only one output of the axis. At the beginning, acceleration due to gravity, *g,* lies in the z direction. The acceleration changes along with body movement. Acceleration threshold had been set to 1.9 *g* as in the literature [9]. A typical fall event ends with the person lying on the ground or leaning on walls, or furniture that will cause significant change in truck angle. In this case, it is desirable to consider changes on the truck angle to detect whether the detected acceleration was due to a fall event. Trunk angle (ϑ) can be defined as angle between the SMV and positive z-axis and can be calculated by inverse trigonometric function as in equ. (2)The threshold for ϑ has previously been given as: to 60◦ classified as upright and 60 to 120◦ classified as a lying posture [19].

$$\theta = acc \times \cos(Acc_z / SM \quad (2)$$

The emergency case can be classified into four levels:

- Caretaker level: When the system is setup, it will check whether the SMV and temperature is over threshold. If it does not, it would frequently check the heart rate. Once the heart rate gets over a threshold value, the system will assume an emergency event has occurred and would request the caregivers to check out the elderly condition.
- Relatives level: Once the system noticed the acceleration is over threshold in the first decide loop, the system will then examine the value of heart rate. If it higher than the preset threshold, the call will be forwarded to the relatives and they contact the elderly person's home.
- Caretaker and relatives level: In addition, in case the acceleration, pressure, heart rate values are get higher than the preset thresholds, then system can contact the caregivers and relatives irrespective of the trunk angle as a distinct floating in heart rate coupled with high acceleration is a significant warning.
- Emergency level: If all four thresholds, SMV, heart rate, pressure, acceleration are higher than normal, the system as assumed that an accidental fall has happened. The system will contact the emergency centre immediately requiring an ambulance.

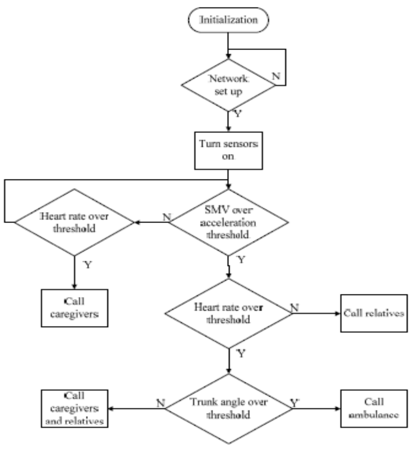

Fig. 2 Flow chart for fall detection

V. PERFORMANCE EVALUATION

A. *Laboratory Based Tests*

To evaluate the accuracy of proposed method, 30 healthy male and female participants were invited to take part in this research. Their ages range from 19 to 45 years, weights range from 48 to 80 kg, and heights of 160 to 185 cm. TABLE lists 13 kinds of fall detection experiments including 6 falls and 7 activities representative of Active Daily Lives (ADL). In order to obtain meaningful data, participants are asked to perform every sub-experiment three times. Participants are asked to wear a pulse pressure sensor on their wrist and the integrated sensor board on their chest. After sensors are implemented carefully, participants were asked to do the tests set out in TABLE. Two assistants stood next to the falling participant to make sure that there was no accident during the experiment procedure. Finally, heart rate change threshold can be set as 15%. Participants under 30 years old have relatively small fluctuation when suffering a fall event. Fig. 3 illustrates the pressure change before and after fall events. Therefore, if a fall event happened on an elderly person, the proposed heart rate threshold will normally be triggered. Four misses were found in running down stairs were caused by suddenly stopping at stair corners but as running is rare among elderly persons then the false positive reports were not considered further analysis.

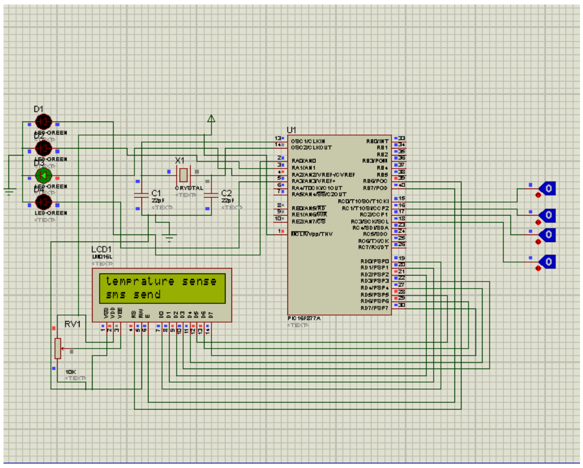

Fig. 3 Temperature monitoring

This inconsistency always exists in threshold based systems. Thus searching a balance between sensitivity and specificity is one very important issue under practical implementation. When using the system to do the ADL tests, 16 false positive reports existed, including running down the stairs, picking up an object from the floor, and standing up fast from a chair. Among the three events, the system missed 5 times in picking up an object from the floor. Also there are 8 false negatives reported in a forward fall, landing on knees and seating on a chair. After checking the raw data, this was because that trunk angle did not exceed the preset threshold. A lower trunk angle threshold may solve this issue.

However, reducing the trunk angle threshold will cause the increase of false positive reports were not considered further analysis.

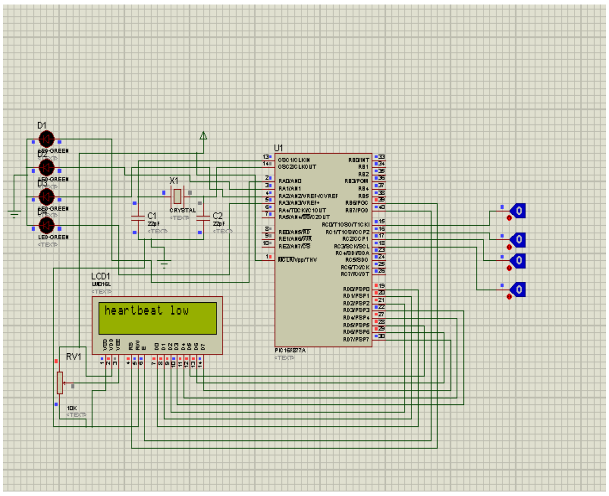

Fig.4 Heartbeat monitoring

This may be caused by the fact that some participants sub- consciously brake the fall with their arms causing low acceleration and therefore not reaching a trigger threshold. Also there are 8 false negatives reported in a forward fall, landing on knees and seating on a chair. After checking the raw data, this was because that trunk angle did not exceed the preset threshold. A lower trunk angle threshold may solve this issue. However, reducing the trunk angle threshold will cause the increase of false positive reports.

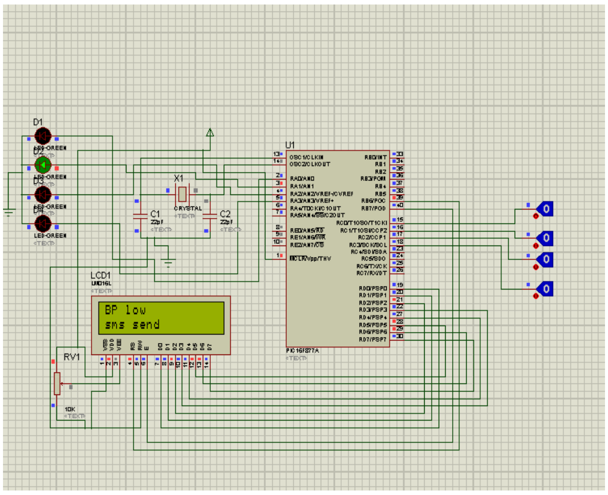

Fig. 5 Pressure monitoring

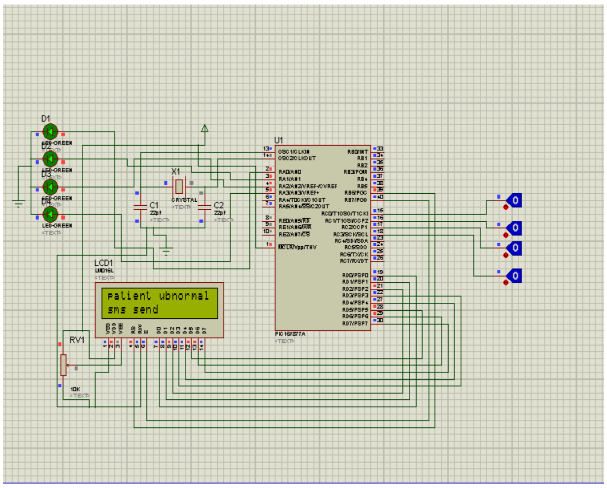

Fig. 6 Abnormal condition

VI. CONCLUSION

In this paper, an enhanced fall detection system based on smart sensors which are worn on body. It was proposed, implemented, and deployed successfully in a consumer home application. In future work, a new device with lower energy consumption and longer communication distance will be developed to make the system more suitable for a broad-range of healthcare applications. By using information from an accelerometer, smart sensor and cardio tachometer, the impacts of falls can successfully be distinguished from activities of daily lives reducing the false detection of falls. From the dataset of 30 participants, it is found that the proposed fall detection system achieved a high accuracy of 96.4%, and the sensitivity and specificity are 95.7% and 98.2% respectfully. The proposed system is ready to be implemented in a consumer device.

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