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An Enhanced Fall Detection System using Sensor, GPS, GSM Technology

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Abstract: Various fall-detection solutions have been previously proposed to create a reliable surveillance system for elderly people with high requirements on accuracy, sensitivity and specificity. In this project, an enhanced fall detection system is proposed for elderly person monitoring that is based on smart sensors worn on the body and operating through consumer home networks. With treble thresholds, accidental falls can be detected in the home healthcare environment. By utilizing information gathered from an accelerometer, cardio tachometer and smart sensors, the impacts of falls can be logged and distinguished from normal daily activities. The proposed system has been deployed in a prototype system as detailed in this paper. From a test group of 30 healthy participants, it was found that the proposed fall detection system can achieve a high detection accuracy of 97.5%, while the sensitivity and specificity are 96.8% and 98.1% respectively. Therefore, this system can reliably be developed and deployed into a consumer product for use as an elderly person monitoring device with high accuracy and a low false positive rate.

Keywords: Fall Detection System, Elderly Monitoring, Heart Rate Fluctuation, ARM Microcontroller, GPS,GSM.

I. INTRODUCTION

In recent years, many types of consumer electronic devices have been developed for home network applications. A consumer home network usually contains various types of electronic devices like sensors and actuators, so that home users can control them in an intelligent and automatic way to improve their quality of life. Some representative technologies to implement a home network are Ultra Wide Band, Bluetooth and accelerometer.

Accelerometer is suitable for consumer home networks because various sensors can be deployed to collect home data information in a distributed, self-organizing manner with relatively low power. The structure of projected fall detection system core structure relies on a Micro programmed Controller Unit (MCU). The cardio tachometer and accelerometer are integrated on one single board, recording real time acceleration and heart beat. Each acceleration and heart beat information is first captured by analog-to-digital converter (ADC).

Then, the digital signal is transmitted to the MCU for any process. The system is complemented with a customer interface designed to watch information in period. This system is designed such that it can help the elder persons who are residing in the house. Global Positioning System consists of a constellation of 21 satellites orbiting the earth every 12 hours at a height of approximately 10,900 nautical miles. Six orbital planes contain four satellites each and have an angle of inclination of 55 degrees with respect to the plane of the earth's equator. Control of the system is aided by five globally located monitoring stations. These stations continuously evaluate the system performance and upload data which is then rebroadcast to the user.

II. METHODOLOGY OF DETECTION

An initiatory estimation of the body movement can be obtained from the Signal Magnitude Vector (SMV)defined as:

$$SMV= ((Ax)^2+(Ay)^2+(Az)^2)^{0.5} \quad ..... (1)$$

Where Ax ,Ay, Az represent the outputs of x-axial, y-axial and z-axial, respectively. 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, furthermore, vibration becomes significant when the fall happens. A typical fall events ends with the person lying on the ground or leaning on walls, or furniture that will cause a significant change in trunk angle. In this case, it is desirable to consider changes on the trunk angle to detect whether the detected acceleration was due to fall event. Trunk angle can be defined as angle between the SMV and positive z-axis and can be calculated by trigonometric function as

$$\Theta = \mathrm{Arcos}(Az/SMV) \quad ….. (2)$$

III. RELATED WORK

Many fall detection techniques are available to detect fall detection rate, some of the techniques are described in this existing system which are illustrated below very clearly.

I. Akyildiz, W.Su,Y. Sankarasubramaniam, and E.Cayirci, have designed “Wireless Sensor Networks: A Survey”. Which describes two thirds of elderly with hip fracture never regain their pre-fracture activity status and one-third require nursing home placement. Given these facts, human behavior analysis can contribute with a strong point both on the prevention and detection of this type of hazardous

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situation. Systems monitoring the elderly living space could analyze potential risks of falls occurring and identify potential causes of falling and consequently correct adaptations on the living space. In terms of fall detection, it would be advantageous, for those situations where full monitoring is not possible, to have systems with the capabilities for alarming cares about abnormal situations. This system use only alarm to indicate the elders falling situation.

M.Yu, A.Rhuma, S.Naqvi, L.Wang, and J.Chambers, have proposed “A Posture Recognition-Based Fall Detection System For Monitoring An Elderly Person in a Smart Home Environment”. In this paper global (ellipse) and local (shape context) features from static postures and an improved Directed Acyclic Graphic Support Vector Machine (DAGSVM) is applied for posture classification. After classifying different postures, certain rules are set to detect falls. This fall detection system is shown by evaluation on real datasets to achieve a good fall detection performance. For a comprehensive evaluation of this fall detection system, the volunteer is asked to simulate 32 fall activities and 64 non-fall activities. Final results which show that 31 out of 32 (96.88%) falls can be detected while only 3 out of 64 (4.7%) non-falls were mistaken as falls; and a high fall detection rate is obtained with an acceptable false detection rate.

Y.W Bai, S.C. Wu, and C.L. Tsai have designed “Design and Implementation of a Fall Monitor System By Using a 3-Axis Accelerometer In A Smart Phone” Here the Various fall-detection solutions have been previously proposed to create a reliable surveillance system for elderly people with high requirements on accuracy, sensitivity and specificity. In this paper, an enhanced fall detection system is proposed for elderly person monitoring that is based on smart sensors worn on the body and operating through consumer home networks. By utilizing information gathered from an accelerometer, cardio tachometer and smart sensors, the impacts of falls can be logged and distinguished from normal daily activities. The proposed system has been deployed in a prototype system as detailed in this paper. From a test group of 30 healthy participants, it was found that the proposed fall detection system can achieve a high detection accuracy of 97.5%, while the sensitivity and specificity are 96.8% and 98.1% respectively.

S.Demura, S.Shin, S.Takahashi, and S.Yamaji, have developed “Relationships Between Gait Properties on Soft Surfaces, Physical Function, and Fall Risk For The Elderly” Which describeshealthcare technologies are slowly entering into our daily lives, replacing old devices and techniques with newer intelligent ones. Although they are meant to help people, the reaction and willingness to use such new devices by the people can be unexpected, especially among the elderly. We conducted a usability study of a fall monitoring system in a long-term nursing home. The results gave us useful insights, leading to ergonomics and aesthetics modifications to our wearable systems that significantly improved their usability and acceptance. New evaluating metrics were designed for the performance evaluation of usability and acceptability. This system took motion pictures only. In case of falling any objects it can took a image and send an indication. Where there any elder person falling means the image is sending delay. In case the picture was not accuracy, the message is not sent.

IV. PROPOSED WORK

The structure of proposed fall detection system whose core structure is based on a Micro programmed controller unit. The accelerometer sensor along with cardio tachometer is integrated on one single board, recording real time acceleration and pulse rate. Both acceleration and pulse rate are first captured using an analog-to-digital converter. Then the digital signal is transmitted to the MCU for further processing. The heart rate is captured by a pulse pressure sensor and also passed directly to the MCU and the location is detected using GPS and communicated using GSM. The message can be set to reach the nearest hospital and the relatives. The message contains latitude and longitude values of accident place. Thus, wearable sensor based methods are considered in this research. By using information from an Accelerometer and cardio tachometer, the impacts of falls can successfully be distinguished from activities of daily lives reducing the false detection of falls. This system has a set value to distinguish a high fall detection rate and low false detection rate.

A. Block diagram

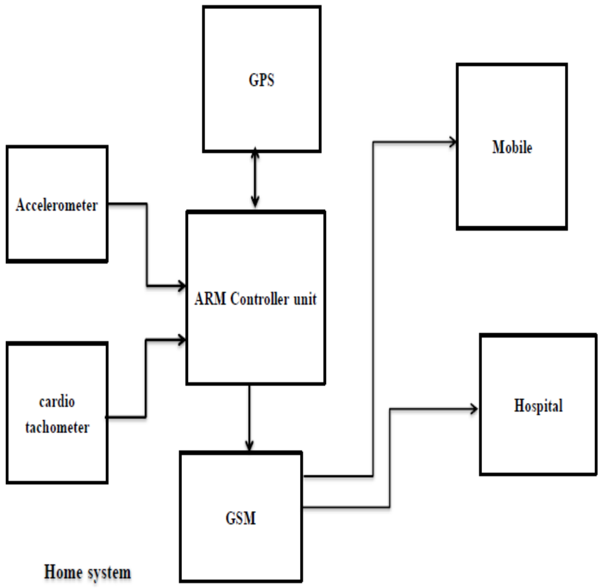

Fig. 1. Block diagram of the complete system

B. Block Diagram Description

This block diagram comprises MCU, mobile interfacing circuit, signal conditioning circuit (sensor).The GSM MODEM is interfaced to the MCU by using RS232 interface.

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The sensor may be a load cell or sprain gauge which is used to detect the level of the impact and the signal to the MCU. If the controller predicted that the sprain gauge value is more than the critical limit then the information is sent to the presto red number in the microcontroller through SMS to Hospital or their relation to rescue.

Liquid crystal display is very important device in embedded system. It offers high flexibility to user as he can display the required data on it. But due to lack of proper approach to LCD interfacing many of them fail. Many people consider LCD interfacing a complex job but according to me LCD interfacing is very easy task, you just need to have a logical approach. This page is to help the enthusiast who wants to interface LCD with through understanding.RS232+5VPowered, Multichannel RS-232 Drivers/Receivers.

The LPC2148 microcontrollers are based on a 32-bit ARM7TDMI-S CPU with real-time emulation that combines the microcontroller with 8 kB, 16 kB or 32 kB of embedded high-speed flash memory.

A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical performance in interrupt service routines and DSP algorithms, this increases performance up to 30 % over Thumb mode. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty. Due to their tiny size and low power consumption, the LPC2148 is ideal for applications where miniaturization is a key requirement.

A blend of serial communications interfaces ranging from multiple UARTs, SPI to SSP and two I2C-buses, combined with on-chip SRAM of 2 kB/4 kB/8 kB, make these devices very well suited for communication gateways and protocol converters.

The superior performance also makes these devices suitable for use as math coprocessors. Various 32-bit and 16-bit timers, an improved 10-bit ADC, PWM features through output match on all timers, and 32 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers particularly suitable for industrial control and medical systems.

The GPS provide the latitude and longitude of the test position which can be referred as the location of accident. & sent In the form of text message through GSM to the caretaker/hospital.

C. Flowchart

The following flowchart Fig. 2 will represent the full operation of an enhanced fall detection using GPS & GSM.

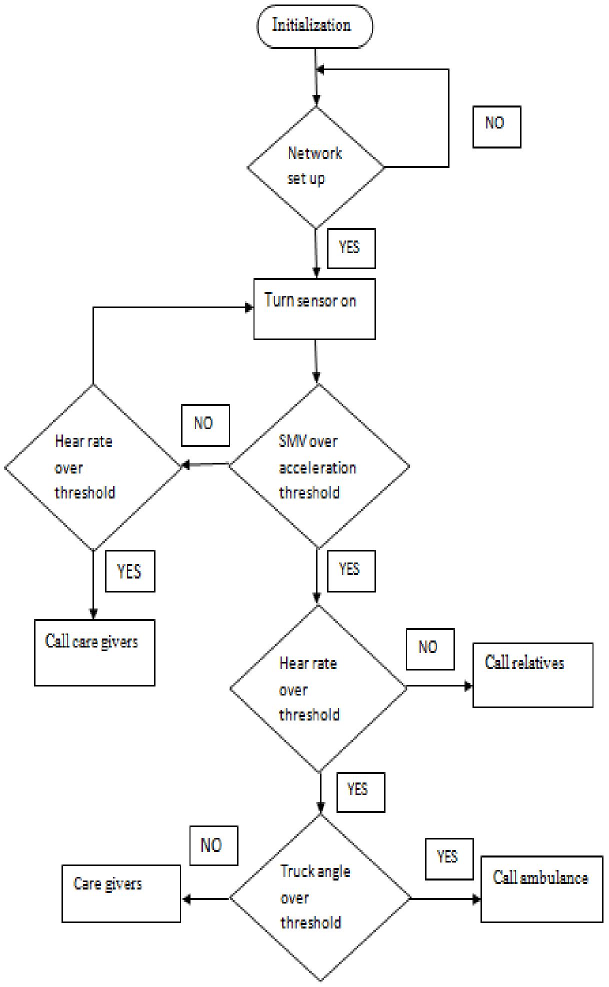

Fig. 2. Flowchart showing the complete functionality of the system

D. Threshold details

The various conditions are tested practically and the following value have been specified as threshold and fed to the microcontroller. The typical parametric values are tabulated in TABLE I

TABLE I

Condition	**Threshold Range**		
	Parameters	**Heart rate**	**SMV**
Case 1	Person Heart rate has increased but no fall has occurred.	> 100	< 3
Case 2	Person Heart rate is normal but fall has occurred.	60 - 100	> 3
Case 3	Person Heart rate has increased & fall has occurred.	> 100	> 3

E. Performance test

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, eights range from 48 to 80 kg, and heights of 160 to 185 cm. TABLE II lists 6 kinds of fall detection experiments. In order to obtain meaningful data, participants are asked to perform every sub-experiment three times. The tests were accomplished by falling on thin mats in a configured laboratory. Their fall related data was transmitted to a laptop for further analysis. As discussed earlier SMV and trunk angle thresholds have been proposed by previous research. The threshold of heart rate changes needed to be carefully selected as the heart rate examination acts as the last classifier. 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 II.

TABLE II

Case	**Experiment**
1	Backward fall, lying on ground
2	Backward fall, seating on ground
3	Backward fall, seating on chair
4	Forward fall, landing on knees
5	Forward fall, lying on ground
6	Seating in bed, falling to ground

F. Results and Discussion

From the dataset of 30 participants, it is found that the proposed fall detection system achieved a high accuracy of 97.5%, and the sensitivity and specificity are 96.8% and 98.1% respectfully. The proposed system is ready to be implemented in a consumer device.

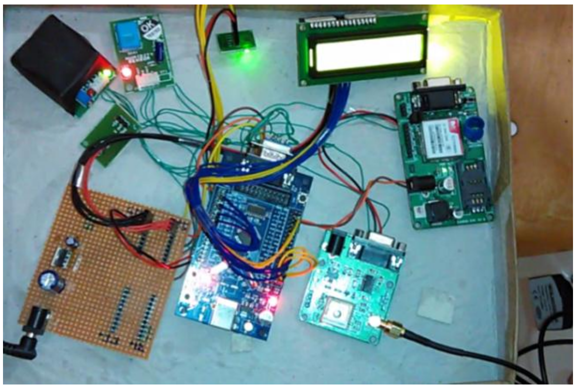

Fig. 3. Working model of the system

Case 1- Person Heart rate has increased but no fall has occurred then message to caretaker is delivered.

Case 2- Person Heart rate is normal but fall has occurred then message to relative is delivered.

Case 3- Person Heart rate has increased & fall has occurred then message to the hospital is delivered.

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.

V. Conclusion

A sensor interface design based on Advanced RISC Machine (ARM) system is proposed. An enhanced fall detection system using on–body smart sensor is implemented and deployed which can successfully detect accidental fall and decreased pulse rate in elderly people. Accidental falls can be detected by using wearable sensor (accelerometer) by setting a value of 1.01g, decreased heart rate can be detected using a wearable sensor (Cardio tachometer) by setting a value of 79 as pulse rate. Ideally combining GPS and GSM with this on-body smart sensor can help to communicate the outputs and track the location of impact of elderly people wearable sensor system can be of good use to monitor elderly people and GPS location tracking along with this system provides a logical solution which is unique in this proposal.

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