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RESEARCH ARTICLE

Fall Detection System for Elderly Person Monitoring Using GSM Network

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Abstract-- The World Health organization (WHO) indicated that falls are the second leading cause of unintentional injury, deaths for those over 65 years old worldwide. Non-fatal injurious falls can not only cause disability or functional impairment, but also have psychological effects that reduce the range of Activities of Daily Living (ADLs).A combination of sensors such as accelerometer and ultrasonic sound sensor is a cost efficient method for fall detection. Arduino boards are used to detect the fall events based on threshold values. A pair of RF transmitter and receiver is used for wireless communication. Moreover in case of emergency sending an alert to the caregiver would help in timely medical aid. When the microcontroller in the Arduino board senses drastic changes from the threshold values of the sensors outputs, an emergency alert is sent as SMS to the caregiver through a GSM.
Keywords -- Accelerometer, ultrasonic sensor, fall detection, SMS, GSM.

1. INTRODUCTION

The world is ageing. People aged 60 and older make up over 11 percent of the global population, and by 2050, that number will rise to about 22 percent [13].Falls are a major health problem among the elderly people. About one third of every person aged above 65 is affected by the fall and related health issues. Falls are a major cause of psychological problems which reduce the independent living of the elderly people. This age of the growing global elders population needs a lot of support from the technology to improve and monitor healthcare. Advancement in smart sensors, Internet of Things (IOTs) plays a vital role in present health monitoring solutions. Sensors create a more interactive and immerse world. Wireless technologies made these sensors as a good candidate to provide the next paradigm shift in health care. MEMS base sensors facilitate the universalization of wireless health solutions. They have the potential to lower production and operational costs, increase in accuracy of measurements in low resource environments. In the industrialized countries, MEMS based sensors will transform the healthcare delivery system to make it patient centric, ubiquitous, and preventive. In underdeveloped regions, these sensors will eliminate the need to develop complex infrastructures for clinical laboratory settings. Tri-axial accelerometer gives more accurate readings to detect tilts. RF link provides efficient and low cost transmission for medium ranges. The main reason that pushed for the development of the presented prototype device is to allow older people to live safely in their own houses as long as possible. This is important not only for health aspects regarding the assisted people, but also for the consequent social advantages, like the possibility for care-giver institutions to employ more efficient and optimized services, at lower cost, and hence available to a wider part of the population. This will help the children of elderly to monitor the physiological condition of their parents from their working sites. Automatic devices to classify between the daily activities and emergency situations seem to be a good solution to reach this objective. In particular, recent miniaturization and cost reduction of MEMS accelerometers and availability of reliable wireless communication technologies enabled the realization of affordable wearable monitoring systems that can be worn by people performing their normal daily activities.For these reasons, in the last few years, the use of portable devices in the health monitoring of chronic patients has considerably increased. Furthermore, in order to prevent false or missed alarms, the use of multi-sensor systems is reliable and the wearable accelerometer has the fundamental role to validate system decisions.

II. RELATED WORKS

NorbertNoury et al., [2] used pyro-electric infrared sensor and a magnetic contact to detect the approach or the passage of the person. The system is implemented with Atmel processor (AT9OS8535). The communication with the local Personal computer is performed via a RF transceiver. Gerard M.Lyons et al., [3] measured mobility by an accelerometer-based portable unit, worn by each monitored subject. Mobility level summaries are transmitted hourly, as an SMS message, directly from the portable unit to a remote server for long-term analysis. Tong Zhang et al., [4]usedthe experiment system consisting of two computers and a cell phone with a box affixed. The computers are used as remote servers. The circuit and the cell phone compose a fall detector.Fletcher et al., [5]carried out their work using wearable sensors. Wearable sensors have been successfully integrated into clothing garments as well as fashion accessories.J.Wang et al., [6]proposed a fall detection system whose core structure is based on a MCU. The accelerometer sensor is complemented by other smart sensors including temperature and humidity sensors, all integrated on one single board, recording real time acceleration and ambient environment information.

III. PROPOSED DESIGN

There are 2 major steps involved in this project

1. First is to sense the position of elderly person using sensors. Accelerometer gives details about movements and ultrasonic sensor detects free fall.
2. The care-giver must be alerted by means of a SMS once the fall of elderly is detected.

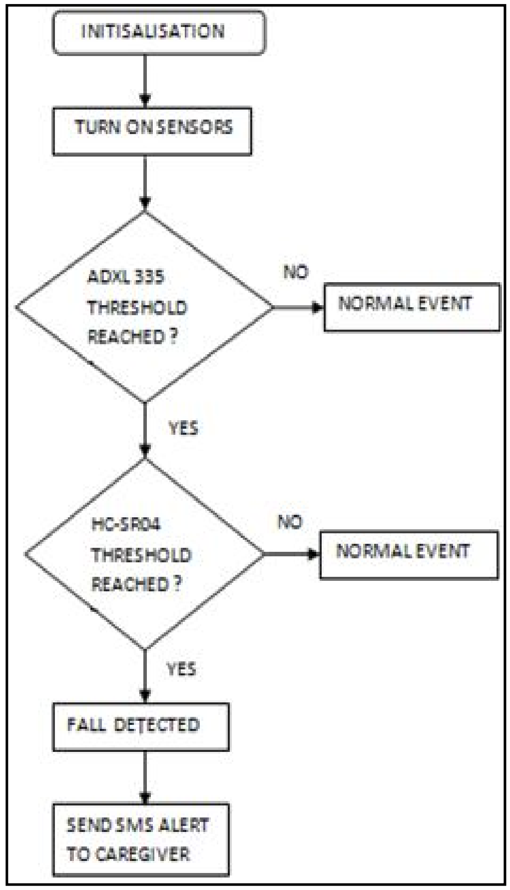


Figure.1 Flow Chart of the experimental system

The fall detection rate is effective when we combine and use the two or more conventional approaches. This reduces the amount of false alarms and increases the efficiency to 90% - 95%. The choice of choosing which methods are to be employed and the test conditions to be set decides the scope of the entire systems functioning. Among choosing the fall detection methods, position detection plays a vital role. To detect the position, tri-axial accelerometers are most preferred. Accelerometers are compact as well as low cost. The accelerometer readings alone are not sufficient to determine the fall detection of the elderly. Because it shows steep change in the values when a person sits suddenly. The choice of a support system to detect a fall using passive sensors avoids most false alarms. Ultrasonic sound sensors are employed in this project for this purpose. This sensor is preferred over IR sensors as they are not affected by thermal interferences. Moreover the impact of a fall can be sensed reliably by reading the abrupt change in distance and checking for obstacles like the floor, etc. . A pair of 433MHz RF transmitter and receiver proves to be a cost effective wireless medium to be employed. Upon reaching the test condition, a GSM module interfaced to the receiver section will send an emergency alert to the care-giver. The transmitter section consists of a microcontroller to sense the sensor values and RF transmitter to transmit these values to the receiver section. The receiving section consists of a microcontroller board to read the RF receiver values and a GSM module to send an alert to the care-giver upon reaching the threshold values set for emergency alert.The program for testing the system modules and entire system is written in Embedded C. The codes are compiled, verified and uploaded to the microcontrollers using Arduino IDE.

IV. EXPERIMENTAL SYSTEM

The experimental system consists of sensors along with an arduinoUno board to detect the fall event on the transmitter side. On the receiver side, a GSM module with arduinoUno board is used to send an SMS emergency alert to the care-giver. A pair of 433MHZ RF link is used for wireless transmission of data between these sections. For this experimental purpose the power supply is given through 9V dc adapter.

a) *Transmission Section*: The transmitter section consists of a Arduino board, accelerometer, ultrasonicsound sensor and encoder. The ADXL335 is a triple axis accelerometer with extremely lownoise and power consumption. To test the functioning of the ADXL335 accelerometer the connection used is as follows GND-to be connected to Arduino's GND, VCC-to be connected to Arduino's 5Vand X,Y,,Z-to be connected to any three analog pins.If each axis is placed in the same plane the values should be the same. On altering the sensitivity the values will be different. With the axis horizontal (i.e. parallel to the ground or 0°), the accelerometer reading should be around 512, but values at other angles will be different. The HC-SR04 ultrasonic sensor is a very affordable distance sensor mainly used for object avoidance. It essentially gives the Arduino data about special awareness and can detect falling of objects/persons. To test the working of the ultrasonic sensor, the connection used is as follows -GND-to be connected to Arduino's GND, VCC-to be connected to Arduino's 5V and trigger and echo pins to any two digital pins in Arduino board. Preferably the connections for trigger and echo pin are to be made from digital pins 13 and 12 respectively.

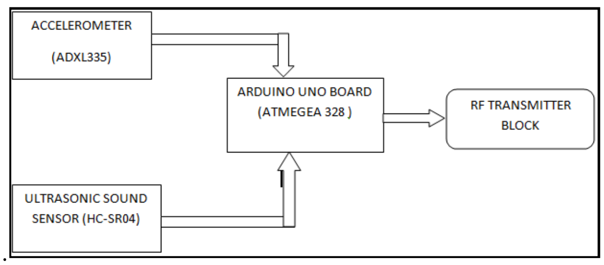


Figure.2 Block Diagram of Transmitter Section

The connection used for the RF transmitter is as follows -GND-to be connected to Arduino's GND, VCC-to be connected to Arduino's 5V, the data pin to any digital pins in Arduino board. But when used along with an encoder, a separate 4*1 connection to the digital pins (barring digital pins 0 and 1) is made.

b) Receiver Section: The receiving section consists of an arduino board to read the RF receiver values and a GSM module to send alert to the care-giver upon reaching the threshold values set for emergency alert. The Arduino boards microcontroller is used to check and execute the test condition. The test condition set here is a change in accelerometer analog readings beyond 60 readings and also the ultrasonic sensor to detect the obstacle. When any obstacle or the sensor reading is beyond its range, an indefinite value is sensed. This is taken into account for setting the test condition.

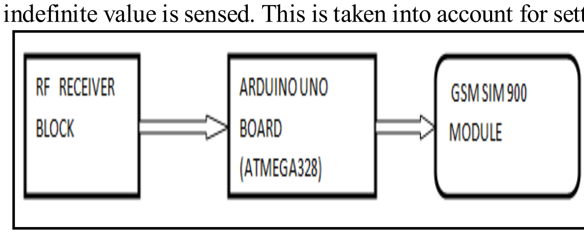
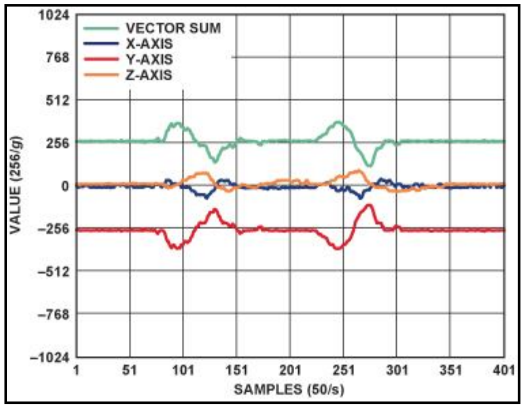


Figure.3 Block Diagram of Receiver Section

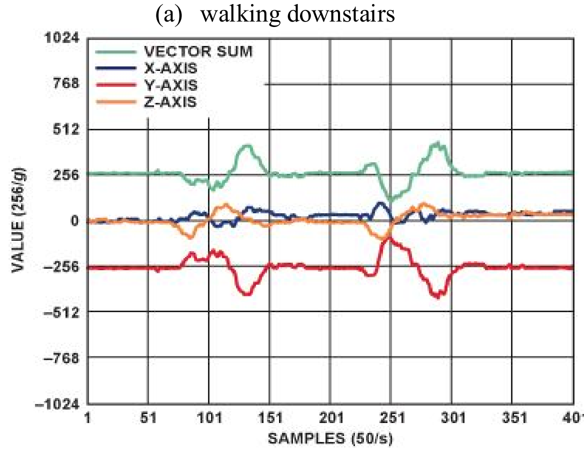
All the modules are powered using a 12V DC adapter. Initially the programs of system modules and entire system is written in embedded C is uploaded using USB cable into the Arduino board. Reset the Arduino boards upon powering. The functioning of GSM module is checked by making a call to the SIM in it. GSM module works when the ring goes to this module as in mobile phone. Once the test conditions are satisfied the GSM module sends the text message "Emergency".

V. EXPERIMENTAL ANALYSIS

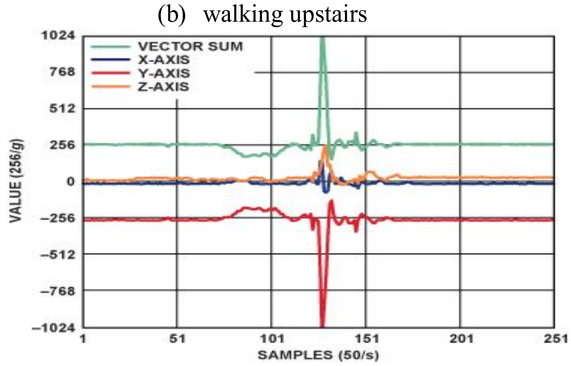
The main research on the principles of fall detection focuses on the changes in acceleration that occur when a human is falling. Figure 4 illustrates changes in acceleration that occur when (a) walking downstairs, (b) walking upstairs, (c) sitting down, and (d) standing up from a chair. The fall detection sensors are mounted to a belt on the individual's body. The red trace is the Y-axis (vertical) acceleration; it is –1 *g* at equilibrium. The black and yellow traces are the respective X-axis (forward) and Z-axis (sideways) accelerations. They are both 0 *g* at equilibrium. The green trace is the vector sum magnitude, 1 *g* at equilibrium. Because the movement of elderly people is comparatively slow, the acceleration change will not be very conspicuous during the walking motions.



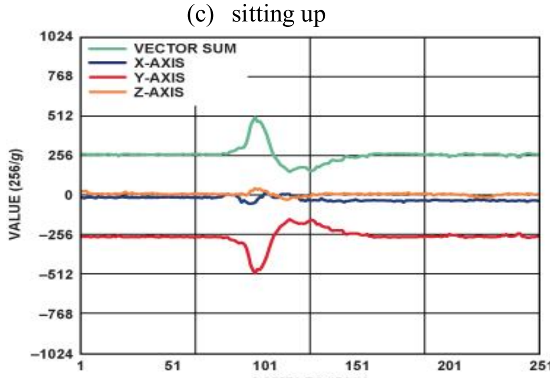
(a) walking downstairs



(b) walking upstairs



(c) sitting up



(d) sitting down

Figure.4 Accelerometer responses to different types of motion.

The most pronounced acceleration is a 3-*g* spike in Y (and the vector sum) at the instant of sitting down. The accelerations during falling are completely different. Figure 5 shows the acceleration changes during an accidental fall. By comparing Figure 5 with Figure 4, we can see four critical differences characteristic of a falling event that can serve as the criteria for fall detection. They are marked in the red boxes and explained in detail as follows:

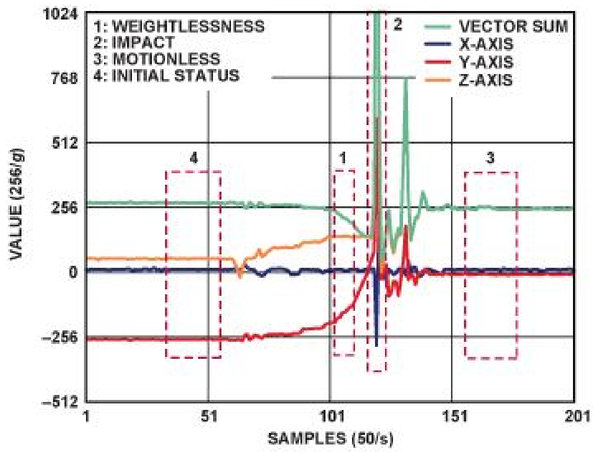


Figure. 5 Acceleration change curves during the process of falling.

1. *Start of the fall*: The phenomenon of weightlessness will always occur at the start of a fall. It will become more significant during free fall, and the vector sum of acceleration will tend toward 0 *g*; the duration of that condition will depend on the height of freefall. Even though weightlessness during an ordinary fall is not as significant as that during a freefall, the vector sum of acceleration will still be substantially less than 1 *g* (while it is generally greater than 1 *g* under normal conditions). Therefore, this is the first basis for determining the fall status.
2. *Impact*: After experiencing weightlessness, the human body will impact the ground or other objects; the acceleration curve shows this as a large shock.
3. *Aftermath*: The human body, after falling and making impact, cannot rise immediately; rather it remains in a motionless position for a short period (or longer as a possible sign of unconsciousness). On the acceleration curve, this presents as an interval of flat line.
4. *Comparing before and after*: After a fall, the individual's body will be in a different orientation than before, so the static acceleration in three axes will be different from the initial status before the fall (Figure 5). Suppose that the fall detector is belt-wired on the individual's body, to provide the entire history of acceleration, including the initial status. We can read the acceleration data in all three axes and compare those data with the initial status. So the fourth basis for determining a fall is if the difference between sampling data and initial status exceeds a certain threshold.

The combination of these qualifications forms the entire fall-detection algorithm, which, when exercised, can cause the system to raise an appropriate alert that a fall has occurred. Of course, the time interval between interrupts has to be within a reasonable range. Normally, the time interval between weightlessness stage and impact stage is not very long unless one is falling from the top of a very high building. Similarly, the time interval between impact stage and essentially motionless stage should not be very long.

If a fall results in serious consequences, the human body will remain motionless for an even longer period of time, a status that can still be detected by the ultrasonic sensor, so a second critical alert could be sent out if the inactive state was detected to continue for a defined long period of time after a fall.

VI. CONCLUSION

The proposed project gives an easy mechanism to detect falls in elderly persons using user friendly tools. Time is one of the key factors that determine the severity of a fall. This provides an opportunity for the immediate medical attention to the elderly at the earliest once the fall detection alert is sent. The performance under real-life conditions, usability, and user acceptance as well as issues related to power consumption, real-time operations, sensing limitations and record of real-life falls are analyzed using this kit. The system can be implemented with inclusion of a few more sensors to improve its efficiency. Gyroscope, along with accelerometer, performs better than accelerometer alone. Blood pressure sensor and heart beat sensor provides the state of the person during normal and fall events. By incorporating the above sensors in the system more reliable false alarms and also the health of the elderly can be monitored.

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