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# Low-Cost Elderly Healthcare Monitoring System

Angelina A. Silverio<sup>1,\*</sup> Angelito A. Silverio<sup>2</sup> Al Mathew Remot<sup>1</sup>

<sup>1</sup>Department of Mathematics and Physics, College of Science, University of Santo Tomas.

<sup>2</sup>Department of Electrical Engineering, Faculty of Engineering, University of Santo Tomas.

\*corresponding author: arsilverio@ust.edu.ph

**Abstract.** One of the most common problems we face today is the lack of a proper home-based health care system for the elderly. In the Philippines, there are several elderly people living alone in their homes, with no one to look after them. This is a problem because it's going to be difficult for them to ask for help if they ever get into an accident. Some systems are already available to monitor a person, but they are limited to only one or two parameters, namely the pulse rate and the temperature. In this study, a low-cost elderly health monitoring system was designed and developed using Arduino Uno, ADXL345 (Accelerometer), LM35 (Temperature Sensor), Pulse sensor and GSM module. This system includes pulse rate monitoring, temperature monitoring and fall detection with the addition of an SMS notification system that will notify the contact person if there is an accident or if the patient's vital signs are below normal. The initial results showed that the system was able to accurately measure the temperature, the pulse rate, detect falls and to notify the registered number via SMS.

## 1. Introduction

The world population is both growing and ageing[1]. As a result of this statistical change, the increase in constant age-related illnesses, such as diabetes, heart disease, cancer and so on, has also been compared [2]. In addition, there will continue to be an increase in all out of the number of individuals suffering from some kind of disability (either long-term, or related damage, or more generally identified with unceasing conditions)[3]. However, approximately 33% of people over 65 years of age and half of people over 85 years of age fall every year [4,5]. For this population, social insurance costs are increasing, while personal satisfaction and productivity are falling [6]. Thus, this makes them to be dependent on others [6].

These issues, in addition to the difficulties of managing and treating postoperative recovery patients, people with disabilities and people with unique capacities, include the need for new and creative approaches to providing social insurance to patients. Continuous advances in sensor correspondence, sensor scale and microelectronics have empowered medicinal service providers to monitor and manage endless infections and to distinguish conceivably serious or eminent conditions [7]. Well-being observation in the home condition may be cultivated by either or both accompanying equipment, such as walking screens that use wearable sensors and de-indecencies to record physiological signs and sensors inserted in the home condition, and by subtly collecting behaviour and physiological information [8].



Early identification, in any case, requires consistent cautiousness. Because of the nature of their conditions or the absence of preparing and experience, numerous among this populace are either unwilling or unfit to identify and report the basic perceptions that could make a difference. Early methodologies to address this issue were used by social insurance experts to screen patients directly or through relatively unrefined and cumbersome physiological information gathering gadgets[9]. Clearly, gadgets of such size and cost, which additionally incorporate a few wires and require the patient to be immobilized in order to secure reliable estimates, are not acceptable when there is a need for ubiquitous, unpretentious, long-haul and minimal effort to monitor well-being [9]. Be that as it may, the new age of modest, discreet wearable / embedded gadgets[9,10] may lead to early and scheduled recognition of basic changes to the patient's well-being. In this specific situation, such gadgets should not simply be simple information accumulation apparatuses, nor should they merely report varieties of the population standards examined.

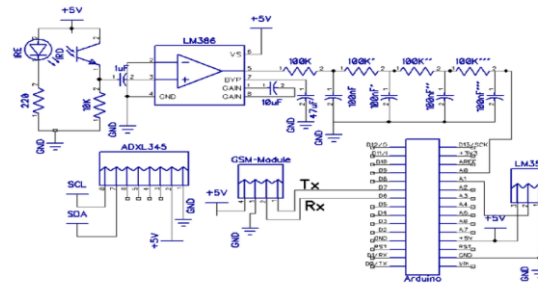
There are elderly people in the Philippines who live alone and without anyone to take care of them. This is a problem because no one will be able to monitor them from time to time. Three of the eight elderly said they could walk slowly without any instrument or companion to help them while the rest needed help to help them walk. Due to the after-effects of aging, there are instances where the elderly could lose their balance and fall at any time that is very alarming [11]. Falling poses problems for the elderly because it can cause minor injuries, permanent damage or even death.

The aim of this study is therefore to design and develop a low-cost elderly health care monitoring system that can monitor the patient's body orientation, heart rate and temperature. It focuses on developing an algorithm that can detect falling activities and make a notification system that will allow the contact person to get a person's condition through the Short Message Service (SMS). Finally, the aim of this study is to design and develop a wearable 3D design of the system. This study focuses on the design and development of an elderly health monitoring system. The system will only include fall detection along with pulse rate and temperature monitoring, which will only be used by the GSM module to transmit data from all sensors.

## 2. Methodology

### 2.1. Materials

The following are the main components used in this study. The LM35 is a 3-terminal temperature sensor that outputs a voltage proportional to the temperature (in Centigrade). The sensor can produce 1 mV per 0.1 deg. The ADXL345 is a low power 3-axis digital accelerometer capable of measuring up to  $\pm 16$  g. The device consists of a Microelectromechanical system or MEMS that has a test mass which is suspended between two parallel plates. The Arduino Nano is a microcontroller based on the popular ATmega328P chip with 14 digital I/O pins, 6 analog inputs and a 10-bit analog to digital converter. The Global System for Mobile Communications (GSM)/General Packet Radio Service (GPRS) module enables Arduino to call, send or receive messages using text messages. Figure 1 shows the entire schematic diagram of the system together with the modified pulse detection circuit, which measures the person's pulse rate. The circuit works by using an IR emitter and receiver that is placed around a finger, the output of the IR receiver will go to an operating amplifier with a gain of 200. The output of the op-amp will pass through a 4111 order low-pass filter with a 16Hz cutoff frequency as the heartbeat is a low-frequency signal and, finally, the output will pass through the analog to the digital converter of the Arduino Nano, which will measure the time between the pulses or the frequency to get the period (time).



**Figure 1.** Final Schematic diagram of the system.

### 2.2. System Algorithm

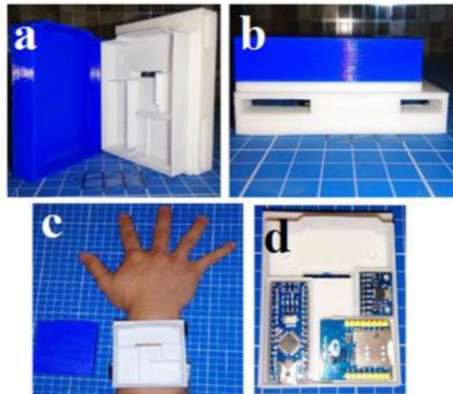
The system will begin by initializing the parameters from the Accelerometer, in particular the free fall duration, the impact threshold and the activity and inactivity threshold. Next, the system will check the acceleration in the x, y and z axes and see the magnitude of the acceleration. If the time and magnitude is greater than the freefall duration and impact threshold, it shall be recognized as having an impact and shall go to state 1. State 1 shall constantly monitor the activities in x, y and z. axes. If the person has moved after that specific delay, it will be recorded as a false alarm and the system will restart itself. If there is no noticeable movement after that specific delay time, state 2 will trigger the person's temperature, heart rate and location by using the GSM module. Then the system will restart and go back to 0. The heart rate sensor will be placed around the finger while the temperature sensor will be placed on the wrist so that it can be read more precisely. The GSM module will always be idle unless state 1 is triggered because it needs time to connect to GSM / GPRS servers. This is because the module draws a relatively large amount of current and, if it is always on, the battery life of the system will suffer. If the person wearing the device falls and registers it as a false alarm, the user can still send another SOS signal by pressing the distress signal button three times in a row.

### 2.3. 3D enclosed design

The 3D object has been designed using a Microsoft 3D builder. All necessary measurements were made to fit all the circuitry inside the enclosure. The design has a slit on the side where the velcro or elastic band can be mounted. The design was then printed with the Anet A8 and CR 10 mini 3D printers. Due to the inconsistent layers, the bottom part of the base was sanded down to a finer texture. The final 3D printed enclosure can be seen in Figure 2 along with the initial test fitting of each component.

### 2.4. System Testing

Following the wiring of each component in place, the system was then tested by 5 persons each with 8 randomized trials. The test was done by letting the subjects fall on the ground as if they had fallen. The first trial focused on testing if the system is capable of detecting status 1. Subjects were advised to get up after a certain period of time to trigger false alarm flags. The second and third trials focused on testing if the system is able to successfully detect status 2, which sends the SOS message to the registered number. The subjects were then advised not to get up and try to stay dormant until status 2 was triggered. Also, some of the actions related to falling were emulated in order to have a baseline for the acceleration output of a person standing up, getting something from the ground, sitting down, walking, crawling, falling back and forth.



**Figure 2.** 3D printed enclosure and initial test-fitting of the components: (a) Front view (b) side view (c) top view (d) component layout.

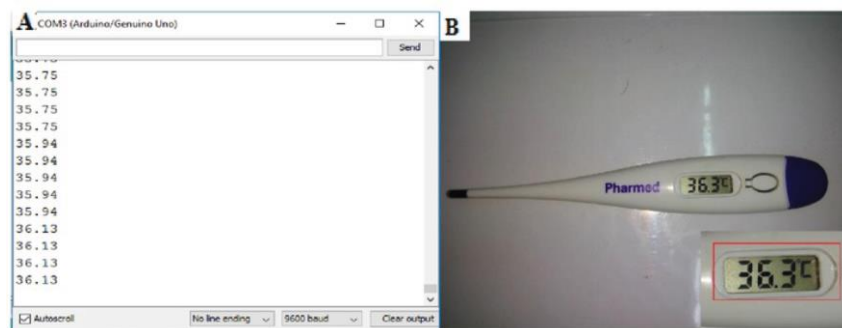
**3. Result and Discussion**

*3.1. Comparison of temperature readings of LM35 output and Thermometer*

The comparison between the lm35 and the commercially available digital thermometer is shown in Table 1 and Figure 3. The LM35 was able to read the temperature of the person. Initially, the sensor produced incorrect results because the sensor was placed next to the heart rate sensor, which is wrapped around the finger. This was addressed by changing the location of the temperature sensor so that it had direct contact with the skin, which produced a very accurate result.

**Table 1.** Thermometer output vs Sensor output

Temperature from Thermometer (°C)	Temperature from Sensor (°C)
35.7	35.64
35.2	35.15
35.8	36.01
34.3	33.81
33.5	33.45
36.1	35.97
36.3	36.13



**Figure 3.** LM35 output compared with a digital thermometer for reference: (a) LM35 output from Arduino Serial Monitor and (b) baseline output from thermometer

3.2. Pulse sensor output

The modified pulse sensor was able to detect and read a person's heart rate. Initially, the sensor was placed in the wrist area along with the temperature sensor, which caused motion disturbance (noise). This was compensated by moving the sensor to the index finger, resulting in a very accurate result as shown in Figure 4.



Figure 4. Pulse sensor output vs. Digital Blood pressure sensor

Tables 2 and 3 showed that the system was able to detect most of the occurrences of the induced fall. Improvements can still be made by modifying the working parameters and changing the hardware to a more sophisticated one, in order to improve the classification of the incident and the accuracy and accuracy of the device.

Table 2. Confusion Matrix for Accuracy , Error Rate, Sensitivity, Specificity and Precision Determination

n=40	Predicted No	Predicted Yes	
Actual No	TN =11	FP=8	19
Actual Yes	FN=5	TP=16	21
	16	24	

Where TP = True Positive, TN= True Negative. FP=False Positive, FN=False Negative

Table 3. Result of Accuracy, Error Rate, Sensitivity, Specificity and Precision

Accuracy	0.675
(TP+TN)/Total	
Error Rate	0.325
(FP+FN)/Total	
Sensitivity	0.762
TP/Actual Yes	
Specificity	0.579
TN/Actual No	
Precision	0.667
TP/Predicted Yes	

Figure 5 shows the expected transition of the acceleration when falling which, compared to Figure 6, which is the experimental raw output acceleration when intentionally falling for three times, both graphs showed similar results to the one stated on [12]. The raw acceleration signal was filtered by the magnitude of all axes. It is also easier for the microcontroller to read the filtered output than to read the raw values, since all the negative values from the raw output will shift since the reference will now be zero and will measure both the freefall time and the magnitude of the impact at the same time as shown in Figure 7. The system was able to detect the induced fall by triggering state 1. Status 1 is the

code indicator that tells Arduino to wait for a certain amount of time and then check for any activity in all axes (x, y, z). In addition, the device will automatically send a text message if the device registers it as status 1. If there is a noticeable activity in either axis, Arduino will interpret it as a false alarm that resets the code indicator to standby mode (Status 0).

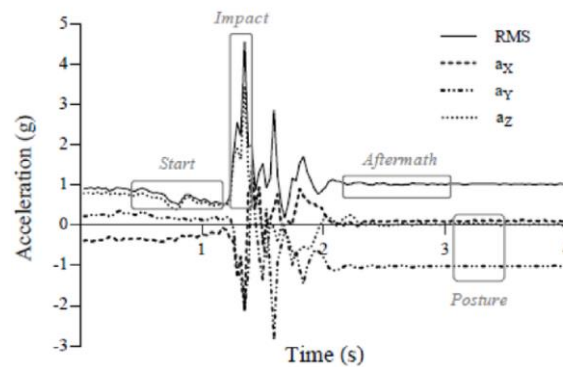


Figure 5. Acceleration Changes during an accidental fall [12]

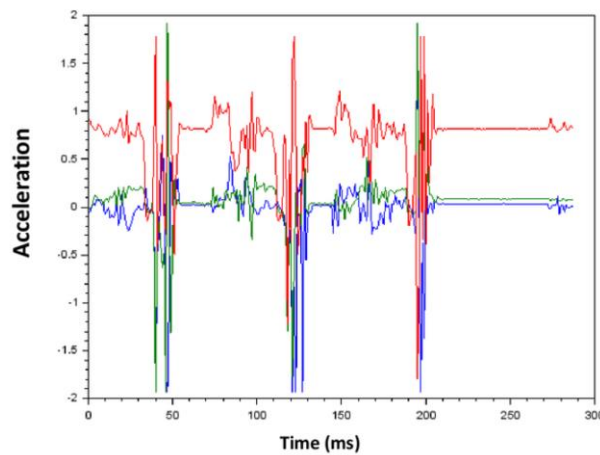


Figure 6. Accelerometer raw out 1mt from falling three times

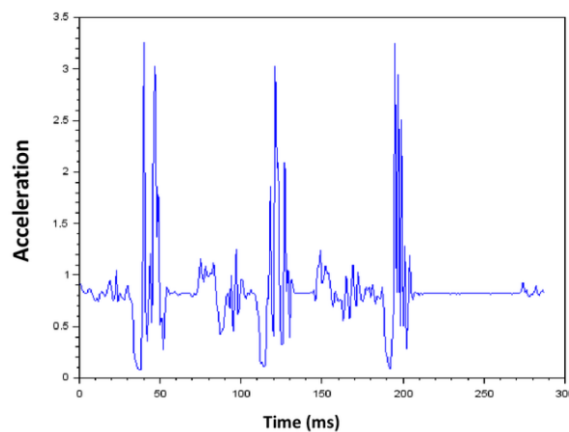
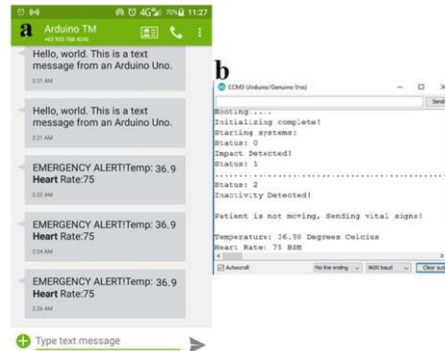


Figure 7. Accelerometer filtered out 1mt from falling three times



However, if the subject has not been able to get up (assuming he / she is unconscious), the Arduino will trigger status 2 will execute the temperature and heart rate measurement codes. The data from all the sensors will then be sent to the registered number shown in Figure 8 by SMS. The person wearing the device can still seek help from the contact person if he / she has ever dropped, and has been registered as a false alarm by pressing the distress button for three consecutive times.



**Figure 8.** System output when the subject fell and was not able to stand up (a) Emergency Text message (b) Serial Monitor output

#### 4. Conclusion

A low-cost, wearable health care monitoring system capable of detecting falls, simultaneous measurement of temperature and heart rate, and an SMS notification system have been successfully designed and manufactured. The cost of the manufactured device is around P 1600.00. The use of a GPS module and a PCB-based circuitry for a more modular and compact device is recommended for future applications. It is also suggested that, in addition to the sensors used here, other sensors should be incorporated for better performance and greater capability.

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