HUMAN FALL PROTECTION SYSTEM USING MEMS ACCELEROMETER

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Abstract- It was estimated that the rate of bone fracture due to normal fall during walking was large among the people aged between 30 to 65 years. Trochanter fracture was one of the common cases in the fall of elders. To protect from the fracture due to fall towards ground, an airbag system was designed which continuously monitor and protect the disabled person in real time. A MEMS accelerometer based embedded system is developed to detect fall and an airbag unit is used to protect humans from fall. The accelerometer used in this system is a triaxial accelerometer. The designed airbag system was a portable type system that gives more convenience to the wearer. The fall detection was done on the basis of threshold value that was obtained from the evaluation of different set of values taken during the experimental analysis process. In most of the fall detection system alarm will be produced if a fall is detected. Instead of producing alarm during fall motion, an air bag was inflated to protect the person from fracture and to reduce the injuries due to impact of body on the ground.

KEYWORDS: MEMS accelerometer, fall detection

I. INTRODUCTION

It is well known that the world is facing an increasingly aging population. Falls and fall-induced fractures are very common among the frail and elderly person. Of all the fall-induced fractures, hip fractures account for most of the deaths and costs. After a hip fracture, an elderly person usually loses his/her independence of functional mobility, and hence, has poor quality of life. The elderly is also more susceptible to experience a second hip fracture. Hip protectors are protective devices made of hard plastic or soft foam and are placed over the greater trochanter of each hip to absorb or shunt away the energy during mechanical impact on the greater trochanter. They are widely demonstrated both biomedically and clinically to be capable of reducing the incidence of hip fractures. However, the compliance of the elderly to wear them is very low, due to discomfort, wearing difficulties, problem with urinary incontinence and physical difficulties.

This paper proposes a human fall detection and protection system to measure the acceleration of body with respect to earth's gravity. The acceleration is measured by the MEMS accelerometer which is very compact in size. The airbag system is optimized for overall system volume and cost. The important factor to be considered in the fall detection and fall protection system is that a proper airbag triggering mechanism to be used with appropriate fall identification.

II. RELATED WORKS

Fundamentally wearable, non-wearable ambient sensor [24] and vision-based systems [15, 17, 22, 23] are the three basic approaches used to detect human fall. Falls can induce serious injuries, fracture and at the maximum it may lead to death among elder people. Usage of micro sensors like MEMS accelerometer will improve the performance of fall protection system [3, 7]. The human fall protection system using airbag is one of the fall protection system that uses threshold-based method to protect the elders from the effects of fall [1, 5]. Out of the

three methods used for fall detection wearable sensor-based method [13, 21] is the cheapest and compatible method to detect human fall [6, 7, 9]. Due to the immense usage of smart phone, some works [18, 19] are proposed to detect fall using mobile applications. An extensive survey on fall detection systems are conducted by few authors [14,20].

Normally the human motions may be walking, running, sitting, lying, falling etc. Generally human motion can be classified into two categories, static and dynamic posture [4]. Machine learning algorithms are used to predict the activities of a person [2, 11, 12, 16], but efficiency of the algorithms mainly depends on its complexity. Frail person cannot run, so fall happens only while they walk or sit. The objective of the proposed system is to differentiate the fall motion and the non-fall motion of the human being. To monitor motion of a person wearable device has to be used [6, 7, 9]. The non-fall motions include sitting, walking, lying. In the case of elderly person most of the time fall occurs when they were walking. Whenever the fall occurs the airbag should be inflated. The airbag should not be opened under normal condition. Since the threshold-based method was used to detect the fall, some experimental arrangements have to be made to obtain the threshold value. Normally the human body may not maintain their stability after an inclination of 30° [5]. So, it is assumed that the fall will happen after the inclination of 30°. A triaxial accelerometer is used to detect the occurrence of fall among the elder person. Fall detection and protection device have to be mounted on waist [8]. At every degree of inclination of the body equivalent acceleration will be produced by the accelerometer.

III. PROPOSED WORK

The proposed work can be divided into hardware and software segments. The hardware section includes accelerometer (ADXL327), microcontroller (PIC16F877), actuator, gas cartridge and airbag. The software part is concerned with the microcontroller programming to detect human fall.
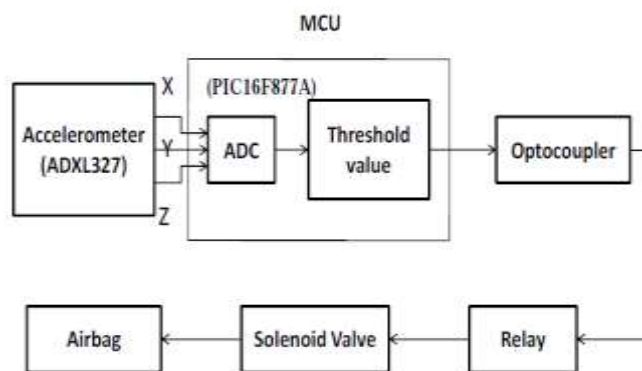

Fig. 1 Block diagram of fall protection system

The schematic block diagram of the human fall protection system is shown in fig. 1. Depends on the human motion the accelerometer produces analog voltage signals. The voltage signals are generated in all the three axes (X,Y,Z) according to the movement of the wearer. The operating supply voltage is given to the accelerometer through portable battery. The accelerometer needs 1.8 V to 3.6 V for its normal operation. The analog signal generated at the output of the accelerometer is in the order of few mV along with the offset voltage for corresponding axes. The analog voltage signal coming from the accelerometer to be signal conditioned before it is given to the microcontroller. The signal conditioning circuit is a simple rectifier circuit with filter to provide an analog DC voltage to the microcontroller. The analog signals given to the microcontroller are converted to the corresponding digital signals by the A/D converter in the microcontroller unit.

The digital values are continuously compared with the threshold values that are obtained from the experimental analysis. Once the analog signals are converted to the digital values, the values obtained from the accelerometer are compared with the threshold value that was already stored in the microcontroller database. If the obtained value exceeds the threshold values then it is considered to be the fall condition and the actuator is triggered

to open the gas cartridge. The gas from the cartridge will inflate the airbag before the person fall on the ground [1,10].

IV. EXPERIMENTAL RESULTS

The proposed system is tested in a prototype model. From the trials conducted in the prototype, it is found that the system is able to predict the fall accurately. The threshold values for various human motions are determined from the experimental setup as shown in Fig. 2.
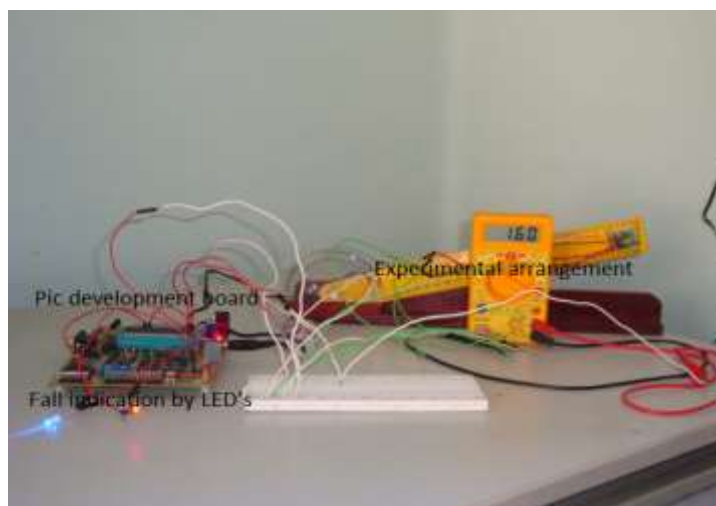

Fig. 2 Experimental setup to determining threshold level

Analog voltages are obtained for different angular positions of accelerometer. Keeping any one axis as primary sensing axis and other two axes as cross sensing axis the fall test is conducted for different angular positions of accelerometer. Similarly, other two axes are also kept as primary axis and to measure angular positions. In the proposed system threshold-based method is used to distinguish the fall and non-fall motion.

To obtain the threshold value accelerometer output voltage values have to be measured at different angles. In the experimental setup shown in fig. 2 accelerometer outputs are measured for various positions. Table 1 shows the output values of the accelerometer at different angular positions. The values shown on table 1 are taken by keeping X-axis as primary axis and other two axes as cross axis.

The voltage values are measured in the order of 10° from 0° to 180°. The threshold values are fixed based upon the readings on the table I. By keeping X-axis as primary there were variations in output of Y-axis, but Z-axis values are almost constant. Likewise, by keeping Y-axis and Z-axis as primary the variations in the output of X-axis is measured. By measuring the amount of static acceleration due to gravity, we can find out the angle the human body is tilted with respect to the ground. Tilt is a static measurement where gravity is the acceleration being measured. The change in degrees of tilt directly corresponds to change in the acceleration due to a changing component of gravity acted on the accelerometer. The graph shows static acceleration produced on the three axes for tilt of different angles from 0 to 180° by kept X-axis as primary.

From the observed experimental values, a graph was drawn as shown in fig. 3. It is assumed that the acceleration obtained above 30° are normal motion (non-fall motion) and the acceleration obtained below 30° inclination are falling values because of the fact that the human beings cannot maintain their stability after an inclination of 30°. Therefore, the acceleration value obtained at 30° is considered as threshold value.

Graph is drawn by keeping voltage along vertical axis and degree along horizontal axis. From the graph it is clearly shown that there are variations in Y and Z axis is almost constant by keeping X-axis as primary. For every

axis two threshold values are set. One threshold value is set for 0 to 90° and the second threshold value is set for 100 to 180°. In case of keeping X-axis as the primary axis threshold values for both the axis are more or less same, but there is a difference in values of Y-axis. So, the two threshold values are set for Y-axis and one value is set for X-axis. The X and Y-axis values are sufficient to find the lateral fall, but to find the front and backward falls it is necessary to sense the Z-axis. To sense fall on all the four directions threshold values were set for X, Y, and Z axis separately.

Table I

Accelerometer reading for three axes

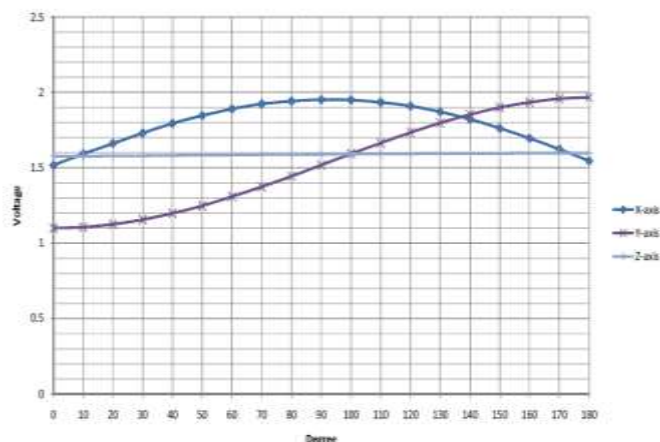| X-axis Readings			
Degree	X-axis (Primary axis)	Y-axis (Cross axis)	Z-axis (Cross axis)
	X-axis	Y-axis	Z-axis
0	1.517	1.1	1.577
10	1.592	1.106	1.577
20	1.661	1.125	1.579
30	1.73	1.156	1.58
40	1.794	1.198	1.582
50	1.846	1.248	1.583
60	1.89	1.309	1.585
70	1.923	1.374	1.587
80	1.942	1.444	1.588
90	1.951	1.518	1.589
100	1.949	1.593	1.591
110	1.934	1.664	1.592
120	1.909	1.734	1.593
130	1.871	1.798	1.594
140	1.822	1.853	1.594
150	1.762	1.9	1.595
160	1.696	1.934	1.596
170	1.623	1.958	1.596
180	1.546	1.968	1.597

Fig 3 Voltage values for various angular positions

After fall is detected successfully by the fall detector, fall protection system is developed. The fall protection device is shown in fig 4 and fig 5. Once fall has been detected signal from microcontroller is send to relay through optocoupler. The solenoid valve used is normally in closed position. Whenever fall is detected solenoid valve is opened by the relay. When solenoid valve opens compressed gas in gas cartridge fills the airbag.
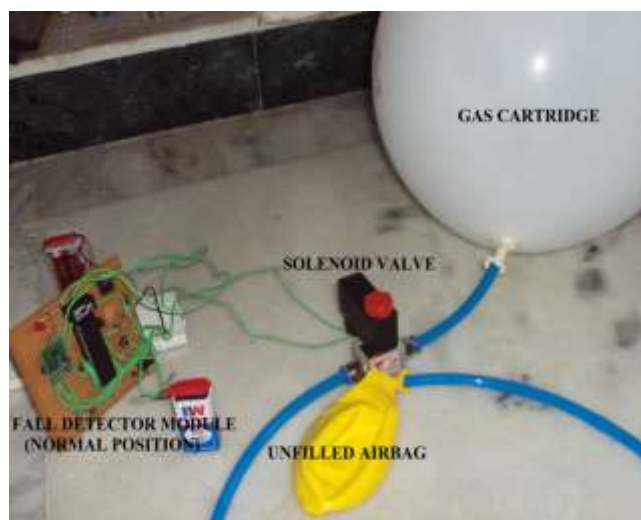

Fig. 4 Non-fall motion

Fig. 4 shows operation of the fall protection system at normal motion. It is clearly shown that the airbag is not filled at normal position of human being.
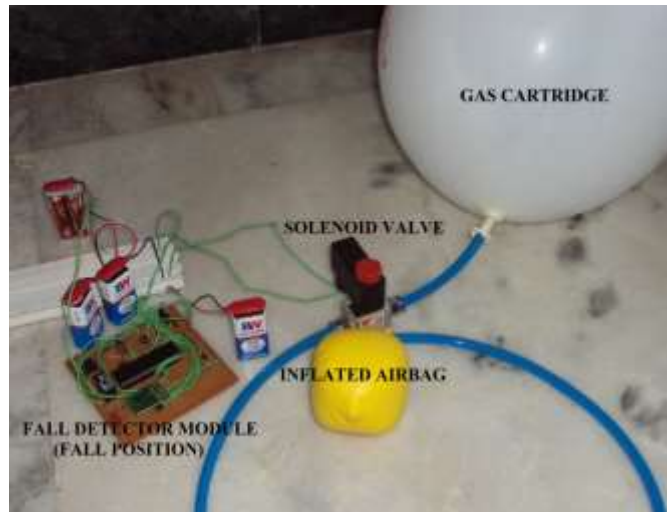
Fig. 5 Fall motion

Fig. 5 shows the operation of fall protection system at fall position. Whenever fall occurs, the relay opens the solenoid valve to fill airbag. From fig 10 it is shown that airbag is successfully filled by the gas that is already present in the gas cartridge.

V. CONCLUSION AND FUTURE WORK

In the proposed work static acceleration values at different positions of the human body from 0° to 180° are measured in all the three axes. The obtained voltage value at 30° and 150° were set as threshold values for fall motion. The threshold values for X, Y and Z axis were set separately to find fall in all the three axes. Once the fall has been detected in any one of the three axes, signal is sent to fall protection system to inflate airbag. The proposed fall protection system filled the airbag by receiving signal from microcontroller. From the experiments performed with the prototype it is observed that the proposed fall protection system is able to detect the fall and inflate the airbag in time so that it can protect a person from fracture and injuries whenever some fall occurs. In future the proposed prototype will be test with human beings in real time with compressed gas cartridge to fill airbag and solenoid valve will be replaced by micro actuator to make the device more compact. The proposed work will also be extended further with some sophisticated algorithms to detect human fall.

VI. REFERENCES

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