Fall detection for hard impact falls of elderly on level surfaces at home

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Abstract

Falling is a common cause of injury in the elderly, often leading to disability and even death. In Singapore, 58% of unintentional falls happen to elderly in the age group of >65 years, and 63% of such incidents happen at home [1]. A prototype of fall detection system which incorporates a 3-axis accelerometer and a tilt sensor will be presented in this report. We will consider the device being placed on the hip to collect real time data when an individual is performing daily activities.

Keywords: Elderly, fall detection, sensor

I. INTRODUCTION

Fall is especially common amongst elderly; within our target age group of >65, falls are considered dangerous and to a certain extent, deadly. In Singapore, the number of elderly people above 65 years living alone has tripled over the past 15 years and the percentage of the population living alone is expected to increase very rapidly. [2] Hence, it is very important to cater to this group of elderly and give them medical attention as soon as possible when any mishap happens. There are many monitoring systems currently in the market, but most involve video surveillance cameras and research shows that 80% of elderly mind being videotaped and monitored around their own house. [3] Thus, for our project, we decided to focus more on wearable fall detectors.

While there are fall detection devices that also use a 3-axis accelerometer, those are sold at very steep prices, going up to $300 per piece (Angel4 Fall Detector). Hence, we aim to build a fall detector that would be priced more affordably yet work as effectively as those commercial fall detectors. From our research on existing fall detectors, most of them use a 3-axial accelerometer to detect a sudden acceleration and a gyroscope to determine the position of the detector.

II. IDEATION

In our detector, we plan to incorporate both a tilt sensor and a 3-axial accelerometer, much like those used in commercial devices. By incorporating both a tilt sensor and an accelerometer within the device, it would improve the accuracy of detecting falls. For example, if a transition before a lying position is not intentional/natural, we can better pinpoint that a fall has occurred. Thus, a tilt sensor and accelerometer fall detector is able to reduce the false positives and false negatives, thus improving fall detection accuracy.

For the accelerometer, we considered a few different types such as using a capacitive accelerometer, piezoresistive, piezoelectric and finally decided on the variable resistor. This is because while most commercial detectors use capacitive accelerometer, creating a small capacitive accelerometer requires very accurate and machine fabricated circuit, so we felt that the variable resistor accelerometer would be a more feasible idea for a homemade accelerometer. We are trying to build a fall detector which is much cheaper and as effective as those already in the market and a variable resistor accelerometer would fit that criteria.

For the tilt sensor, the concept is similar and we will be using a variable resistance to support that as well. The main idea behind the variable resistor accelerometer is to have a metal ball bearing which is able to move freely and the change in resistance will be calculated to determine the acceleration. By using 3 axis, we would then be able to accurately determine the acceleration in the x, y, z direction and hence accurately formulate if the user is in the process of falling down. Coupled with the tilt sensor, we would then be able to figure if a fall has occurred.

III. DESIGN OVERVIEW

The entire design flow of the system are as shown in Fig. 1. The process starts when the elderly puts on the fall detection sensor. The accelerometer/tilt sensor provides voltage data to the digital controller which will determine the state of elderly. If a signal is detected that the elderly have fallen down, an alarm will sound until the the elderly presses a button. However, if the elderly remains unconscious and does not respond, this will trigger an emergency signal.

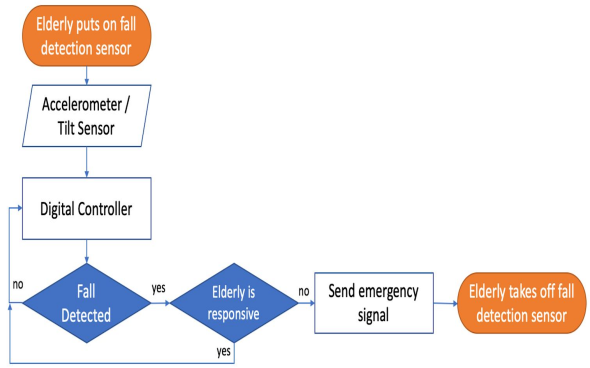

Figure 1. Flowchart of Design

IV. SENSORS & CIRCUITS

A. Tilt sensor

The first tilt sensor design (Fig. 2) was made using the concept of variable resistors. Springs were used as variable resistor and tested by a simple DC circuit with variable resistors. However, the sensor produced inconsistent results and bad spring material (spring becomes really hot from 1.5V) renders the need for a better sensor.

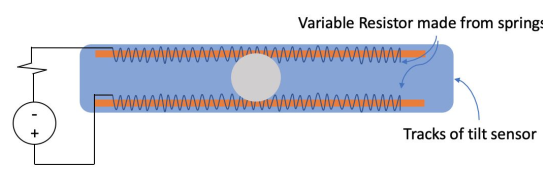

Figure 2. First Version of tilt sensor, using springs as variable resistors.

An improved version of the tilt sensor is then designed with a series of resistors which varies as the conductive ball move on one side of the track, and other side as a conductive end. Hence resistance of the circuit is varied in sections. By placing resistors along the tracks (Fig. 3), resistance varies as the conductive ball moves due to the effect of gravitational force and inclination from user. Since resistors are arranged in series, resistance of circuit changes as conductive ball moves which changes the voltage. From the change of voltage, we then can determine if the user have fallen down after tilting at a certain angle.

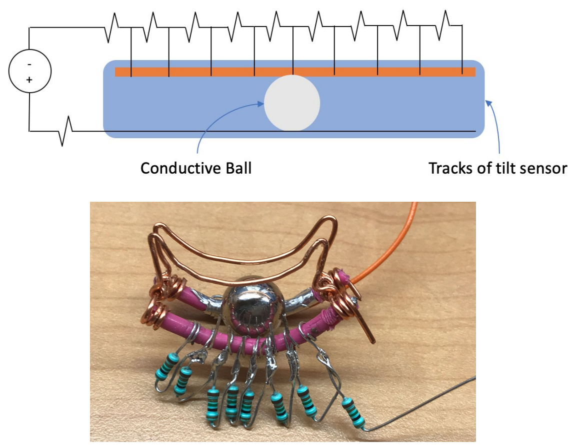

Figure 3. Second Version of tilt sensor, using resistors to sectionalise position of conductive ball.

B. Variable resistor

The second design we had come up with makes use of a variable resistor to detect acceleration (Fig. 4). For this design, we had to make a straight track for the proof mass (a metal ball) to move along so that when the entire sensor accelerates, the ball would move along the variable resistor and thus change the effective resistance of the circuit accordingly.

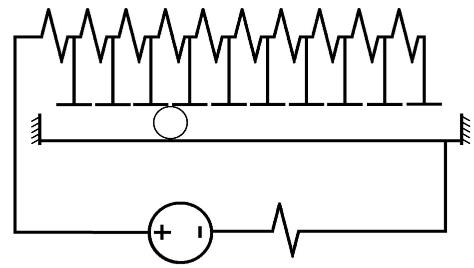

Figure 4. Circuit of variable resistor accelerometer

For our accelerometer, we are aiming to achieve about 5mm movement for every 1 gravitational force ($9.81ms^{-2}$).

Equating both Hooke's Law and Newton's Second Law,

$$kx = ma$$

where k is the spring constant, x the extension, m the mass and a the acceleration.

$$k\,(5 * 10^{-3}) \; = \; 9.81m$$

For our proof mass, we are using a metal ball bearing of mass 0.05kg

$$k\,(5 * 10^{-3}) \; = \; 9.81 * 0.05$$

$$\Rightarrow k = 0.0981 N/mm$$

Hence, a spring constant of 0.0981N/mm would be necessary for a 5mm movement for every 1g force.

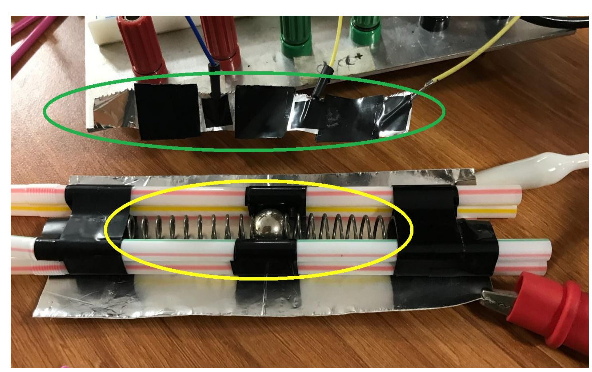

Figure 5. Prototype of variable resistor accelerometer.

We designed our sensor design based on this circuit diagram and made a prototype to test if the change in resistance was significant. As can be seen in the image, the straws act as the tracks to ensure that the ball only rolls along one axis. Referring to the part circled in yellow, the ball is held in the middle by a spring on each side, so that the ball would not just roll all the way to one side should the person just bend over or tilt slightly. The springs are not part of the circuit in this design. The green circle shows the alternating conductive and insulative tape, with the conductive parts connected to different parts of the resistors in series. It would be placed directly above the ball such that the ball is always in contact with it.

V. CURRENT RESULTS

A. *Tilt sensor*

The tilt sensor is tested by variating the angle of inclination and measuring the resistance at intervals of 10 degrees. As the resistors are connected in series, we can expect a linear change of resistance as shown from the test result shown in Fig. 6.

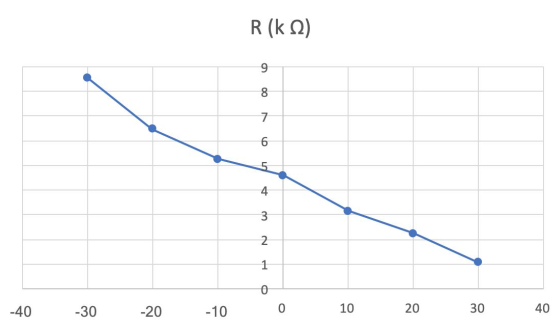

Figure 6. Linear change in resistance when the ball bearing in the tilt sensor moves from one end to the other

B. *Variable resistor*

Our tests showed that due to the spring constant of our springs being too high, our springs did not compress/stretch much when the ball moved as a larger force was required to compress/stretch the spring. When we used the multimeter and slid the tip across our alternating conductive-insulative tape, the resistance change was substantial but we still have to test if the change in resistance can be detected if the motion is fast as the ball would be rolling extremely quickly if the wearer were to fall and accelerate at free fall.

VI. CONCLUSION

The end goal of our project is to create a sensor that can accurately detect hard-impact falls so that we can minimise the negative consequences that arise from falls, including both the physical impact from the fall as well as the long durations of staying on the floor when they are unable to get up after a fall. From here, we will continue our feasibility tests on both the tilt sensor and variable resistor accelerometer to find the most accurate and cost efficient method to detect falls. If time allows, we hope to make our sensor smaller so that it is more suitable for wearing on the hip.

REFERENCES

[1] Health Promotion Board (May 2015). Fall Prevention Among Older Adults Living in the Community. [Online] Available from https://www.hpb.gov.sg/docs/default-source/pdf/cpg_falls_preventionb274.pdf?sfvrsn=abedeb72_0

[2] Straits Times (August 2015). Old and Home Alone in Singapore. [Online] Available from https://www.straitstimes.com/singapore/old-and-home-alone-in-singapore

[3] Boise. L., Wild. K., Mattek. N., Ruhl. M., Dodge. H., Kaye. J., (2013). Willingness of older adults to share data and privacy concerns after exposure to unobtrusive in-home monitoring. [Online] Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3604979/