Fall detection system with 3-axis accelerometer

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Abstract. In this work, the designed and developed process of a fall detection system using a NodeMCU microcontroller is described. A 3-axis acceleration sensor is used to obtain the data of the movement of humans and changes in acceleration are used to determine trends in falling. The ESP8266 microcontroller is used to receive the data in real time and alert the family through the LINE application. Experimental results show that the system is capable of precisely producing alarms for falling actions and has a high detection precision and effectiveness.

1. Introduction
Thailand is predicted to completely become an elderly society within the next eight years. According to the demographic data of Thailand collected in December 2018, the Thai population is 66,188,503 people, with 10,225,322 being elderly, representing 15 percent of the entire population. When the number of elderly people is increasing, concerns for the safety of the elderly also increase. The problem of falling in the elderly population is one of the main causes of loss due to falling being a major factor leading to injuries or death in elderly persons.

Numerous falling detection systems have been developed using various approaches such as a wearable sensor [1, 2], video cameras [3, 4] and Kinect sensor fall detection [5, 6]. The most common method for wearable-device based fall detection involves the use of data acquired from a 3-axial accelerometer and a threshold-based algorithm for triggering an alarm.

In this work, the design and development of a low-cost system for a fall detection system is proposed. A 3-axis acceleration sensor is used to obtain the acceleration values from the movements in daily life, which are used to determine trends in falling. The ESP8266 MCU is used as the microcontroller for processing. The proposed system is capable of precisely performing the delivery of alarms for falling actions and has high levels of detection precision and effectiveness.

2. Method
2.1. The fall detection system
The proposed system for the fall detection using the ESP8266 NodeMCU microcontroller is presented in figure 1. A 3-axis acceleration sensor (ADXL 345) is used to acquire the data of acceleration resulting from the various types of activity in Active Daily Lives (ADLs). Then, the data set is sent to the MCU (ESP8266 NodeMCU) for processing. The system is designed to monitor the activities of an elderly person in daily life. When a fall is taken (an acceleration value is lower than the threshold value), the system sends an alert to their faraway family members by the LINE application using LINEBOT and an alarm with a buzzer for a nearby family in the area. The flow chart of the fall detection algorithm is shown in figure 2.
2.2. Falling model simulation

In this paper, a falling model is used to simulate the falling of an elderly person. This falling model is an approximate simulation of a falling action in which a rigid falling motion is provided by modeling a rod of length L with a uniform bar falling from a vertical position, as seen in figure 3. Each simulation is conducted 20 times for three different lengths of the rod. The data logger shield with the Arduino UNO R3 was installed at the topmost end of the falling model, which represents the location of the waist. This data logger is used to collect the acceleration data when a fall occurs. The data set is obtained by the data logger shield with the Arduino UNO R3.

Figure 4 shows the acceleration for rods of three different lengths corresponding to a variety of waist height ranges of a person (0.9 – 1.1 m), indicating that the acceleration during falling decreases toward zero (≈ 2 m/s²) before the rod impacts the floor in every length of the rod. After that, the acceleration further increases when the rod impacts the floor. Thus, in this system acceleration at 2 m/s² was chosen as the threshold value to decide when the event of falling has occurred.
3. Results and discussion

To evaluate the performance of the proposed system, six types of activity experiments were conducted, including one fall and five activities representative of Active Daily Lives (ADLs), namely walking, standing-sitting down in a chair, standing-sitting down on the floor, sitting-lying on the floor, and walking up-down the stairs. Each action was performed 100 times. And thus, 600 test samples were collected. The device was set up on the tester's waist. Performance of the falling detection system was analyzed by accuracy, sensitivity and specificity, which can be calculated from four possible outcomes, which include true positive (TP), true negative (TN), false positive (FP), and false negative (FN), as follows:

\[
\begin{align*}
\text{Accuracy} & = \frac{TP + TN}{TP + TN + FP + FN} \\
\text{Sensitivity} & = \frac{TP}{TP + FN} \\
\text{Specificity} & = \frac{TN}{TN + FP}
\end{align*}
\]

In these equations, true positive (TP) is defined as an event in which the device produced an alert when a fall was detected. True negative (TN) is defined as an event in which the device did not produce an alert when a fall was not detected. False positive (FP) is defined as an event in which the device produced an alert, but a fall was not detected. False negative (FN) is defined as an event in which the device did not produce an alert, but a fall was detected.

| Activity experiments | Number of experiments | True positive (TP) | False negative (FN) | True negative (TN) | False positive (FP) | Performance |
|----------------------|-----------------------|--------------------|---------------------|-------------------|---------------------|-------------|
| Sensitivity          | Falling               | 100                | 88                  | 12                |                     | 88%         |
|                      | Walking               | 100                |                     | 96                | 4                   |             |
|                      | Standing-sitting down in a chair | 100 | | 99 | 1 | |
|                      | Standing-sitting down on the floor | 100 | | 99 | 1 | 98.4% |
| Specificity          | Sitting-lying on the floor | 100 | | 100 | 0 | |
|                      | Walking up-down the stairs | 100 | | 98 | 2 | |
| Accuracy             | 600                   | 88                 | 12                  | 492               | 8                   | 96.7%       |
The results of the experimental data are shown in table 1. A total of 88 out of 100 fall actions triggered the alarm, therefore the sensitivity was 88%. Eight out of 492 ADLs triggered the alarm; thus, the specificity was 98.4%. The accuracy of the proposed system is 96.7%, which is very high. A total of 12 out of 100 non-triggering falls occurred because the falling acceleration was not below the threshold. The eight out of 500 triggering falls occurred because the tester moved too fast during the activity experiments, and the system mistook this for a falling action.

4. Conclusion

In this work, we presented a designed and developed process for a fall detection system using a NodeMCU as a microcontroller. The proposed system can send alerts to the faraway family members through the LINE application via LINEBOT. The reason for choosing the LINE application to send the alert is because it is free software and a popular program. Everyone can access the program easily, and it is not overly complicated. The accuracy of the proposed system is 96.7%, and this proposed system is a prototype device. It is cost-effective based on its total cost (US$15.79), which is very low compared to its effective performance.

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