final project

smart walking stick for fall detection and step monitor

New York University
ZEXIN LI
Robots for Disability
Advisor: Professor Vikram Kapila
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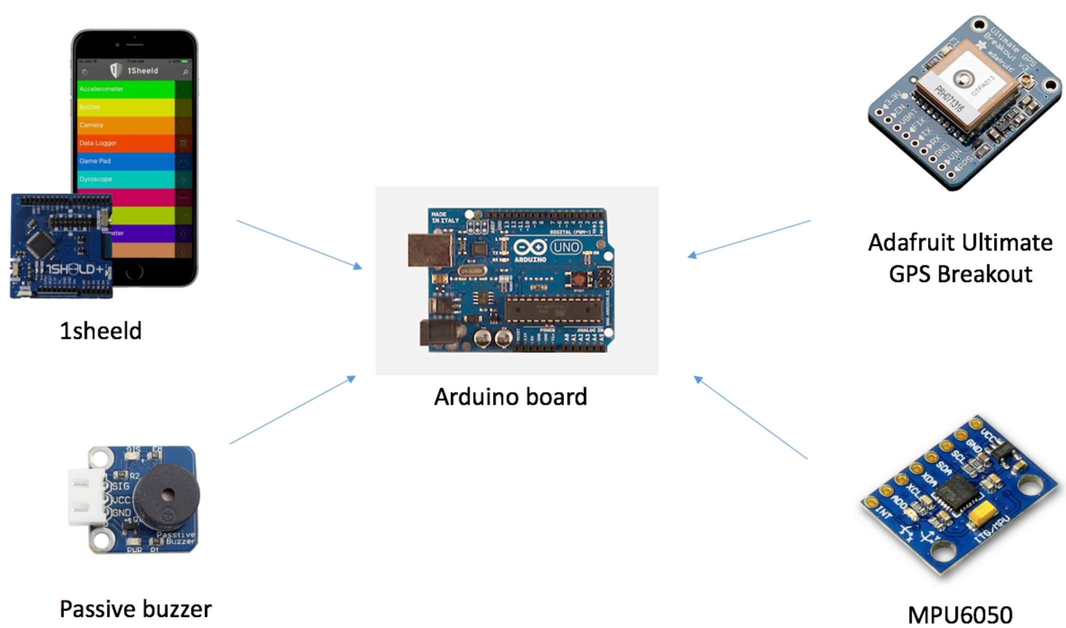
1. introduction

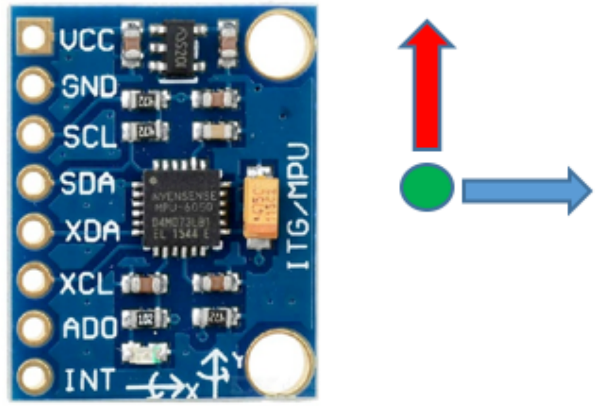
At times the elderly may have to face the reality that certain mobility aids are necessary not just to assist with movement but also as a preventative measure to avoid falls. A walking stick, also referred to as a walking cane, is probably the most basic yet highly versatile mobility aid. It is primarily used to assist with balancing, improve stability and at times even reduce pressure that may be causing pain. Most walking sticks are thought of to be a straight, long stick either with a straight or curved handle but there are actually various different types depending on the individual need of the user. It is not the only type of mobility aid or ambulatory device but is among the most flexible, least cumbersome and easy to use.

In this paper, we present the design and the implementation of Smart walking stick, an automatic fall detection system based on multistage thresholding and an intellectual step monitor, based on subsequence matching, which can detect fall with high accuracy and provide a prediction for potential fall or disease.

2. Electronic unit

Microcontroller: Arduino board;
Accelerometer: MPU6050;
SMS unit: 1sheeld;
GPS: Adafruit Ultimate GPS breakout;
Passive buzzer.





MPU 3 axis direction

3. Fall detection and alarm

- Data collection: acquired from the accelerometer installed at the bottom of the walking stick. Because essentially all measured body movements are contained within frequency components below 20 Hz (indeed, even in gait, 99% of the energy is contained below 15 Hz). Our operating system is used to acquire tri-accelerometer signals sampled at 1000Hz which guarantee that every signal of movement can be recorded. As displayed in following figure, X-axis, Y-axis and Z-axis data of accelerometer were collected by the walking stick.

- Data preprocessing: The output of an ideal accelerometer worn on the human body originates from several sources:
    1) acceleration due to body motion;
    2) gravitational acceleration;
    3) external vibrations, not produced by the body itself (e.g., resulting from vehicles);
    4) accelerations due to bouncing of the sensor against other objects, eventually resulting in mechanical resonance

Sources 1 and 2 are directly related to intentional movement of the body. However, sources 3 and 4, However, sources 3 and 4, which may add extra noise to the accelerometer outputs, should be attenuated by adequate filtering techniques. The median filter with n = 3 is applied to the raw data to attenuate the noise.

Filtered raw data

- **Feature Extraction**:
    - **Signal Magnitude Vector (SVM):**

$$\mathrm{SVM} = \sqrt{x_i^2 + y_i^2 + z_i^2}$$

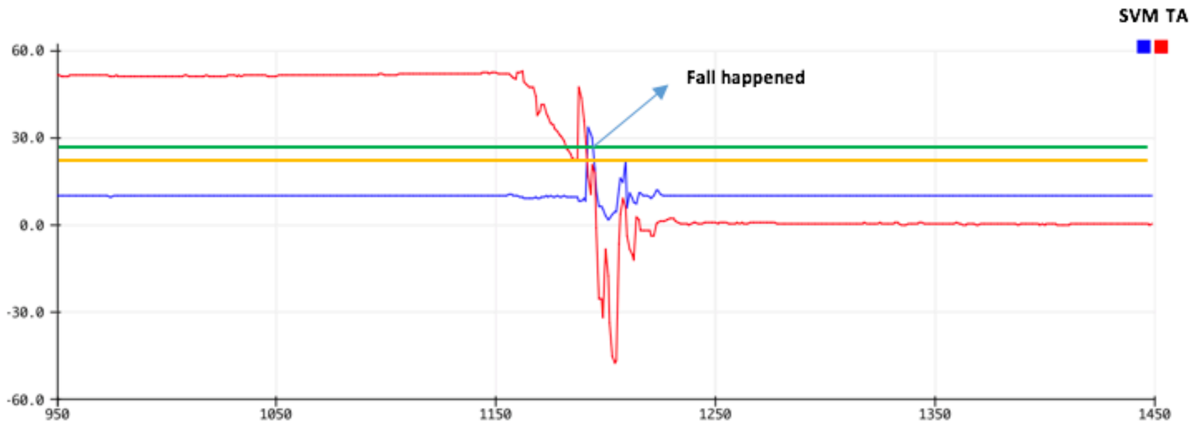
where xi is the ith sample of the x-axis signal (similarly for yi and zi). The test results identified the most suitable parameter to be SVM at a threshold of 25 When an SVM value was above the threshold, fall could be deemed to have occurred.

- **Tilt Angle (TA)**

Postural orientation refers to the relative tilt of the body in space. As indicated in, the tilt angle of user was defined as the angle between the positive y-axis and the gravitational vector g by the relation:

$$\mathrm{TA} = \arcsin\left(\frac{y_i}{\sqrt{x_i^2 + y_i^2 + z_i^2}}\right)$$

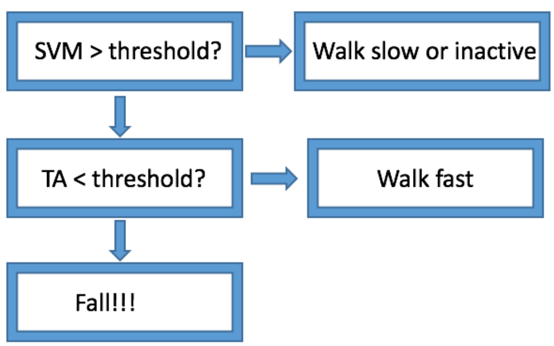
If TA was below the threshold 20 degree, it was classified as fall or lie.



- **Threshold for SVM: 25**
- **Threshold for TA: 20**

- **Classification Algorithm**

  This flowchart displays the major steps of the algorithm embedded into walking stick.



4. **SMS(short message service) and GPS location**

- Core code for SMS

```
SMS.send("phone number","text0");
```

Notice: can only do SMS work on android cellphone

- Core code for GPS location

```
if (GPS.fix) {
  Serial.print("Location: ");
  Serial.print(GPS.latitude, 4); Serial.print(GPS.lat);
  Serial.print(", ");
  Serial.print(GPS.longitude, 4); Serial.println(GPS.lon);
```

5. **Step monitor for prompting potential falling and potential disease**

- Acquired data: AcY(acceleration on Y-axis)
- Method: Euclidean Distance based on Subsequence Matching

Subsequence matching is a technique commonly employed in data mining and discrete time series analysis to find exact or closely matched segments of a given subsequence (a query) in a much longer sequence (a candidate), A query of length k is defined as

$$Q = Q_1, Q_2, \ldots, Q_k$$

whereas a candidate of length n is defined as

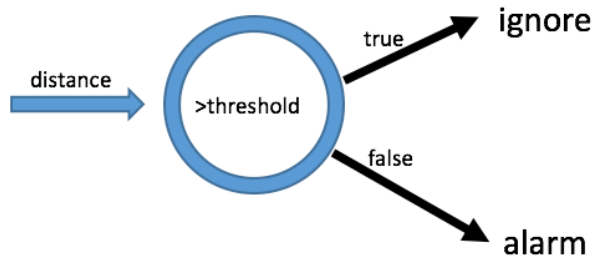
$$C = C_1, C_2, \ldots, C_n$$

The matching process involves sliding Q along C in the time axis direction and computing a distance metric(Euclidean Distance) that is proportional to the dissimilarity between Q and the corresponding segment of C at time t. A commonly used distancenmetric is Euclidean Distance, which is defined as the square of the difference square-rooted,

$$D(Q,C)_t = \sqrt{\sum_{i=1}^{k}(Q_i - C_{t+i})^2}$$

Euclidean Distance is really a special case of another popular metric known as Dynamic Time Warping (DTW). DTW maps a point in the query to its closest neighbor in the candidate segment to minimize the effect of phase shifting, data misalignment, and speed difference. While DTW has been successfully applied to speech recognition , bioinformatics , and fingerprint verification , it is not suitable for our application due to the high O(n3) overall time complexity and the relatively poor performance in discriminating signals that are subtly different.

- Algorithm:



6. **Improvements in the future**

- Instead of Subsequence Matching, try to employ sophisticated classification methods such as Artificial Neural Network (ANN) and Supporting Vector Machine (SVM)
- The current prototype has a circumstance that trigger the fall alarm when walking stick bump into an obstacle(table/ground). Try to use one more accelerometer stashed at the top of stick for SVM and TA calculation, or use other kind of sensor(pressure sensor, gyroscope, etc.)
- Build all hardware into stick

7. **Reference**

- Lan, M., Nahapetian, A., Vahdatpour, A., Au, L., Kaiser, W. and Sarrafzadeh, M., 2009, April. SmartFall: an automatic fall detection system based on subsequence matching for the SmartCane. In *Proceedings of the Fourth International Conference on Body Area Networks* (p. 8). ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).
- He, Y., Li, Y. and Yin, C., 2012. Falling-incident detection and alarm by smartphone with Multimedia Messaging Service (MMS)
- E. Keogh, K. Chakrabati, M. Pazzani, and S. Mehrota. Dimensionality reduction for fast similarity search in large time series database. KAIS Journal, 3:263–286, |2001|.