A Smart Phone-based Fall Detection System

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Introduction

Today smartphones or mobile phones serve as the central computing and communication device in people lives. These phones embed various sensor including accelerometer, digital compass, GPS, and camera, enabling new applications in various domains such as elder healthcare. Therefore, various systems are proposed to improve elderly people health and quality of life. One good example of these systems is fall detection. The acceleration-based detection is the most widely used method. This study focuses on acceleration-based detection, utilizing smart phone as the platform to detect fall.

Smart Phone-based Fall Detection System

This section presents the proposed smart phone-based fall detection system design. Figure 1 shows the system architecture. The proposed system has three major components: Fall detection process, emergency notification and, system pre-configuration as indicated by different colors. In the fall detection process, the mobile device continuously monitors the sensing data from the embed sensors in real time. Here we consider two sensors, tri-axis acceleration sensor and orientation sensor. In this step, we calculate two parameters to identify the fall behavior. The first parameter is the overall acceleration value$|A_T|$, computed as

$$|A_T| = \sqrt{|A_x|^2 + |A_y|^2 + |A_z|^2}$$

The second parameter is vertical acceleration value$|A_V|$, computed as

$$|A_V| = |A_x \sin\theta_z + A_y \sin\theta_y - A_z \cos\theta_y \cos\theta_z|$$

The algorithm is based on these thresholds and the online-calculated parameters.

In the emergency notification process, the mobile phone starts an alarm message on the screen and records the alarm time after detecting fall. When users receive the message, they can determine whether healthcare assistance is required or not. In this step, we further design an interface which allows users to manually disable the alarm to avoid false positive and to reduce transmission costs.

In the system pre-configuration process, the mobile devices have to load the thresholds that are determined during the offline stage. In this system, the threshold of the vertical acceleration is 1G, representing the free fall during falling. The threshold of overall acceleration is obtained from training data. We find the best threshold that can provide the highest accuracy in the validation test.

The system compares performance in terms of the sensitivity and specificity. Sensitivity and specificity are statistical measures of the performance of a binary classification test, resulting from the signal detection theory. Generally, there are four conditions in fall detection. True positive (TP): a fall occurs, the algorithm correctly detected. False positive (FP): an alternative state, but the algorithm detects fall. True negative (TN): an alternative state and the algorithm correctly detected. False negative (FN): a

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fall occurred, but the algorithm misses. Sensitivity relates to the system's ability to identify fall. It measures the proportion of actual falls which are correctly detected as such. This can be written as

$$\text{Sensitivity} = \frac{TP}{TP + FN}$$

Clearly, a high sensitivity results in a low false negative errors. On the other hand, specificity relates to the ability of the system to identify negative results. It measures the proportion of negatives (not fall activities) which are correctly identified. This can be written as

$$\text{Specificity} = \frac{TN}{TN + FP}$$

Similarly, a high specificity resulting a low false positive errors. A perfect fall detection system aims to achieve 100% sensitivity and 100% specificity; however, there is usually a trade-off between them.

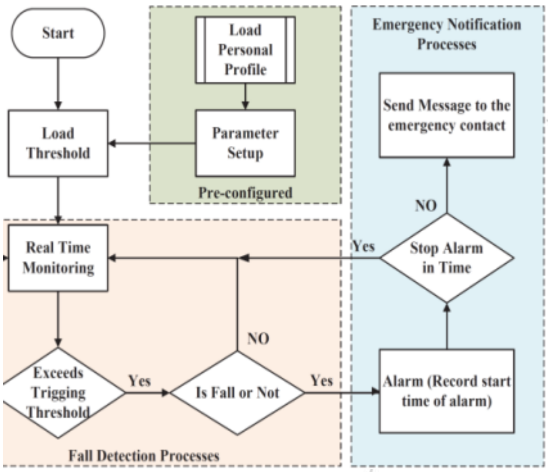

Fig.1.The architecture of the android phone

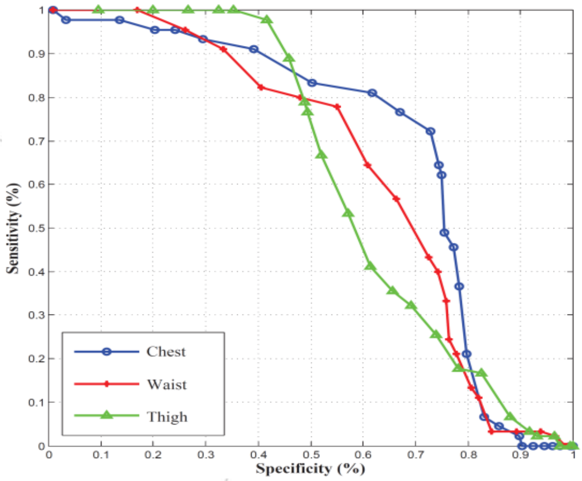

Fig.2.The sensitivity versus specificity in different phone-attached Locations based on overall acceleration

We implemented the fall detection system using Android based devices, HTC Desire and Tattoo mobile phones, with version 1.6 of the SDK platform. These phones were attached to different locations of human body, including the chest (pocket), waist (leather belt), and thigh (pocket),we used these phones to collect realistic three-axis acceleration and orientation measurements for different activities of daily living, including walking, sitting, standing and falling. The collected data was manually labeled as falling and other activities and divided into training and testing sets. The trainings data is used to find the threshold of the overall acceleration. Figure 2 shows the sensitivity versus specificity in different phone-attached locations based on the overall acceleration. For each location, we adjust the thresholds and compute the sensitivity and specificity, as indicated by the markers of each line.

Conclusion

The proposed system we adopt different algorithms to design fall detection algorithms, and conduct various experiments to evaluate performance. The results show that the proposed system can recognize the fall from human activities of daily living, such 73.78% specificity.