Pedestrian Activity Detection in a Multi-Floor Environment by a Smart Phone

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Abstract— Indoor localization has attracted considerable attention recently. One approach is to use inertial sensors mounted on pedestrians to characterize the users’ motions. However, few studies have focused on a multi-floor environment where users’ activities may include walking, running, and going up/down stairs. This paper proposes a lightweight activity detection system using inertial sensors on a smart phone to detect the behaviors of a pedestrian in the multi-floor indoor environment. The system first identifies strides using the accelerations values. It then uses the displacement, duration, and acceleration to classify their types. Our experimental results show that the stride detection accuracy is about 99%. In addition, the types of strides, namely walking, running, going upstairs, and going downstairs, can be detected with the accuracy of 94%, 91%, 95%, and 92%, respectively.

I. INTRODUCTION

Location-based service (LBS) [1], [2] is regarded as a killer application in mobile computing. Currently, GPS provides an adequate solution for location tracking and LBS in outdoor environments. To provide LBS in indoor environments, many researchers have focused on the alternative positioning techniques. Pedestrian dead-reckoning (PDR) [3], [4], [5] is an indoor localization approach which uses inertial sensors, such as accelerometers, electronic compasses, and gyro sensors, to detect the pedestrian activities. Recently, the pedestrian activity detection has attracted considerable attention for the healthcare and navigation applications [6], [7].

Among the various applications, several approaches have proposed useful systems to identify the users’ motions. In [8], the authors proposed a gait analysis and activity-monitoring system using the support vector machine. In [9], the authors proposed a pedestrian tracking system for handheld devices to derive strides from vertical accelerations. In [10], the proposed system uses inertial sensors mounted on the upper body to capture human behavior patterns. It then uses a pulse pattern-matching technique to detect the behaviors. However, few studies have focused on a multi-floor environment by smart phones.

This paper proposes an activity detection system to detect the behaviors of a pedestrian in the multi-floor indoor environment. The main idea is to use inertial sensors on a smart phone to identify strides by the accelerations values. (The walking motion actually comprises a series of strides.) The smart phone can be held in user’s hand or put into a bag. The proposed system checks the displacement in the z (vertical) direction to detect the types of stride, namely going upstairs and going downstairs. It also checks the duration and amplitude values (the gap between the peak and the valley values) to identify the running and walking events. We believe that the success of this research would further trigger more indoor navigation applications.

II. SYSTEM MODEL

Our use scenarios include carrying a smart phone in a bag or in one hand as shown in Figure 1. This system includes two components: data processing and activity detection. The data processing component uses a low pass filter to extract the accelerations from raw data. It then transforms relative accelerations into absolute accelerations by rotation matrices with respect to yaw, pitch, and roll values. The activity detection component uses the accelerations in the z direction to identify strides.

Fig. 1. Use scenarios in our work.

More specifically, the gap between the peak and the valley values of accelerations are used to identify the events of strides. After a stride event is identified, we classify its type as follows. If the displacement is above a threshold, we consider...
it as “going upstairs/downstairs” (the direction is easy to tell). Otherwise, we check (i) if the gap between the peak and the valley values of accelerations is above a threshold and (ii) if the duration of the stride is below a threshold. If either condition is true, the type is “running”; otherwise, the type is “walking”.

III. EXPERIMENTAL RESULTS

Figure 2 shows the accelerations of taking 10 strides in the z direction for walking and running. As can be seen, the events of strides can be clearly classified by the gap between the peak and the valley values. The duration values of the running event are smaller than those of the walking event. In this paper, if the duration of the stride is less than six samples, the type is “running”.

![Fig. 2. (a) Walking events and; (b) running events.](image)

The accelerations in the z direction for upstairs and downstairs in 10 strides are shown in Figure 3. The gap values between the peak and the valley values of the upstairs event are smaller than those of the downstairs event. The direction and displacement can be calculated by integrating the accelerations in the z direction.

![Fig. 3. (a) Going upstairs and; (b) going downstairs.](image)

Figure 4 shows the accuracy of activity detection in 200 strides. The stride detection accuracy is about 99%. The walking, running, going upstairs, and going downstairs events can be detected with the accuracy of 94%, 91%, 95%, and 92%, respectively.

IV. CONCLUSION

In conclusion, this paper proposes the activity detection system using inertial sensors on a smart phone to detect the behaviors of a pedestrian in the multi-floor indoor environment. The proposed system first identifies strides by the accelerations in the z direction. It then checks the displacement, duration, and acceleration values to classify their types. According to our experiments, the stride detection accuracy is about 99%. In the future, we will integrate our system into indoor navigation applications.

ACKNOWLEDGEMENT

Y.-C. Tseng’s research is co-sponsored by MoE ATU Plan, by NSC grants 97-3114-E-009-001, 97-2221-E-009-142-MY3, 98-2219-E-009-019, and 98-2219-E-009-005, 99-2218-E-009-005, by ITRI Taiwan Grant Project B352SN2200, by III, Taiwan, by CHT, Taiwan, by D-Link, and by Intel.

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