Pi-Navi: Finding Location of a Pedestrian Using Pace Tracking*

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1 Introduction

Recognizing location may be used to provide mobility helps for blind, context-aware guidance systems for exhibition touring, and spatially-based applications of a wearable computer. Many researcher, therefore, have attempted to develop a variety of systems, sensors, and techniques to find the location of an user [1, 2].

In this paper, we describes a method to find the location of a pedestrian wearing a sensing module, which is one of the basic function blocks in an indoor navigation system called "Pi-Navi". The proposed method uses dead reckoning which integrates incremental user motions, i.e., one step in our case. A bi-axial accelerometer and a digital compass are used to measure the acceleration and heading of a pedestrian, respectively. When the system detects a new step, it updates the current position of an user via dead reckoning. We also propose a classification method of walking behaviors as: walking on level ground ("level"), going up ("up") a stairway, or going down ("down") a stairway. Such recognition is important because it can be used as absolute position information, enabling the system to correct position errors. Experimental results demonstrate the performance of the navigation system.

2 Hardware

The system consists of a notebook PC, a card type data acquisition module and a sensing module. As shown in Figure 1, the sensing module consists of a bi-axial accelerometer, a digital compass module and an infrared light detector. The sensing module is assumed to be fixed to the middle of the waist of the user to measure forward and upward accelerations and heading accurately. The data is read every 20 [msec]. The digital compass module can give us compass heading information of the module via RS-232 serial communication channel.

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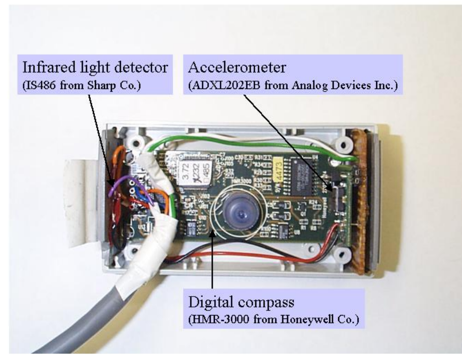

Figure 1: Sensing module

3 Proposed method

Counting steps using a detection method allows the direct determination of the distance. Therefore, we need to find an accurate and robust detection method. We selected positive and negative peaks of the forward/upward acceleration as a basic feature vector, which is detected in the period from the moment of last step detection to current step detection. When all four peaks are found, the system tests the following conditions to determine each new step.

1. Whether the detected four peak values are above the minimum threshold values.
2. Whether the time since the last walking detection is greater than some minimum period.
3. To prevent false detection from other body movements, we introduce a lag parameter on the autocorrelation function of $\ddot{z}(t)$ as:

$$j_{zz,min} \equiv \min_{j=0,\cdots,49}\left[\sum_{n=0}^{49} \ddot{z}(n)\ddot{z}(n-j)\right] \quad (1)$$

   The magnitude of the lag $j_{zz,min}$ must be greater than a threshold value.

If the above conditions are true, then the system increases the step count, and performs the dynamic step size estimation.

To estimate the current step size, we use a first-order polynomial model derived from the relationship between the step size and walking speed. We measured these features from nine persons in walking the same distance at three speeds: slow, normal, and fast. From our measurements, we found that if a user walks faster, both the step size [m] and step rate [steps/sec] increase.

The system tries to classify a step into one of three behaviors: walking on level ground (“level”), going up (“up”) a stairway, or going down (“down”) a stairway. The classification method is based on a nearest neighborhood method on the feature vector space. To increase the recognition ratio, we introduced also a cross-correlation function of forward and upward acceleration as another feature. Because the cross-correlation of “down” behavior is very distinguishable from the others.

At the time a “level” step is detected, the system determines the step size using step rate, then adds the north and east components of this displacement to the total north, $D_n(t)$ and east, $D_e(t)$ accumulator as:

$$D_n(t+1) = D_n(t) + d(t)\cos(\theta_q(t)) \tag{2}$$
$$D_e(t+1) = D_e(t) + d(t)\sin(\theta_q(t)) \tag{3}$$

where the heading $\theta_q(t)$ is a quantized heading from the digital compass.

For error correction, we used a simple infrared transmitter which fixed on certain places. When a signal is detected, the system make the current position to be prestored location. When a “up/down” step is detected at first in normal operation, same as the detection of an infrared signal, the current position is adjusted to the location of the starting place on near a stairway.

4 Experimental results

Figure 2 shows a tracking result when a user walks around a big loop path. The total length of the square path is around 128 [m]. We installed simple infrared light emitters at three places as shown in the figure. By using the infrared transmitter, the system correct the position error as sown in the region denoted by circle. The average of the errors between the final estimated position and the starting position from three trials are 0.83 [m] and 1.83 [m] for east and north components, i.e., x and y in the map, respectively.

We carried out an experiment taking a path include descending stairs as shown in Figure 3. The estimated tracking path is much different from the real path initially, because of a high magnetic interference in the region. When the system detect a “down” step at first, the correction of this error was accomplished. This result demonstrates that the detection of stairway using the proposed classification method can be used as an absolute position measurement like an infrared transmitter.

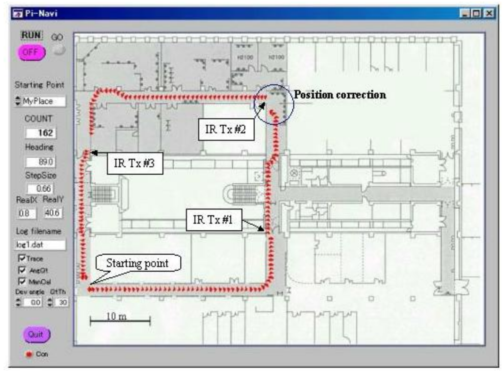

Figure 2: Tracking result of walking around a big square path

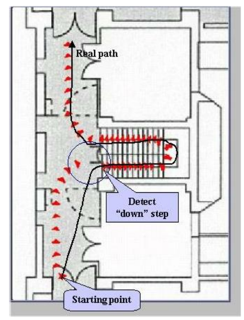

Figure 3: Compensation using detecting a “down” behavior

5 Conclusion

In this paper, we proposed a tracking method of the location of a pedestrian using dead reckoning based on pace tracking and simple infrared beacon method. Experimental results showed a reliable performance of the proposed method. In future works, we are studying how to improve the performances of step detection and step size estimation methods.

References

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[2] C. T. Judd, “A personal dead reckoning module,” in *Institute of Navigation’s ION 97 Conference*, (Cambridge), pp. 169–170, October 1997. (http://www.pointresearch.com/ionpapper.htm).