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（特別研究費に係る論文）

User localization by a wearable sensor

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ABSTRACT : GPS acquires location information by interrogating several satellites so acquisition is problematic indoors. Dead Reckoning is one solution; the path from a known departure point is calculated. This technique needs the length of stride, the velocity, and the estimated regression equation. However, this technique is limited to known individuals and normal walking action. This paper introduces a self-location estimation method for indoor environments that uses multiple regression equations to handle various walking styles.

Keywords : acceleration sensor, navigation system, Dead Reckoning, multiple regression equations

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1. Introduction

WSNs (Wireless sensor networks) are becoming pervasive [1]. This raises the feasibility of various sensor-based services [2], [3]. In addition, more services are plotting useful information on maps. Thus many navigation systems have been developed for pedestrians and car drivers in recent years. Providing a navigation system to walkers via their mobile telephones is attracting attention. This technology displays both a map and the user's present location on the mobile telephone. A recent concept is the three-dimensional (3D) map for navigation to rooms or sites inside buildings. GPS (Global Positioning System)-based navigation systems are becoming popular due to significant advances in ICT (Information Communication Technology). GPS acquires location information by interrogating several satellites so acquisition is patchy indoors.

There are two approaches to self-localization in indoor environments. First is the co-sited sensor. Self-location is acquired from the environment. Examples include Camera, IC tags and so on. The other approach is Dead Reckoning. The user carries a wearable sensor such as an acceleration sensor, angular velocity sensor, magnetic sensor and so on. The path is calculated from a known departure point [4]. Co-sited sensors have several weaknesses. They are expensive to install. Their installation locations must be carefully considered. Therefore, our approach is based on the relatively low cost solution of Dead Reckoning. In addition, current mobile phones contain various sensors. This technique needs the length of stride, the velocity, and a regression equation to estimate the distance traveled and turns taken. However, existing systems are limited to known individuals and normal walking action.

This paper introduces a self-location estimation method for indoor environments that uses multiple regression equations enabling to handle various walking styles.

2. Method

The proposed method is intended to estimate the velocity of the user in real time. Multiple regression equations that can estimate velocity were made from

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the acceleration data captured from walking subjects, six healthy males ranging from 21 to 24 years.

Each wore a three-axis acceleration sensor (Hitachi wireless-T with sampling frequency of 100Hz) on the right waist. As for coordinates, x-axis is traveling direction, y-axis is vertical direction, and z-axis is horizontal direction normal to the direction of travel. Subjects moved 20 m three times using three kinds of walk: “Slow walk”, “Normal walk”, and “Brisk walk”, and “Jog”.

3. Data analysis

Time period for the walk cycle was evaluated using smoothened acceleration data. A cycle was judged when the acceleration value started from the median, passed through the pre-set upper threshold, fell to the median, passed through the pre-set lower threshold, and reached the median again. The peak-to-peak value of each cycle in x and y coordinates was evaluated for 4 cycles of each of the 4 movements. Figure 1 plots acceleration data in terms of x and y peak-to-peak values. We identify the type of movement to get a better estimate of distance moved. For this, thresholds are used to classify the movement type.

Those values were then categorized into 4 groups in terms of x and y values. The 4 groups were a) small x and y value, b) small x and large y, c) large x and small y, and d) large x and y value. Here, group b), c), and d) were further categorized into 2 sub-groups. Multiple regression equations were created from the characteristic data of each subject.

We obtained 7 groups in total, so that 7 multiple regression equations were evaluated. The peak to peak values of 576 points generating the 7 multiple regression equations were here used.

The 2 explanatory variables are the peak-to-peak value of an x-axis cycle (traveling direction) and the peak-to-peak value of a y-axis cycle (vertical direction). The objective variable is velocity. This is obtained by dividing moving distance by the time.

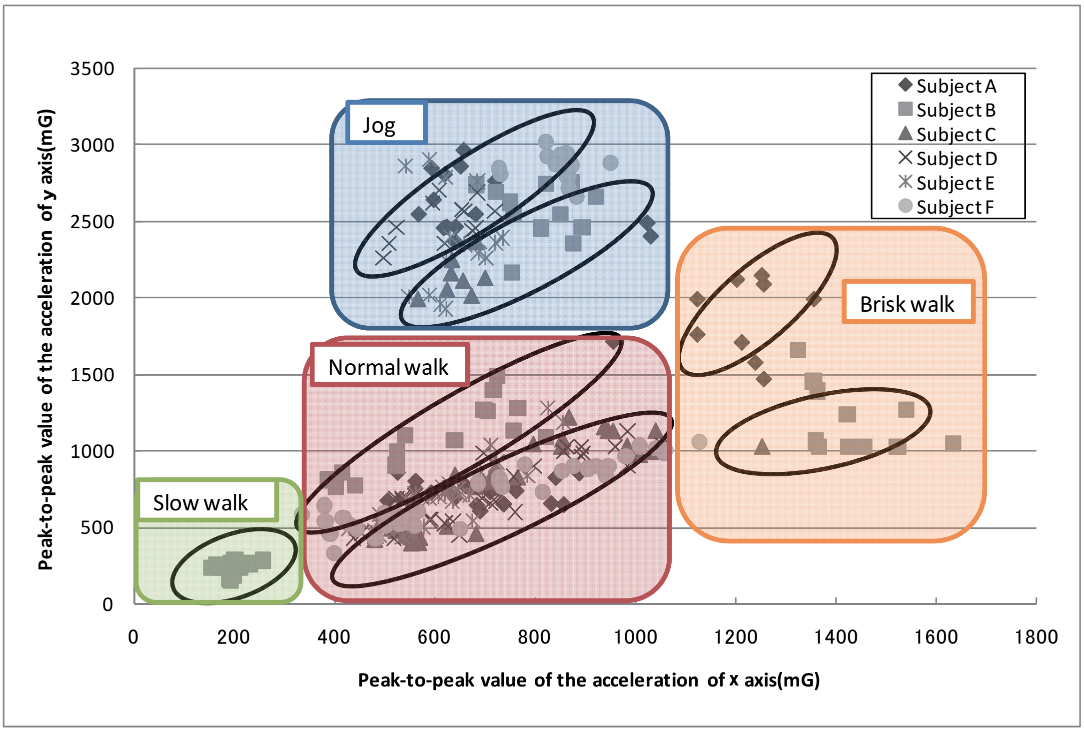

Fig.1 Peak-to-peak acceleration value of each cycle

4. Result

The distance moved was estimated by using the multiple regression equations. The moved distance was calculated from the length of stride and the number of steps. The length of stride was calculated from the velocity of one step and the cycle of one step. The velocity of one step was estimated from the acceleration data by the multiple regression equations. Equation (1) yields the moved distance where D is Distance, T : time of ith cycle, v_i : velocity of ith cycle, and n : the number of steps.

We used different data sets in making the multiple regression equations and evaluated their performance. The measured mean error in estimated distance traveled was 15%.

$$D = \sum_{i=1}^{n} v_i T_i \qquad (1)$$

In addition, we formed multiple regression equations to compare the cases of "no classification", "classification of walk" and "classification of individual" for a performance comparison. Table 1 sammarizes the measured mean error (ME).

Table.1 The measured ME and SD

	ME(%)	SD(%)
No classification*	26	6
Classification of walk**	22	12
Classification of characteristic	15	11
Classification of individual***	10	6

*The multiple regression equations made using all data.

**The multiple regression equations made using 4 groups of data.

***The multiple regression equations made using individual data.

5. Discussion

Classification of characteristic yields better accuracy than no classification and classification of walk. The multiple regressions equation made using 7 groups of data that have similar characteristic distributions yield more accurate estimated movement distances. However, classification of characteristic may not achieve convergence to a single line because the standard deviation (SD) is rather high. This may be the cause of the mean error.

6. Conclusion and future works

Accuracy is expected to be improved by repeating the classification. Larger data sets are necessary to create really effective universal regression equations that can be applied to anyone.

These experiments considered 4 styles of movement. However, humans use a much wider range of styles, so additional data from various cases must be collected and analyzed.

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