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A Classification Scheme of Ambulatory Movements with Barometer and Accelerometer of a Smart-Phone

Younghoon Kim, Nammoon Kim, Youngok Kim

Department of Electronic Engineering, Kwangwoon University,
20 Kwangwoon-ro, Nowon-gu, Seoul, 139-701, Republic of Korea
kimyoungok@kw.ac.kr

Abstract. As various smart devices are introduced, the application software for analyzing the pattern and the quantity of exercise is addressed as a promising smart-phone application. In this paper, we propose a classification scheme of ambulatory movements with barometer and accelerometer of a smart-phone. According to the experimental results, the difference of barometer datum can provide the characteristics of vertical ambulatory movements, while the vertical axis data of accelerometer can solve some limitations of barometer.

Keywords: Barometer, accelerometer, ambulatory movement

1 Introduction

In these days, various smart-phone applications have been developed. One of most popular smart-phone applications is related with analyzing exercise pattern and quantity of the user. Recently developed smart-phones tend to be equipped with various sensors, such as GPS, barometer and accelerometer. However, the GPS does not work well in indoor environments. It is also known that the barometer sensor can replace vertical movement of GPS in case of some environments like downtown crowded by buildings and covered with roofs and walls [1], [2], [3]. Meanwhile, the rapid and steady changes like typhoon or heating system can make the barometer hard to detect the movements. As presented in [4], therefore, it is known that temperature and sensor drift can affect atmosphere.

In this paper, we propose a classification scheme of ambulatory movements with barometer and accelerometer of a smart-phone. Without high complexity scheme like energy detection methods in [5], it is shown that the proposed scheme can distinguish the ambulatory movements stably through experiments. According to the experimental results, which are achieved with a conventional smart-phone model, the difference of barometer datum can provide the characteristics of vertical ambulatory movements, while the vertical axis data of accelerometer can solve some limitations of barometer.

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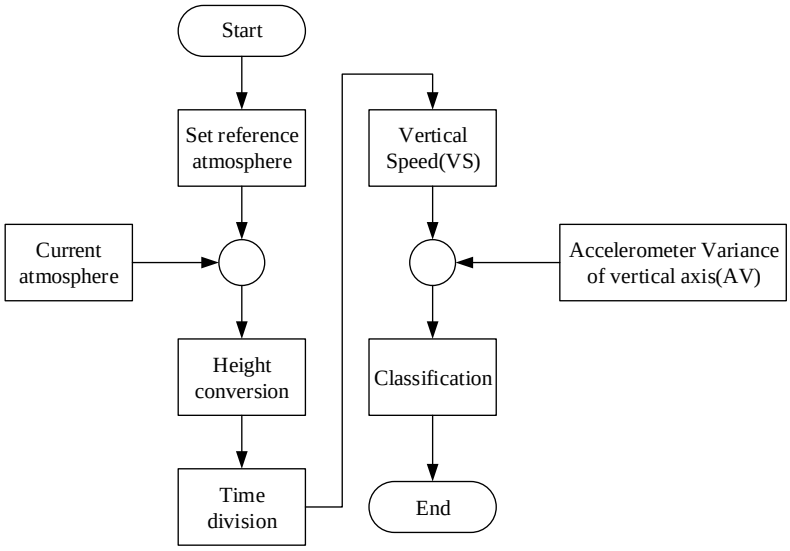

Fig. 1. Proposed scheme for classification of ambulatory movements

2 System Description

The proposed scheme for classifying ambulatory movements is shown in Fig. 1. After setting the mean of first 10 atmosphere samples as a reference, as shown in the figure, the height can be derived from both the reference and the current atmosphere. Note that the sampling rate is 10Hz.

The vertical direction is considered as an important factor to classify the ambulatory movements because the direction of elevator and stair is vertical, while it is impossible to walk upwards or downwards in the aisle and elevator. By dividing the time that it takes to go upwards or downwards, the vertical speed (VS) can be derived from the estimated height and both each threshold of VS and the accelerometer variance of vertical components (AV) can classify the ambulatory movements. The sign of VS can decide the direction, upwards or downwards, of movements.

2.1 Calculation of height

The height can be derived with the equation converting atmosphere to altitude as follows [6]:

$$h_c = h_b - \frac{R \cdot T_b \cdot \ln(P_c / P_b)}{g_0 \cdot M} \quad (1)$$

$$h = h_c - h_r = -\frac{R \cdot T_r \cdot \ln(P_c / P_r)}{g_0 \cdot M} \quad (2)$$

where h_c is height at current location, h_b is height at the bottom of atmospheric layer, h_r is height at reference location, h is difference height between current and reference location, R (= 8.31432 $N \cdot m/(mol \cdot K)$) is universal gas constant, T_b (= 288.15 K) is standard temperature at sea level, T_r is temperature at reference location level, P_c is pressure at current location level, P_b is pressure at sea level, P_r is pressure at reference location level, g_0 (= 9.80665 m/s^2) is gravitational acceleration constant , and M (= 0.0289644 kg/mol) is molar mass of earth's air.

The equation (1) is used to convert from current atmosphere to current altitude. By replacing sea level to reference value, the difference of height, (2), between current and reference location can be derived from ratio of reference atmosphere to current atmosphere. The current floor can be estimated roughly by (2) if the height of the floor is known.

2.2 Variance of vertical accelerometer component

To classify movements, several combinations of accelerometer variance are considered. As a result, variance of Z-axis is considered as most powerful information to detect each movement. The AV in elevator is the least value than another ambulatory movement except for the stop. The AV can be the reference variance to classify ambulatory movements because it is impossible to walk upwards or downwards. Meanwhile, the user should stand and wait while the user uses the elevator. It means that it does not depend on individual characteristics. With the threshold value of elevator variance, it can distinguish elevator ambulatory movements.

2.3 Height Speed

As the sampling rate is 10Hz, time that it takes to correct data can be calculated by dividing total samples by sampling rate.

$$V = \frac{h}{t} \tag{3}$$

where V is velocity in period of h , t is time in period of h

The Eqn. (3) can be used to distinguish vertical movements with stair or elevator from horizontal movements likewise walking, and standing motion. If (3) is positive, it means upward direction. In contrast of upward direction, downward direction has negative sign of (3).

With the velocity threshold and the AV, 6 kinds of ambulatory movements, stand, walk, upstairs, downstairs, upward movement on elevator, downward movement on elevator, can be distinguished. Movements of walk and stand are independent with sign of estimated height, VS, because those are horizon movement.

3 Experiments and Results

3.1 Description of Experiments

On the sixth floor building of our university, barometer data and accelerometer data are collected. The height of the floor is 4.2m, and two elevators and two sets of stairs exist. The recorded temperature was 293.65K at the moment of experiments, which are shown with results in Fig. 2.

According to [5], temperature affects atmosphere. In the building, each floor has different temperature because the heating situations are different. It makes hard to estimate current floor, but it does not mean the limitation of classification of ambulatory movements. When the change of floors is monitored, atmosphere changes at least 50 samples ago. Small period means small error. Thus the window size for classification was set to 50. The AV and the VS are applied to determine threshold to distinguish the movements. Current states and movements are determined by utilizing previous 50 samples after floor changes. The height is estimated from atmosphere changes before floor changing is recognized

3.2 Results

Fig. 2 shows the experiment results of the proposed scheme. The 1st graph is about real height at each floor and estimated height. The 2nd graph is index of ambulatory movements. The index 1 and 2 mean elevator case, while the index 3, 4 mean stair case. The index 5 means walk in ambulatory movements. Index 6 means the standing motion in ambulatory movements. For movements, odd number indicates upward direction in elevator and stair, while even number means downward direction. In other ways, walk and stand do not need a direction when they are distinguished from others. The 3rd graph is for the estimated floor. In case of floor, it is identified from 1 to 6. The 4th and 5th graphs are for the AV and the VS, respectively.

Various movements, which are with 4 walks, 2 up-stairs, and 1 upwards elevator, are tested and detected correctly. During the experiments, the standing motion at start position and the waiting motion in the elevator are also figured out. In case of floor, all of the floors are estimated except for the 6th floor.

3.3 Considerations

We proposed the classification scheme of ambulatory movements with barometer and accelerometer of a smart-phone. The proposed scheme has lower complexity than the conventional methods that use combination of barometer sensor and accelerometer sensor in introduction. However, rapid changes of temperature can cause additional errors. For example, in summer, winter, nights, temperature can be different from temperature of each side and floor in building. In addition, the drift of sensor can also make error.

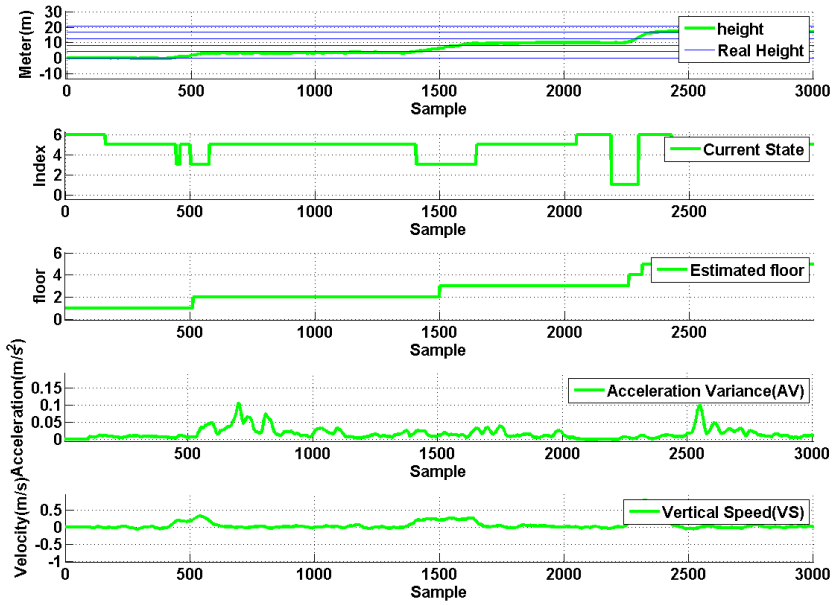

Fig. 2. Result graphs: Estimated height, ambulatory movements (Current State), AV, VS.

4 Future works

In this paper, we performed relatively simple experiment for the realization of proposed scheme. Even though the proposed scheme provided adequate performance at the simple and short path, there would be some problems, such as drift error and errors caused from changes of temperature. As a future work, we have a plan to set the path that can happen in actual life in order to verify the performance of the proposed scheme. Moreover, the enhancement of the proposed scheme will be provided by applying the optimized threshold of VS, AV as well as minimizing the errors.

5 Conclusions

In this paper, we proposed a classification scheme of ambulatory movements with barometer and accelerometer of a Smart-Phone. As shown in the experimental results, simple aids of accelerometer can help barometer sensor to detect ambulatory movements all the time. It is shown that the proposed scheme is powerful and simple method to distinguish the ambulatory movements. If it is possible to compensate

atmospheres for the temperature changes or changing the reference atmosphere value, it is expected to be more useful that it would have advantages in estimate the current floor. Without high complexity scheme like energy detection methods, it is shown that the proposed scheme can distinguish the ambulatory movements stably through experiments.

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