Elevator Motion States Recognition Using Barometer Support Indoor Positioning System

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Abstract. Indoor positioning is widespread applications in health monitoring, navigation and other indoor position services. There are a variety of researches focusing on solving indoor position problem, but most of them are using the accelerometer to solve horizontal positions. Nevertheless, there are a lot of buildings and houses that people are using the elevator in moving among the floors. Hence, it is difficult to estimate the positions vertically when the users use the elevator in motion. This paper aims to integrate a barometer in indoor positioning system (IPS) for elevator motion recognition and proposes a new feature name "pressure standard deviation" from barometer recording data to distinguish among elevator up, elevator down, still, stairs up, stairs down to track the position of user in vertical axis. The experimental results achieve 100% accuracy in distinguishing the state of elevator up, elevator down, still, stairs up, stairs down and estimate exactly and real-time in vertical axis.

Keywords: Indoor Positioning System, Barometer, Elevator, Vertical Position, Pressure Standard Deviation.

1 Introduction

Activity recognition is important for widespread applications like IPS, patient tracking, health monitoring. Recently, most of the researches have focused on using acceleration data for activities classification. Nevertheless, the limitations of acceleration data are difficult to estimate the activities in vertical. The using built-in smartphone sensor like accelerometer, barometer, Global Positioning System (GPS), Wi-Fi, Bluetooth,… are more and more popular because these sensors are integrated in a smartphone. The GPS is unreliable for IPS because it is unstable in indoor environments. Using Wi-Fi and Bluetooth requires pre-installed system to emit and transfer the signal among insides and between inside and outside. Hence, it is not applicable for IPS like firefighting and rescue because the pre-installed system may be destroyed by flame and heat from fire burning.

In [1][6][7], the authors proposed to use the accelerometer for state classification. The accelerometer is only suitable to estimate the states of walking, running and still state in horizontal. The accelerometer reading in the vertical is not very different among in-elevator up, in-elevator down and still states. Furthermore, using accelerometer in stairs up, stairs down and walking classification achieves low accuracy because the accelerometer reading values are not very different in these states.

The publication [8][9] used barometer in vertical estimation, the authors proposed to integrate this sensor for measuring the pressure without eliminating abnormal parts in barometer reading. Hence, the reading values of the barometer will be affected by environment like weather, temperature and humidity and noise in sensor or the suddenly changing in air pressure.

Based on the above limitations, this paper proposes to integrate barometer in our IPS and add new feature "pressure standard deviation" to eliminate abnormal part in barometer reading.

2 System Design

2.1. The 3-DOF accelerometer

The 3-DOF accelerometer is used to acquire the acceleration in three axis Ax, Ay and Az. This kind of sensor is also popular in outdoor positioning system [9-14]. Nevertheless, the accelerometer is only applicable to distinguish among activities like running, walking and still states by using the magnitude of acceleration as:

$$A_n = \sqrt{A_x^2 + A_y^2 + A_z^2}, \quad (1)$$

The acceleration data is difficult to recognize amongst still states, in-elevator up, in-elevator down and walking stairs up, walking stairs down and walking on the floor. It can be seen that, the Fig.1 shows the acceleration (m/s^2) of walking stairs up, walking stairs down and walking on the floor (see Fig.1). Also, it is difficult to distinguish among these states when using only the accelerometer for states classification.

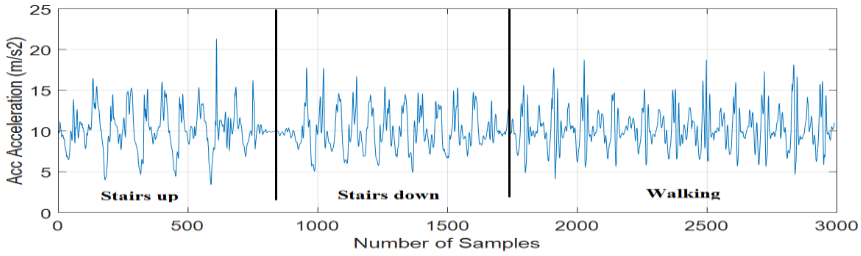


Figure 1. Acceleration magnitude of walking stairs up, walking stairs down and walking on the floor

2.2. Barometer BMP180 and Map Information

a) Barometer BMP180

BMP180 is a sensor used for measure pressure and temperature. The temperature parameter supports to calculate the pressure of the environment because the pressure depends directly on the temperature, weather and humidity of the environment. Based on current measured pressure p and the pressure at sea level $p_0 = 1013.25$ hPa to calculate the altitude by using the international barometric formula [5]:

$$altitude = 44330 * \left(1 - \left(\frac{p}{p_0}\right)^{\frac{1}{5.255}}\right), \quad (2)$$

Based on the $altitude$ value and map information (see Fig. 2b and Fig.3) we can estimate the vertical position of the user. Nevertheless, the barometer reading has always existed an abnormal signal (see Fig.2a), it leads to the wrong position estimation (see Fig. 2) when we integrate barometer into an IPS without eliminating abnormal parts in the signal. The raw measured pressure data may cause of the wrong prediction vertical position as the below figure:

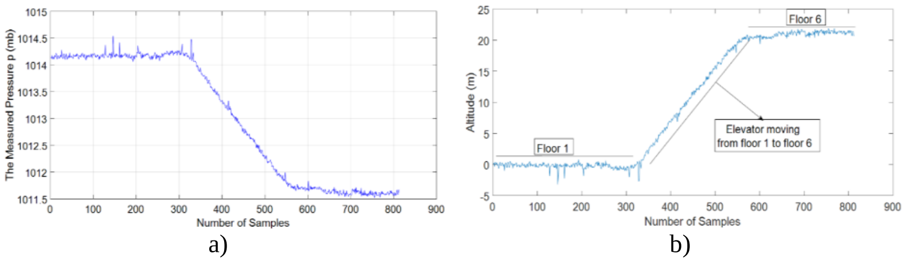


Figure 2. a) The raw measured pressure p (mb) and b) the altitude based on the raw measured pressure

b) Map Information

All buildings need designing before constructing, and there are all parameters like the height of the building, the height of each floor, stairs and elevators positions…etc that are also clarified (see Fig. 3). These are useful information to support for finding the position of users inside of the building.

2.3. The Proposed Method

a) System Design

The proposed IPS integrates of a low-cost 9-DOF IMU MPU-9250 (9-axis Motion Processing Unit), a wireless data transmitter/receiver, a barometer BMP180 and other supporting sensors for data fusion.

b) The Pressure Standard Deviation

To detect the level of the floor, we uses the height which is calculated from the processed pressure data by the formula (2). The data in each window are a group of 4 barometer samples *(baro(i), baro(i+1), baro(i+2), baro(i+3))*. The pressure standard deviation algorithm is used for calibration data as Fig.5.

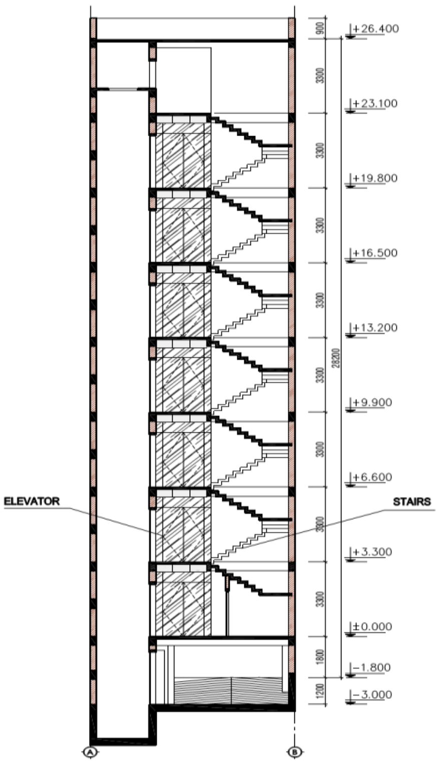


Figure 3. The map information of a building (the building height, floor height, elevators and stairs positions)

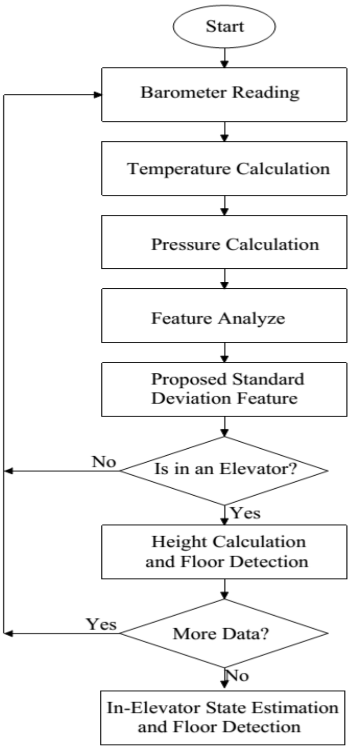


Figure 4. The flow chart of our proposed method

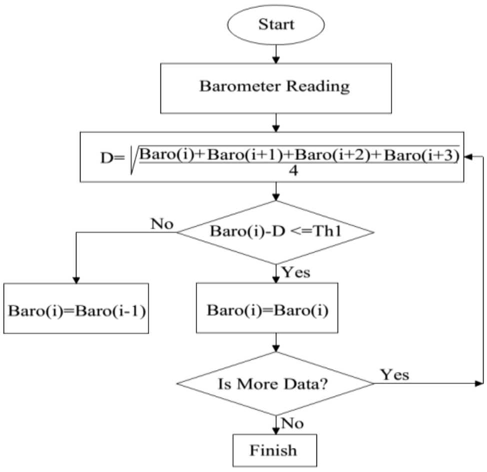


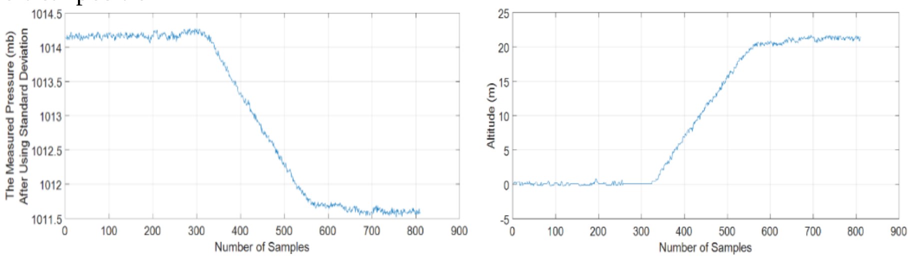
Figure 5. The flow chart of our proposed “Pressure Standard Deviation” feature

To eliminate abnormal signal recorded from a barometer, we proposes that: if *abs(baro(i) - D)* ≤ *Th1* then *baro(i)* = *baro(i)* else *baro(i)* = *baro(i-1)*. Then the altitude can be derived from the measured pressure as in (1). We can distinguish being still from being in a vertical motion state by calculating the difference of data after 2s. If the difference is larger than the threshold, it can be considered that the user is moving vertically. With the given building schematics, we are able to estimate the instant altitude of the user and which floor the user is currently in.

3 Results and Discussions

For the experiment testing, we carried out a test on 6 firefighters selected from The University of Fire Fighting and Prevention (UFFP) aged from 18 to 22, height: 1.65m – 1.78m, weight: 65 kg – 79 kg. The volunteers recorded two types of data: walking – elevator up – walking - elevator down – walking and stairs up – stairs down. For each type of data, the volunteer would record 3 times.

The Fig.6 and Fig.7 bellow illustrates the altitude and position of firefighter in vertical position



a) b)

Figure 6.a) The measured pressure (*mb*) and b) The altitude (*m*) after using the “pressure standard deviation” feature in elevator up

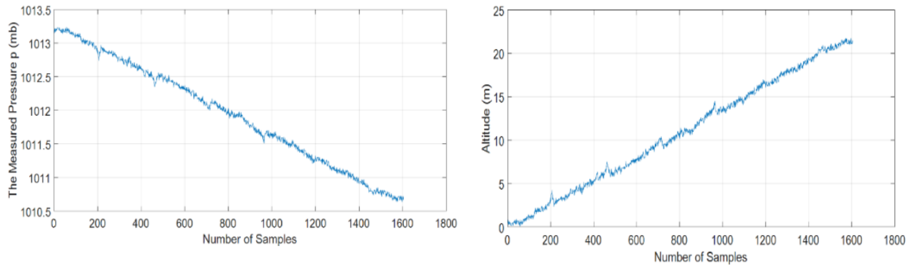


Figure 7. The altitude and vertical position of volunteer after using the “pressure standard deviation” feature in walking stairs up

In Fig.6a, the volunteer carries our device and walks on floor 1, then use the elevator to move to floor 6 and walks on it. The achievement results in Fig.6 illustrates clearly of the states of walking – in-elevator up – walking from floor 1 to floor 6; a) the measured pressure (*mb*) b) the altitude (*m*).

The result in Fig.7a is also very clear about the changing pressure and altitude among the floors. The proposed pressure standard deviation features will eliminate all abnormal parts in the signal (see Fig.6 and Fig.7).

4 Conclusion

In this paper, we proposed to use barometer integrated into an IPS and a new feature "pressure standard deviation" for states classification. The achievement results are significant improvements in states classifying and floors estimation. In future work, we will combine recording data from IMU, Barometer and other supporting sensors for data fusion and build map information to enhance the performance of our proposed IPS.

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