Research of Differential Pressure Altimetry in Location Based Services

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Abstract. In recent year, as a major national strategic emerging industry, location based services (LBS) have been widely used and been affecting people's daily lives. With the speeding up development of urbanization and further improvement of people's living standard, the demand of three-dimensional location-based service grows rapidly when dealing with indoor navigation, asset management, security monitoring, security dispatching, emergency rescue, and many other aspects. However, at present the mainstream navigation and positioning system only provides users with two-dimensional position information that is accurate longitude and latitude, but not vertical positioning information because of the poor precision. This paper focuses on researching the differential pressure altimetry by comparing pressure altimetry. The differential pressure altimetry can provide accurate vertical height information for indoor and outdoor navigation and positioning system and will provide important theoretical basis and technical support for the evolution of traditional two-dimensional LBS for the high precision of three-dimensional indoor and outdoor seamless LBS.

1. Introduction

Firstly, this paper studied pressure altimetry by testing performance and analyzing the advantages and disadvantages of it. Secondly, the differential pressure altimetrywasproposed which can be used for indoor and outdoor high precision three-dimensional indoor and outdoorseamless LBS. Finally, this paper researched the performance of the differential pressure altimetry and put forward temperature difference correction model to improve robustness of this altimetry for the measurement of local temperature difference abnormal environment.

2. Pressure Altimetry

The principle of pressure altimetry is using the force balance principle of gravitational field and atmospheric pressure to calculate the altitude of testing point. The international standardization of organization (ISO) put forward the "international standard atmosphere"concept which rules functional relationship model between the atmospheric pressure and height. It is the following:

$$H = \frac{T_0}{\beta}\left[\left(\frac{P_H}{P_0}\right)^{-\frac{\beta R}{g}} - 1\right] + H_0 \quad (1)$$

P_h is pressure value of test point. β is temperature gradient coefficient of the atmosphere in space. R is Gas constant and g is the acceleration of gravity. $H_0 = 0m$, $P_0 = 1013.25hPa$. Using the formula(1), we can calculate the altitude of test point by measuring pressure.

Pressure altimetry is simple and low costmeasurement but it is greatly influenced by environmental factors including the movement of the atmosphere, the change of atmospheric temperature and humidity. The calculatingaltitude of fixed testing point by pressurealtimetry within 24h is shown as Fig. 1.

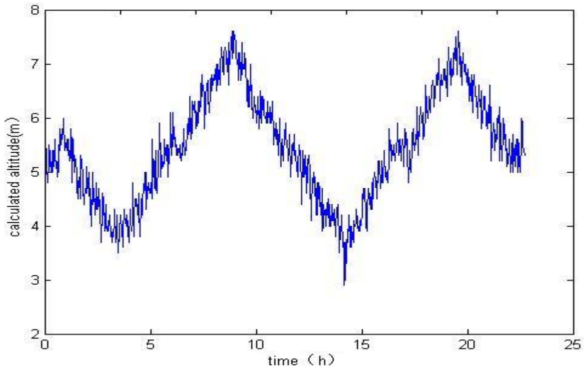

Fig. 1Calculating altitude of fixed testing point by pressure altimetry within 24h

As shown in Fig. 1, we know the altitude driftof fixed testing point within 24hwas2m. So pressurealtimetry has a poor stability and reliability.

3. Differential Pressure Altimetry

Principle. Pressure altimetry has poor stability and reliability. In order to solve those problems, we can adopt differentialconcept to compensate the result of pressure altimetry because local atmospheric pressurehas the same change trend in physicalcharacteristics. Specific testing process is compensating the result of pressure altimetry by the trend of pressure of pressure benchmark station with a determined altitude. Based on the pressure altimetry, the phenomenon that force balance state between gravitational field and atmospheric pressure is defined as atmospheric pressure hydrostatic equilibrium. In this state, there is a functional relationship between atmospheric pressure and altitude which is expressed as follows:

$$\frac{dP}{dz} = -\rho g \quad (2)$$

P is the current pressure value. Z is the current altitude. G is the gravitational acceleration. On the premise ofair density is constant, pressure decreases with altitude rising.

Temporarily don't consider the effect of air humidity to local pressure, the gas state equation withoutany water vapor is expressed as follows:

$$P = \rho R_d T \quad (3)$$

T is the current air temperature $R_d (R_d = 287.05 J/(kg \cdot K))$ is the gas constant of dry air. Because of $p \propto P/T$, we can deduce:

$$P = P_0 \exp[-\frac{1}{R_d}\int_{h_0}^{h}\frac{g}{T}dz] \quad (4)$$

And

$$h - h_0 = -R_d \int_{P_0}^{P}\frac{T}{g} d\ln P = \frac{R_d}{g}\int_{P_0}^{P} T d\ln P \quad (5)$$

The above two formulas reflect the relationship of pressure, temperature and height in state of atmospheric pressure hydrostatic equilibrium.The above formula derivation makes the g as a constant.

Assuming that the gas temperature is equal in local limited scope and the average temperature of the two vertical position is T_m , we can deduce:

$$h - h_0 = \frac{R_d T_m}{g}\int_{P_0}^{P} d\ln P = 29.27 \cdot T_m \cdot \ln\frac{P_0}{P} \quad (6)$$

P_0 is the pressure value at h_0 height position and P is the pressure value at h height position. This formula is Laplace high pressure equation that is the principle of differential pressure altimetry.

Performance Analysis. The methods of differentialpressure altimetry as follows: randomly select four testing points in indoor and outdoor environment at different height position under normal atmospheric pressure local environment. Those four test pointsmarked A, B, C and D. Respectively use the same type of pressure sensor at the same time at four testing points measuring and recording data including pressure and temperature information. The test time was about 24 hours. Test point A, B and D were inside of building but C was outside. The difference in height between A and B is 1.00m, A and C is 10.06m, A and D is 20.85m. After the test, we got those results, as shown in Fig. 2.

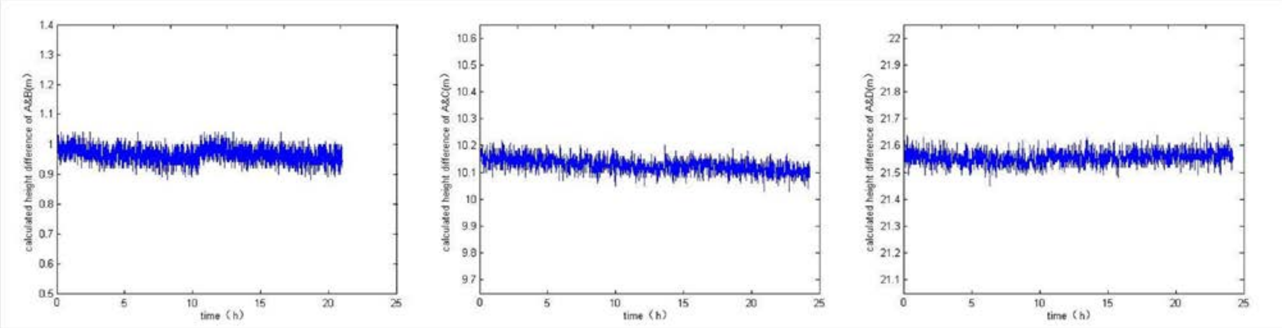

Fig. 2Calculating height difference between test points by differential pressure altimetry

As shown in Fig. 2, we summarized the test results, as Table 1.

Table 1 The test results

Height Difference	Average Value	Standard Deviation(1σ)	True Value	The Error
A and B	0.9655m	0.02757m	1.00m	0.03345m
A and C	10.1267m	0.02920m	10.06m	0.0667m
A and D	21.5561m	0.02738m	20.85m	0.7061m

The test results show that the differentialpressure altimetryperformance is excellent and precision is better than 1min the indoor and outdoor testing environment. So if we know the accurate altitude, perssure and temperature information of reference point, accurate altidtude of any position can be calculated by differential pressure altimetry.

Comparison of Pressure Altimetry and Differential Pressure Altimetry. Based on the above research for two altimetries, we compared them with Table 2.

Table 2 The comparison of two kinds of altimetries

Altimetry method	Advantage	Disadvantage	Whether can be used for Three-Dimensional LBS
Pressure Altimetry	Simple, rapid and convenient	Accuracy is poor	No
Differential Pressure Altimetry	Convenient	Need reference pressure base station	Yes

4. Temperature Difference Correction Model

Principle. In the local abnormal air density measurement environment which is caused by temperature difference anomaly, local atmospheric pressurehas a completely different change trend in physicalcharacteristics. This leads to differential pressure altimetry measuring height difficultly and having a poor measurement error. This kind of measuring environment includes indoor air conditioning refrigeration and heating, fire rescue environment, etc.

For local abnormal temperature measurement environment, assume that air volume and quality in local space are constant regardless of strong convection. The gas state equation is expressed as follows:

$$pV = nRT \quad (7)$$

In this equation, P is pressure. V is air volume. n is air quality. T is temperature. R is perfect gas constant. Continue to derive:

$$dp = \frac{nR}{V} dT \quad (8)$$

According to the formula, local pressure change is proportional to the temperature change. So we can estimate the pressure change due to temperature difference through a period of time to test the temperature and pressure through a period of time to test current temperature and pressure. This pressure change value estimation in local abnormal temperature measurement environment is applied toamendthe error of pressure change.

In local abnormal temperature measurement environment, ΔP is the pressure change, we can deduce:

$$\Delta P = dp + \Delta P_1 \quad (9)$$

In the formula, dp is pressure change due to the local temperature difference, ΔP_1 is the pressure change because of human movement. Considerhumanbehavioral characteristics:

i) The change of pressure is small and stable.

ii) The pressure change rate is less than 24Pa/s (about2 m/s ofheightchange rate).

Based on formula (9) and humanbehavioral characteristics, wecan calculate the precise height change in this measuring environment for human movement which can be vertical orientation highly reliable calculating data in three-dimensional location basedservices.The temperature difference correction algorithm flow chart is as Fig. 3.

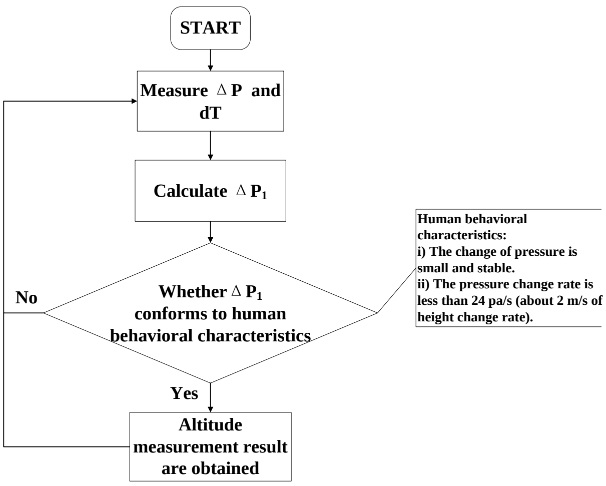

Fig. 3 The algorithm flow of Temperature Difference Correction Model

Modelperformance analysis. To test this correction model’s performance, we set uplocal temperature difference obvious indoor experimental environment which is normal indoor space having a high-power electric heater. The test process was that choosing indoorthreetest points marked A, B and C. The test terminal with pressure sensor started moving from point A to B in a constant speed. Then the terminal kept in B for 0.5 minutes, and moved to C in a constant speed. After 0.5 minutes, we moved it to point A from C. In the process of test, the terminal recorded the pressure testing data at any time and 10 groups testing data was gotten within 1 second. What we call the constant speed is human normal walking speed. The position of test points is shown in Fig. 4.

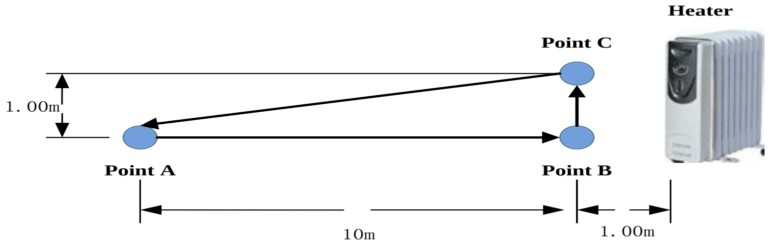

Fig. 4 Local abnormal temperature testenvironment

The performance test result is shown in Fig. 5.

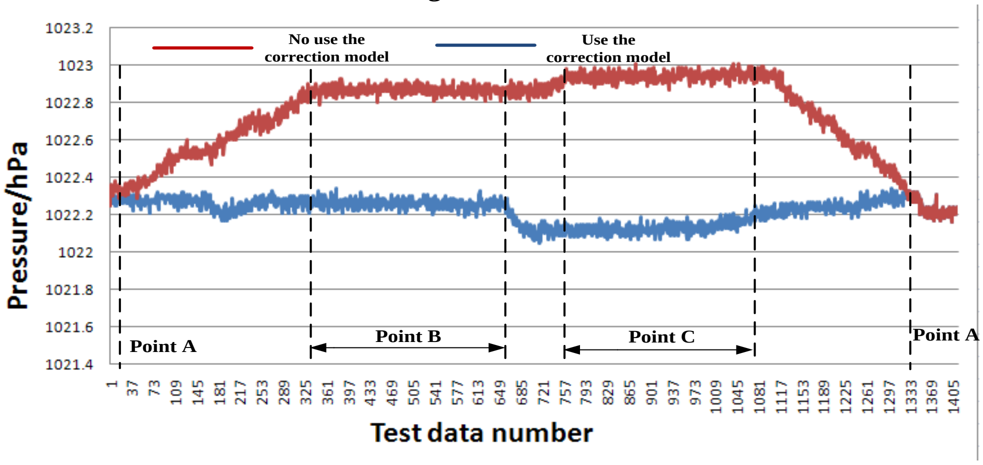

Fig. 5 Performance test result of correction

According to the test result, pressure data of point A, B and C is stable because of temperature difference correction model. The average value of testing pressure data of point A and B is 1022.2635hPa. The average value of testing pressure data of point C is 1022.1139hPa. According to Laplace high pressure equation, we can calculate the differencein height of 1.237m between A(B) and C. The error is 0.237m. However, if didn't use the model, the Fig. 5-14 shows that the test height difference between A and B was 5.15m but the real height difference was 0m. The test shows that temperature difference correction model can realize precise error correction for height measurement in the local abnormal temperature environment.

As shown in Fig. 6, the success rate of channel decoding is descendent with the error rat increasing.But under certain error rat, the effectiveness of improved channel decoding is better than the effectiveness of conventional channel decoding clearly.

5. Summary

This paper, firstly, puts forward differential pressure altimetry which can provide accurate vertical height information for three-dimension LBS. Then the paper verified that the precision of differential pressure altimetry is better than 1m. Finally, temperature difference correction model was proposed for preciseerror correction to the local abnormal temperature environmentapplication of differential pressure altimetry. The performance test verified that this correction model effectively improves robustness of differential pressure altimetry.

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