Pedestrian Indoor Autonomous Navigation Algorithm Based on Portable Intelligent Terminal

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Abstract

Global navigation satellite system (GNSS) does not suitable for the indoor positioning. Therefore, a pedestrian indoor autonomous navigation algorithm based on inertial sensor is proposed. The pedestrian gait detection and step length estimation are achieved by using the data of accelerometer. The roll, pitch and yaw angle are updated in real time using the cosine matrix. PDR is used to calculate the pedestrian position coordinates. The verification under the intelligent positioning terminal platform indicates that the proposed accuracy of the indoor autonomous navigation algorithm is less than 1.5%, which can be effectively applied in the field of intelligent positioning terminal.

Keywords

Autonomous navigation; Dead-Reckoning; Particle filter; Drift error.

1. Introduction

The commonly used Global Navigation Satellite System (GNSS)[1] is only suitable for use in outdoor unobstructed environments and can not accurately track pedestrians' indoor movement. Traditional indoor positioning technologies such as Wi-Fi[2], Bluetooth[3], infrared[4] and other positioning techniques need to advance distribution, and the huge amount of work. Therefore, there is no need to rely on any outside the basic set of inertial positioning technology gradually by the community's attention. With the rapid development of MEMS technology, small size, high-precision inertial sensing devices have been able to integrate into all kinds of intelligent terminals, through the collection of personnel in different directions of acceleration and angular velocity information, combined with the track algorithm to get accurate location information.

In the study of how to improve pedestrian navigation accuracy, most of them focus on the optimization of inertial device calibration and navigation algorithms. Nilsson studied the inertial positioning system bound to the foot, using two inertial measurement units, reducing the complexity of the algorithm implementation, but in the hardware configuration has produced a lot of overhead[5]. Fan Li uses the particle filter algorithm to advance the prediction of the step size and course in the course of the track calculation, but the algorithm needs to map the walking trajectory of the pedestrian[6]. Zhou Liang and so on to build a ZigBee-based wireless sensor network platform, combined with the inertial positioning, design and implementation of the multi-information integration of the indoor positioning system, but need to lay a large number of ZigBee information points in advance, the larger amount of engineering[7].

Based on the analysis of pedestrian route estimation algorithm, pedestrian gait detection based on time difference is adopted, and the dynamic model is used to estimate the dynamic step. The cosine roll angle, pitch angle and pitch angle are realized by cosine matrix. The real - time updating of the heading angle is combined with the pedestrian route estimation algorithm to calculate the pedestrian position coordinates. The experimental results show that the proposed method can effectively eliminate the cumulative error in the inertial positioning process, and the positioning accuracy is 1.5%, which has a wide application prospect in the field of intelligent positioning terminal.

2. algorithm flow

The system uses independent intelligent positioning system as a pedestrian self-navigation hardware test platform, the device integrates a number of sensors, such as 3-axis acceleration sensor, 3-axis magnetometer, 3-axis gyroscope, pressure sensors. The system architecture of the autonomous navigation and positioning algorithm is shown in Fig1.

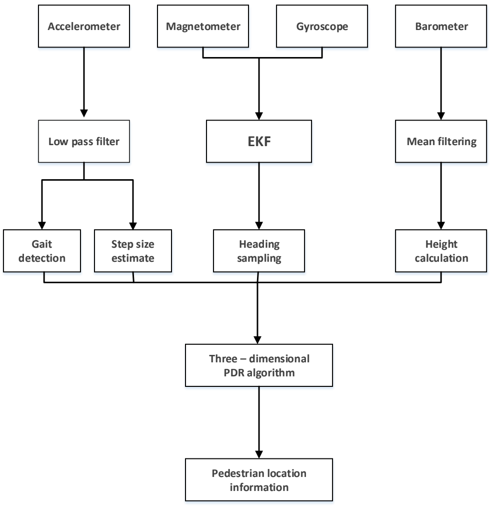

Fig. 1 Algorithm flowchart

Firstly, the data of the three-axis accelerometer, the three-axis magnetometer, the three-axis gyroscope and the pressure sensor are pretreated. Then, the real-time navigation angle information of the pedestrian is obtained by the data fusion algorithm, and the pedestrian's gait Detection and step size estimation, through the pressure sensor after filtering the data settlement of real-time height information, the results into the path calculation algorithm formula, the final output pedestrian position coordinates.

3. PDR algorithm

3.1 Gait detection

In the process of calculating the pedestrian track, the first step is needed to detect the gait characteristics of pedestrian walking. It is usually used to detect the data output by the 3-axis accelerometer. The peak detection method is used to detect the gait, and the 3-axis accelerometer Modulus value to extract the data characteristics, the formula is as follows:

$$A_m = \sqrt{a_x(t)^2 + a_y(t)^2 + +a_z(t)^2} - g \quad (1)$$

Where g represents the acceleration of gravity, and Am represents the difference between the acceleration mode and the acceleration of the acceleration of all three axes of the accelerometer.

The original data of the accelerometer contains a lot of noise will cause a great error, therefore, the need for acceleration signal processing, remove random noise interference[8]. For the de-noising of the original data, it is also necessary to retain as many as possible the various characteristics of the pedestrian movement. Through the filtering process can make the acceleration curve more smooth, more suitable for feature extraction and classification. This algorithm uses a low-pass filter with a window size of 5. The low-pass filtered data is similar to the regularity of the sinusoidal waveform. Each step corresponds to a peak, a zero point and a valley, and the pedestrian real-time gait feature can be obtained by the corresponding detection algorithm. We use the time difference based on the zero crossing method for gait detection, if the two consecutive time difference between zero over 0.5 seconds to determine the invalid step, the detection effect shown in Fig 2. The use of zero cross method can effectively exclude in situ shaking and other small non-displacement step.

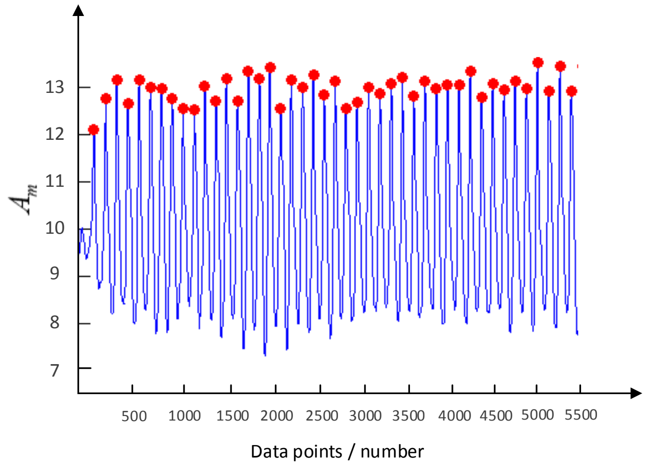

Fig 2. Gait detection

3.2 Step size estimate

The accurate estimation of the pedestrian step is an important factor affecting the positioning accuracy, so the step size estimation has also become the focus of the study of the track calculation algorithm. Step size estimation algorithm has linear model, empirical model, neural network model and so on. In this paper, we establish a linear model for pedestrian height and step frequency to estimate the step size. The formula is:

$$s = h \cdot (a \cdot f_{step} + b) + c \qquad (2)$$

In the formula, h is the pedestrian height, fstep is the pedestrian walking frequency, a, b, c is the linear model calibration coefficient, through a lot of training data can get calibration coefficient a, b, c value.

3.3 Heading angle prediction

In the process of pedestrian heading angle measurement, the azimuth measurement is completed by integrating the angular velocity of the 3-axis gyroscope:

$$\omega_b(t) = (\omega_x(t), \omega_y(t), \omega_z(t)) \qquad (3)$$

Where ωx, ωy and ωz are the angular velocities of the three axes of x, y, and z, respectively, of the gyroscope output. Realize the real-time update of the angle using the cosine matrix (DCM). DCM is a 3 × 3 rotation matrix:

$$C = \begin{bmatrix} \cos\theta\cos\psi & \cos\theta\sin\psi & -\sin\theta \\ \sin\varphi\sin\theta\cos\psi - \cos\varphi\sin\psi & \sin\varphi\sin\theta\sin\psi + \cos\varphi\cos\psi & \sin\varphi\cos\theta \\ \cos\varphi\sin\theta\cos\psi + \sin\varphi\sin\psi & \cos\varphi\sin\theta\sin\psi - \sin\varphi\sin\psi & \cos\varphi\cos\theta \end{bmatrix} \qquad (4)$$

Where the symbols φ, θ, ψ represent the roll angle, pitch angle and heading angle of the IMU output. The rotation matrix must always be updated to track the IMU direction. The matrix C (t + Δt) can be updated as follows:

$$C(t+\Delta t) = C(t)\left(I + \frac{\sin\sigma}{\sigma}B + \frac{1-\cos\sigma}{\sigma^2}B^2\right) \qquad (5)$$

Where Δt is the sampling interval.

$$B = \begin{bmatrix} 0 & -\omega_z \Delta t & \omega_y \Delta t \\ \omega_z \Delta t & 0 & -\omega_x \Delta t \\ -\omega_y \Delta t & \omega_x \Delta t & 0 \end{bmatrix} \tag{6}$$

$$\sigma = |\Delta t \omega_b| \tag{7}$$

I is a 3 ×3 identity matrix. After that, we can calculate the heading angle, from the updated rotation of the heading angle, the Ψ matrix:

$$\psi = \arctan_2(C_{2,1}, C_{1,1}) \tag{8}$$

After completing the pedestrian gait detection and heading process, the pedestrian three-dimensional coordinates can be calculated as:

$$\begin{cases} X(k) = X(k-1) + L_k \sin\theta_k \\ Y(k) = Y(k-1) + L_k \cos\theta_k \\ H(k) = H(k-1) + \Delta \mathrm{h_k} \end{cases} \tag{9}$$

Where X (k), Y (k), H (k) are the current position coordinates of the pedestrian, X (k-1), Y (k-1), H (k-1) Coordinate, LK is the step size of each step, θ_k is current time of the heading angle, for the former time and the $\Delta \mathrm{h_k}$ is current moment of the air pressure difference calculated from the real-time height difference.

4. Experimental verification

The experimental verification system adopts the independent research and development of the intelligent positioning terminal, the terminal integrated 3-axis accelerometer, 3-axis magnetometer, 3-axis gyroscope and barometer , as shown in Figure 4,. Experimental in a university's first teaching building, the experimenter from the first floor of the building building, along the stairs up, layer by layer to the 4th floor, and then down from the fourth floor Back to the first floor of the initial location, the total distance of 600m. The test results are shown in Figure 5:

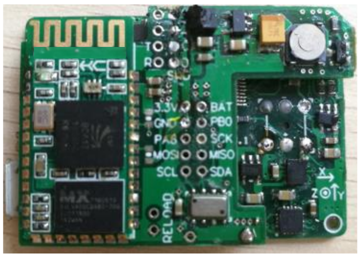

Fig 4 Equipment schematic

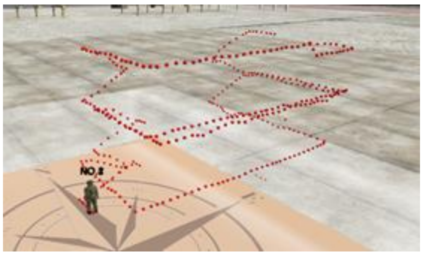

Fig 5 Test results

The difference between the coordinates of the coordinates and the coordinates of the starting point can be used to determine the three-dimensional positioning accuracy. Experiment with 8 individuals (6 boys and 2 girls) as the sample, set the same walking route, record the walking trajectory, calculate the final coordinate accuracy. The final results are shown in Table 1:

Table 1. Test Results

Number	Distance/m	X error /m	Y error /m	Height error /m	Accuracy
1	600	3.8	4.6	0.6	1.5%
2	600	3.0	2.9	1.3	1.2%
3	600	3.5	3.8	1.1	1.4%
4	600	4.1	2.6	0.5	1.2%
5	600	2.8	3.6	1.4	1.3%
6	600	4.5	3.9	0.6	1.5%
7	600	3.3	2.7	1.2	1.2%
8	600	2.5	3.3	0.8	1.1%

5. Conclusion

In order to achieve the accurate indoor positioning of the personnel, this paper has carried on the analysis and the important flow to the important route in the route estimation algorithm, carries on the pedestrian gait detection by the zero time crossing method, uses the linear model to carry on the dynamic step length estimation, Matrix to achieve real-time pedestrian orientation updates, pedestrian location coordinates. The experimental results show that the proposed method can effectively eliminate the cumulative error in the inertial positioning process and the positioning accuracy is less than 1.5%. It has a wide application prospect in the field of intelligent positioning terminal.

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