ISSN: 2414-1895 DOI: 10.6919/ICJE.202005_6(5).0008

Research on an Inertial Navigation-Vision Fusion Positioning Algorithm

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Abstract

For the problem of cumulative errors in long-term operation of inertial devices , a KF-based vision-assisted inertial navigation positioning algorithm is proposed. This algorithm uses the complementarity of visual positioning and inertial navigation positioning to combine visual data and inertial navigation. The derivative data is fused in a Kalman filter, which effectively reduces the cumulative error of the inertial navigation. It is verified by experiments that the algorithm can effectively suppress the cumulative error of the inertial navigation system, which provides a guarantee for the inertial navigation system to perform accurate positioning during long-term work.

Keywords

Inertial navigation; Vision; Kalman filtering.

1. Introduction

Low-cost, lightweight optical cameras are one of the ideal auxiliary sources of INS, and many different visually-assisted INS (VINS) state estimation algorithms have been developed. Among them, Yaojun Li[1] proposed a method based on the INS /SMNS tightly coupled navigation mode, which corrected the coarse positioning of the moving carrier and the visual image by the position and attitude of the inertial navigation output, respectively, and solved the problem of INS drift error accumulation . Kun Liu [2] proposed a method for correcting SINS errors based on three-dimensional visual information. By comparing the estimated value of the image with the measured value of the actual image, the error amount was obtained to modify the SINS parameters, thereby improving the accuracy of its navigation. Long Wang[3] Studied the application of a tightly coupled INS / visual relative pose measurement method in autonomous aerial refueling of UAVs, and compared the measurement accuracy in the tightly coupled mode. Although scholars have carried out a lot of research in this area, there are still problems such as a large amount of algorithm calculation and complicated fusion methods.

Based on the above shortcomings, this paper proposes a KF-based vision-assisted inertial navigation positioning algorithm. This algorithm fuses visual data and inertial navigation data in a Kalman filter in a loosely coupled manner to correct the inertial navigation error and reduce A lot of calculations make it easier to implement.

2. System Design

Compared with the tightly coupled combination, the loosely coupled combination has a simple design and a small amount of calculation. Vision and inertial navigation are combined in a loosely coupled manner. The principle is to put the pose, position, and attitude information of the inertial navigation and vision separately into a Kalman filter (with measurement error as the state) for optimization and give the optimal result. , And feedback to the inertial guide for correction.

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The system designed in this paper can be divided into three modules: vision (camera), inertial navigation (IMU), and Kalman filter fusion modules: first the difference between the output of the inertial guide and the visual output is used as the measurement value of the observation equation, and then Through the Kalman filter fusion module, the error of the inertial navigation is estimated, and the inertial navigation is corrected according to the estimated error, so as to obtain the correct inertial navigation motion parameters.

3. Kalman filter algorithm

According to the basic principle of Kalman filter, the Kalman filter designed by this algorithm takes the error equation of inertial navigation as the state equation of the Kalman filter. The state equation is a matrix containing 15-dimensional states: attitude angle error, gyroscope noise error, speed error, accelerometer noise error, and position error. The system's state equation is:

$$\tilde{X} = \begin{bmatrix} {}^{i}\delta\theta_G^T & \tilde{b}_g^T & {}^{G}\tilde{v}_i^T & \tilde{b}_a^T & {}^{G}\tilde{p}_i^T \end{bmatrix} \tag{1}$$

The continuous-time IMU error state equation becomes:

$$\dot{\tilde{X}}(t) = F(t)\tilde{X}(t) + G(t)n(t) \tag{2}$$

Where F is the error state transition matrix and G is the input noise matrix.

When the camera observes a feature, a series of calculations such as matching of feature points can provide the camera with a more accurate visual measurement value, so our measurement model can be defined as the difference between the visual measurement and the IMU measurement.

$$Z = \begin{bmatrix} Z_\varphi \\ Z_P \end{bmatrix} = \begin{bmatrix} \varphi_{\mathrm{i}} - \varphi_C \\ P_i - P_C \end{bmatrix} \tag{3}$$

The measurement equation of the system is:

$$\tilde{Z} = HX + v \tag{4}$$

Where H is the measurement matrix of the system, and v is the observation noise vector, which satisfies the Gaussian white noise model.

Update according to Kalman update formula:

$$P_{k+1|k+1} = (I - K_{k+1}H_{k+1})P_{k+1|k} \tag{5}$$

Each time the measured value is updated, the optimal value of the current error estimate can be obtained, and this value is used to correct the current pose information of the inertial navigation system.

4. Experimental verification

In order to verify the effectiveness of the algorithm, KITTI data is used for simulation analysis to observe the trajectory of the positioning system.

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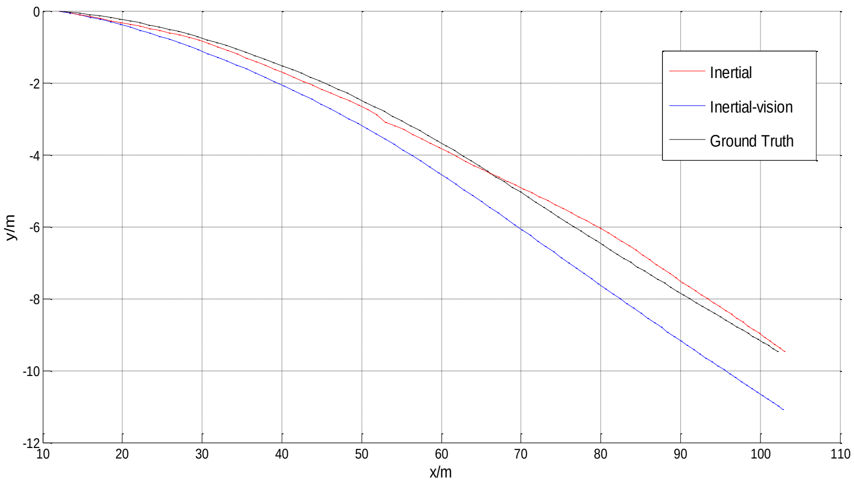

Fig. 1 Trajectory comparison chart

It can be seen from Figure1 that the inertial positioning data increases with time due to the cumulative error of the inertial device, the positioning accuracy is getting worse and worse, the deviation from the actual value is getting farther and farther, and the final positioning error can reach 10 meters. Assisted inertial positioning, due to the correction of visual data, the positioning accuracy approaches the true value, and the final positioning error is less than 1 meter. It is proved that the algorithm can effectively correct the cumulative error of inertial positioning. The fusion of vision and inertial positioning can achieve higher positioning accuracy than a single inertial positioning.

5. Summary

Aiming at the problem that the single inertial positioning error accumulates over time and causes low positioning accuracy, this paper uses a KF-based vision-assisted inertial positioning algorithm. After experimental simulation, it is verified that the algorithm can effectively correct the inertial accumulation error and achieve high-precision positioning.

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