Study of a Multi-Fusion Positioning System Based on Beidou Indoor Inertial Navigation

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Abstract. This article proposes an indoor combined positioning terminal based on Beidou pseudofiles and micro-inertial navigation sensors. Through the built-in Beidou pseudo lite positioning IP soft core, it can receive and analyse Beidou satellite signals. The article creates BDS ground inertial positioning data receiving hardware; performs inertial positioning data primary information identification authentication on the inertial data received by the hardware; performs multi-inertial data fusion estimation calculation on inertial positioning data after authentication, reduces the dimensional error value, and completes the proposed system Design. The program makes full use of the data resources of the existing airborne equipment, does not need to transmit radio signals, and the user capacity is not limited, which is suitable for highly dynamic users. Through simulation and sports car test, it is proved that the scheme is feasible.

Key words: Beidou, inertial navigation, integrated navigation, kalman filter.

1. Introduction
The space part of China's Beidou satellite positioning and communication system is composed of two geosynchronous orbiting satellites (including a backup satellite), which has the functions of active positioning, digital communication and precise timing. In order to make full use of China's satellite positioning and navigation resources to solve the problem of dynamic positioning and long-range navigation of domestic mobile carriers, the passive Beidou dual-star integrated navigation system has been studied in China. The inertial navigation system (INS) uses inertial elements such as gyroscopes and accelerometers to sense the acceleration and Angular velocity, after integration, the displacement of the carrier can be obtained, so as to determine the position of the carrier [1]. The inertial navigation system is a self-contained navigation system, which has the characteristics of not relying on any external navigation equipment to work, so it has good concealment, and at the same time has a high data update rate. It can complete the navigation of high manoeuvrable carriers in real time, and the navigation accuracy is obvious in a short time. Advantages, but as the flight time increases, inertial navigation system errors gradually accumulate. Considering that the Beidou pseudo lite has the same shortcoming as the space navigation signal, that is, it cannot achieve normal positioning in the blocked area. Therefore, in indoor corridors, corners and other areas, the Beidou satellite alone cannot meet the continuous positioning. In this paper, the pseudo lite positioning and micro-inertial navigation positioning are
seamlessly integrated, and the micro-inertial navigation is used for continuous positioning in the obscured area, which solves the problem of discontinuous space navigation signals.

2. **UAV positioning hardware design based on Beidou satellite**

2.1. **Create BDS ground inertial positioning data receiving hardware**

In view of the characteristics that the existing shipborne UAV positioning signals mostly use the signals of the Beidou satellite positioning system independently developed by China, in the proposed system, the independent signal receiving platform based on the Beidou satellite signals is first created-BDS ground inertial positioning data reception Hardware [2]. The hardware is mainly composed of Beidou satellite signal receiving module and Beidou satellite signal inertial data processing unit 2 parts. The Beidou satellite signal receiving module mainly includes: Beidou satellite signal receiving antenna, signal gain receiver, signal register, UM220-IIL Beidou signal timing module. Among them, the support parameters of the UM220-IIL Beidou signal timing module are shown in Table 1.

| Channel       | Based on 64-channel Humbird chip | Positioning accuracy | 2.5mCEP dual system level |
|---------------|----------------------------------|----------------------|---------------------------|
| Frequency     | BDSB12.0m                         | IPPS                 | Better than 20ns          |
| Positioning mode | Multi-system joint positioning   | First fix time       | 30s                       |
|               | Single system line inspection     | Sensitivity          | –160—145dBm              |

The inertial data processing unit of the Beidou satellite signal uses an integrated development board as the integrated carrier of the unit. It is equipped with a Beidou signal micro-processor, multiple signal sensors and RAM memory, as well as a 64-bit signal transceiver and USB3.0 data interface. The development module diagram of the inertial data processing unit of the Beidou satellite signal is shown in Figure 1. By docking the receiving and receiving array in Figure 1 with the Beidou satellite signal receiving antenna and the signal gain receiver in the Beidou satellite signal receiving module, and at the same time, the Beidou signal can be timed by the UM220-IIL Beidou signal timing module. The USB data interface imports the received UAV return positioning inertial data into the processor for inertial data analysis and calculation. So far, the BDS ground inertial positioning data receiving hardware in the proposed system has been created.

![Figure 1. Inertial data processing unit development module for Beidou satellite signals](image-url)
2.2. Realization of primary information identification and authentication of inertial positioning information

After the BDS ground inertial positioning data receiving hardware is created, the positioning data returned by the drone can be forwarded to the creation platform hardware through the Beidou satellite. Through the timing calculation and processing of Beidou inertial data, the internal information of the data can be sorted item by item according to the time logic. The sorted data is transmitted back one by one in the order of the UAV position coordinate data, UAV flight status data, and UAV trajectory data. In order to ensure the security and stability of the data, before analysing the returned inertial data, the design system sets up an information authentication mechanism in the strategy [3]. Binding authentication is carried out through the hardware timing code of the receiving end and the hardware code of the remote drone's return signal, and at the same time, dynamic binary calculation is performed with the timing of the return time point to realize the dynamic update of authentication information and improve the security of inertial data analysis.

3. Sequential filtering fusion algorithm for ship integrated navigation system

3.1. Centralized fusion algorithm of integrated navigation system

Generally, the centralized fusion algorithm transmits all the collected measurement values to the central processor, and then processes them. The multiple measurement equations we give are expanded into the following overall measurement equations:

$$Z(k) = H(k)x^*(k) + V(k)$$

Where

$$Z(k) = \begin{bmatrix} (z'_1(k))^T \\ (z'_2(k))^T \\ \vdots \\ (z'_n(k))^T \end{bmatrix}$$

$$H(k) = \begin{bmatrix} (H'_1(k))^T \\ (H'_2(k))^T \\ \vdots \\ (H'_n(k))^T \end{bmatrix}$$

$$V(k) = \begin{bmatrix} (v_1(k))^T \\ (v_2(k))^T \\ \vdots \\ (v_n(k))^T \end{bmatrix}$$

$$R(k) = \text{diag}[R_1(k), R_2(k), \ldots, R_n(k)]$$

Then the centralized fusion Kalman filter of the ship's integrated navigation system can be given by the following lemma. For the sake of simplicity, we will use $x(k)$ instead of $x^*(k)$ in the following descriptions.

Centralized fusion uses one filter to centrally process all subsystem information. Although theoretically the optimal estimation of the state error can be given, it has the following shortcomings: the state dimension of centralized fusion is high, and the amount of calculation is based on the filter dimension [4]. The third power of is increasing, and the real-time performance of the filter cannot be guaranteed. In addition, we have adopted the self-dimension expansion method to standardize the system model, and the computational burden will be even greater.

3.2. Sequential filtering fusion algorithm of integrated navigation system

The basic idea of sequential filtering fusion is: if the state $x(k-1)$ at time $k-1$ has been obtained based on the global estimated value $\hat{x}(k-1|k-1)$ and the corresponding estimated error covariance $P_{II}(k-1|k-1)$, when $k$ the time comes, use the Kalman filter and the measured values of the effective subsystems at time $k-1$ in turn. The state $x(k)$ is estimated, and finally the estimated value $\hat{x}(k|k)$ based on the global information and the corresponding error covariance $P_{II}(k|k)$ are obtained. Here, at each moment, when the measured value of the navigation subsystem arrives, it is first checked whether the measured value of the navigation subsystem is valid or not in the order of arrival.
If it is invalid, isolate the sub-system; if it is valid, filter [5]. The sequential filtering fusion algorithm of the ship's integrated navigation system is given by the following theorem. The sequential filter of the coloured process noise system is:

\[
\begin{align*}
\hat{x}^i(k | k) &= \hat{x}^i_{c-1}(k | k) + K^i_{c-1}(k)
\left[z^i(k) - H^i_{c-1}(k)\hat{x}^i_{c-1}(k | k-1)\right] \\
\left(P^i(k | k)\right)^{-1} &= \left(P^i_{c-1}(k | k-1)\right)^{-1} \\
&\quad + \left(H^i_{c-1}(k)\right)^T \left(R_i(k)\right)^{-1} H^i_{c-1}(k) \\
K^i_{c-1}(k) &= P^i_{c-1}(k | k) \left(H^i_{c-1}(k)\right)^T \times \left[H^i_{c-1}(k)\left(H^i_{c-1}(k)\right)^T + R_i(k)\right]^{-1}
\end{align*}
\]

The sequential filtering fusion algorithm flow of the coloured process noise system is shown in Figure 2.

4. System Inspection

In order to verify the positioning performance of the fusion positioning method, the performance simulation comparisons of BD single positioning, WIFI single positioning and BD-WIFI fusion positioning were carried out respectively [6]. In an indoor environment of 20m×15m×3m, 6 WIFI beacons are uniformly deployed, with a transmission power of 20dBm, and the signal can cover the positioning area; outdoor 3 BeiDou satellites are used as an outdoor BD positioning simulation environment. In order to verify the correctness of the WIFI ranging positioning model in the actual environment, the model was compared with the measured data. In the actual measurement environment, the height of the beacon node is 1.7m, the transmission power is 20dBm, and the signal strength of the AP node is measured and collected by the XCOMV2.0 acquisition software. The comparison of RSSI curves between different models and measured data is shown in Figure 3. It can be seen that the signal strength of the Huawei model after the correction has the best fit with the measured data. Therefore, the WIFI ranging equation based on this model can truly represent the relationship between the actual signal fading and the distance.
Figure 3. Fitting curve between WIFI ranging model and measured data

Figure 4 shows the trajectory and position error curve of carrier phase time difference/SINS integrated navigation. The solid line is the trajectory of the integrated navigation, and the dot is the trajectory of the GPS. The two are in good agreement [7]. The accumulation of the position error of the horizontal position error curve is obviously suppressed, but overall, it still shows a slow growth trend. The maximum position error at 2300s is less than 15m, which is better than 0.2% (16m) of the voyage.

Figure 4. Pseudo range/carrier phase time difference/lateral sky speed constraint/SINS integrated navigation experimental results

From the position error curve, it can be seen that the position error has no obvious trend of increasing with time, but the jump is large. The mean position error is 4.6m, and the standard deviation is 3m. This shows that due to the addition of pseudo-range observations, the constraints on the position are formed, and the accumulation of position errors is eliminated. However, due to the relatively large observation noise of the pseudo-range, the position error has a larger jump.
5. Conclusion
Aiming at the Beidou-1 dual-satellite/inertial navigation integrated navigation system, this paper analyses the controllability of the various state variables of the integrated system filter under various conditions and which factors are related to it, and the following research conclusions can be obtained: reduce the inertial navigation system accelerometer measurement error (corresponding to the driving external force error) can improve the positioning and speed measurement accuracy of the inertial navigation system, but it cannot significantly improve the attitude accuracy. Reducing the drift of the inertial navigation gyro (corresponding to the driving torque error) can improve the plane positioning accuracy of the inertial navigation system, but it cannot improve its vertical positioning accuracy.

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