Fully Integrated Navigation based on INSGPS Magnetometer

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Abstract: Inertial Navigation System (INS) and Global Positioning System (GPS) composite guidance technology are the most advanced all-weather, autonomous guidance technology. The principle is to use an Almanac filter to combine the two and after filtering, give an optimal estimate of a set of state variables (such as position, velocity, attitude angle, gyro drift, accelerometer bias, clock difference, etc.). And periodically feedback back to INS to correct it. The combined system can output all navigation information at a higher rate, superior short-term and long-term accuracy, greatly improve system availability and smoother positioning and output trajectory. The inertial navigation system (Inertial Navigation Oyster, INS) and the satellite-based positioning system represented by GPS have strong complementary advantages. GPS provides high accuracy and stability and continuously monitors the inertia sensor’s error (gyro drift).

1. INTRODUCTION
In view of the problem that inertial navigation is independent of positioning and positioning, you have proposed a combined navigation system of magnetometer and BPS-assisted inertial navigation. The magnetometer and gyroscope data are preprocessed; the attitude system equations and measurement equations based on the error Quaternary are derived and the gyro and magnetometer data are combined using the Almanac filter. Establish positioning system equations and measurement equations, use GPS measurements to assist the inertial navigation, correct position and velocity information. The experimental verification results show that the integrated navigation system effectively improves the inertial navigation drift problem and can still work normally under GPS failure conditions. The method comprises the following steps: Step 1: analyzing the relationship between the magnetic field component and the position and establishing a geomagnetic field model and a magnetometer output model; Step 2: using a neural network INS and magnetometer combination and an adaptive extended Almanac filter AEKF obtains a relatively stable magnetic field component; Step 3: Trains with radial basis neural network RBFNN when GPS is active and uses the magnetic field component of INS and magnetometer combination output and the trained RBFNN for position prediction when GPS fails; 4: Since the predicted position is discrete and has a large noise, the INS is combined with the predicted position and the AEKF is used to increase the adaptability, thereby obtaining a more accurate and continuous position during the GPS failure[1].

2. ANALYSIS OF INERTIAL COMBINED NAVIGATION PRINCIPLE
After the optimal filter obtains the estimated value of the system error, there are two mainstream methods for correcting the navigation parameters in the project: First, the position and speed of the final output of the integrated navigation system are directly corrected by using the estimated value, hereinafter referred to as the output correction method. This method is simple to implement in engineering, but it cannot correct the state error inside the system. After the navigation time is long enough, the system error will still rise uncontrollably. The second is to use the estimated value to
correct the solution process of each subsystem of the integrated navigation system, hereinafter referred to as the feedback correction method. Although this method is difficult to implement in engineering, it can correct the system error at any time, so it can ensure high precision in long-time navigation. The error of satellite navigation in the same weather conditions depends only on the navigation system error and does not change with time [2]. The output correction method is corrected by the direct output result and more and more will be affected by the inertial navigation error later. The feedback correction method continually corrects the internal error of the system and converges on the error divergence trend than the output correction method.

3. INS/GPS INTEGRATED NAVIGATION SYSTEM DATA SYNCHRONIZATION

When data fusion processing is performed on a system composed of multiple sensors, the data information required to be processed in the fusion center must be at the same time, so that the correct state of the target can be calculated.

For the two subsystems of the GPS/INS integrated navigation system, each using different clock frequency standards, in order to register their data at the same time, they must first be unified into a common time reference system. Since Almanac filtering is generally done by computer, it is possible to use the local time used by the computer as a common time reference system for processing data in two subsystems. Based on this idea, the solution to the data synchronization problem of INS/GPS integrated navigation system can be divided into three methods: software implementation, hardware implementation and soft and hard combination. The software implementation method has the advantage that no special hardware is needed and cost is saved. On the one hand, the data output rate of the inertial navigation is many times higher than the data output rate of the GPS and there is enough data for the high-order holder to achieve the need for precise synchronization of the extrapolation; on the other hand, the order of the keeper used The higher the required extrapolation time, the more real-time the signal will be. Finding a mathematical synchronization method with both efficiency and precision is a research hot spot of INS/GPS integrated navigation system data processing methods [3]. Its update calculation formula is as shown in Equations 1, 2 and 3.

\[
\frac{dx^{(i)}}{dt} = \lim_{\Delta t \to 0} \frac{x^{(i)}(t + \Delta t) - x^{(i)}(t)}{\Delta t} \quad (1)
\]

\[
x^{(0)}(k) = -aZ^{(1)}(k) + b \quad (2)
\]

\[
Z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k - 1) \quad (3)
\]

The hardware implementation method takes the DSP as the core component and connects the IPPS pulse of the GPS output to the CPLD. The internal logic of the hardware realizes that the data of the MIMU and the GPS are synchronized in the whole second. At the same time, the IPPS pulse is also used as the standard synchronization reference of the 1-second timer of the Cpl part and the synchronous sampling pulse output of the corresponding frequency is generated by the hardware logic frequency multiplication to realize the data synchronization between the axes of the inertial navigation system. In the INS/GPS integrated navigation system, the quality of data processing is directly related to the stability and accuracy of the integrated navigation system [4]. After data synchronization of the information collected by multiple sensors, the data is merged. Almanac filtering is mainly used. Incorporating low-level real-time dynamic multi-user redundant data, the recursive characteristics of Almanac filtering make the system processing do not require a large amount of data storage and calculation and it is an effective method for position estimation in information fusion. Its positioning accuracy curve is shown in Figure 1.
For the same integrated navigation system, we can design a variety of filters using Almanac filtering theory. The above-mentioned centralized Almanac filter is used to achieve the combination. It has two fatal problems: First, the amount of filter calculation is in state dimension. The increase in the number of cubic cannot meet the real-time requirements of navigation. Second, the increase of the navigation subsystem will increase the failure rate. As long as one subsystem fails and is detected and isolated in time, the entire navigation system will be Pollution. In order to resolve these contradictions, INS/GPS adaptive Almanac filter, INS/GPS federated filter, INS/GPS decentralized filter and INS/GPS robust filter have appeared. Designed to improve the fault tolerance of integrated navigation systems, the reliability and accuracy of navigation systems.

Since the navigation accuracy of each subsystem participating in the filtering is different, the INS is used as a common reference system and the information is shared by each sub-filter. The output rates of the subsystems participating in the combination vary widely, so there is information in the federated filter. The problem of allocation and information synchronization processing. We can design this way: in the sub-filter, the worse the accuracy of the subsystem, the larger the distribution coefficient of the inertial information should be and the smaller the opposite, but the guarantee, so that the total amount of inertial information is limited \[^5\]. The sub-filter in which the precision subsystem is located can fully play its role; the synchronization of the information is to calculate the synchronous output of each sub-filter at each fusion time point.

5. CONCLUSION
From our research, although the INS/GPS integrated navigation system has great advantages, especially in low dynamic positioning and navigation. At present, the combined system has been successfully applied in remote sensing large-scale mapping, mobile measuring vehicles, missile guidance, etc., but there are still many problems to be solved in many aspects. At present, the loose combination method has basically been engineered and its combined hardware equipment is simple and easy to implement. Now it is mainly to study its data processing; tight coupling, even super-compact coupling is still difficult to implement, they involve the inside of the GPS receiver. The structure is structured, but in terms of navigation capability and reliability, tight coupling has more potential for development. Since the system Almanac filter processes raw measurement data from GPS
and INS, it must determine whether these measurements are degraded due to dynamics or interference. If the measurement is degraded, the filter must have sufficient adaptability to adjust the degree of variation. In the event of a sub-system failure, the filter must be able to switch to a different navigation mode. In-depth study of fault diagnosis techniques to ensure that various states of the system can be tested.

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