Research of Terrain Aided navigation system

Xiaoxu Chen, Chunguang Wang , Xin Wang, Ming Ming, Deming Wang

Aviation University of Air Force,Changchun, 130022,China

Keywords: Terrain Aided Navigation System; Inertial Navigation System ; Navigation accuracy; digital map.

Abstract. Terrain aided navigation system is called the fourth generation of navigation system, this paper analyzes some key technologies of terrain aided navigation system and analyzes the factors that affect the terrain aided navigation system positioning accuracy, proposing solutions to improve the positioning accuracy .

1. Introduction

The so-called terrain aided navigation system(TANS) is the essence of integrated navigation system composed of inertial navigation system(INS) and radio altimeter and digital map[1], the significant feature of the system is to eliminate the accumulated error of INS and modify INS navigation information and improve the navigation accuracy. TANS as a new navigation system attracted widespread attention because it plays a practical good application effect in the Gulf War, Kosovo war, reaching the purpose of precise attack target. But compared with the integrated navigation system usually, TANS only added to the large capacity memory the only hardware and the navigation accuracy can up to an order of magnitude and achieve the positioning accuracy of tens of meters, so is its vitality.

2. Technical analysis of the terrain aided navigation system Brief introduction of terrain aided navigation system

Aircraft in flight, by the terrain feature sensing devices (such as radar altimeter, barometric altimeter and air data computer) measured aircraft below the terrain profile or other features of terrain feature location estimate derived INS, and then to the estimated position based search in the digital map storage device can have the terrain the best fitting of the feature and terrain characteristics measured, the terrain feature position in the digital map, is the precise location of aircraft. Then the accurate position data of INS is modified, so the continuous iteration, can make the precise location of aircraft obtained continuously at any time, so as to measure the exact distance to the target aircraft.

Terrain aided navigation system includes a navigation function required hardware and soft-ware, the basic is composed of a main navigation system (INS), radar altimeter, barometric altimeter, memory(large volume), navigation computer, digital correlator, terrain correlation algorithm and map data scheduling software[2], the navigation principle of as shown in Figure 1.

Terrain aided navigation system except navigation functions, it also has some use of military needs, such as terrain following, terrain avoidance and threat avoidance. In recent years, F-16 and"wind" has been verified successfully on technology, the further modification plans are under consideration, the main form of the future application is combined with inertial system. Terrain aided navigation is a dual-use technology, in which the inertial technology and terrain aided navigation technology and the protection of the relationship more closely.

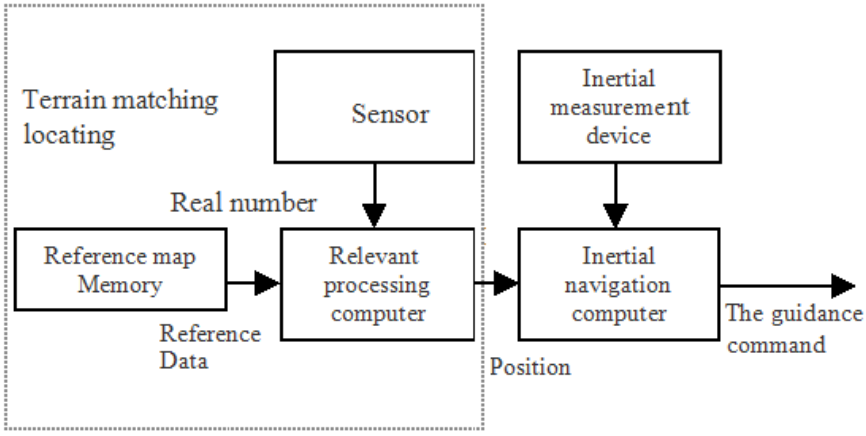

Fig 1 Terrain aided navigation principle

3. Terrain aided navigation system several key links and key technology

One is the position estimation. The position estimation algorithm is combined with the research focus of inertial navigation electronic map of the autonomous navigation system, in order to improve the precision of navigation, navigation system has evolved from single sensor to rely on Development Based on multi-sensor integrated navigation system.Navigation system core - the navigation computer components and the corresponding function is becoming more and more complicated, which not only to realize pure strap down navigation solution, Kalman filtering,magnetic heading auxiliary algorithm relatively time-consuming solution algorithm of multi-sensor data, also need to external with step real-time acquisition. The external sensor output frequency is usually multi-sensor navigation system are not consistent, this requires the navigation computer navigation solution in meet the premise of real-time, realizing the synchronization of multi-sensor data acquisition, related to the acquisition cycle and the navigation solution sequence control cycle has become the key of system design and navigation. Usually in the signal parallel processing of multi-channel sensor, using method of the traditional Kalman filter, adaptive filter [3]. Kalman filtering is an effective method to deal with dynamic positioning data, make full use of previous observation data, according to the linear minimum variance principle, can achieve the optimal estimate.

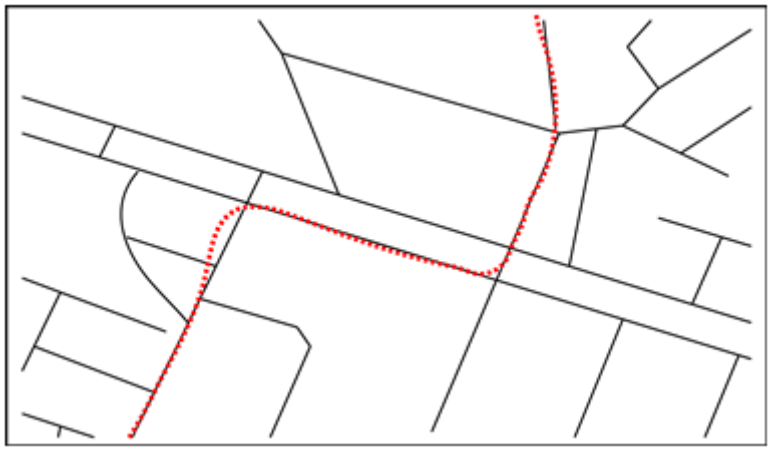

Fig 2 Before matching vehicle trajectory

Two is the map matching. Map matching is a method of positioning error correction based on software technology, the basic idea is to target location information and the digital map of the information, and then determine the target in the location in the map. Therefore, the effect of algorithm is directly related to the target accuracy of navigation map matching, map matching technology is the key technology of the success or failure of the navigation system based

on electronic map. Height of classical terrain matching algorithm mainly has two kinds: one kind is the terrain contour matching (TERCOM) algorithm, another is using extended Kalman filter technology of SITAN algorithm. SITAN is a recursive form matching algorithm developed by Sandia laboratory, it is different from the terrain contour matching algorithm, using a recursive Kalman filter algorithm is extended and has good real-time performance, allowing the mobility of larger, more suitable for high mobility tactical target use. However, due to the nonlinear characteristics of terrain data with higher, SITAN algorithm requires a linear function of the terrain, easy to cause the filter divergence in regional topographic gradient of the dramatic change in. Figure 2 is the flight path before matching vehicle, figure 3 is the flight trajectories for aircraft after matching. As can be seen from the graph,after matching, system navigation accuracy has been greatly improved[4]. From here we can see the importance of map matching in terrain aided navigation.

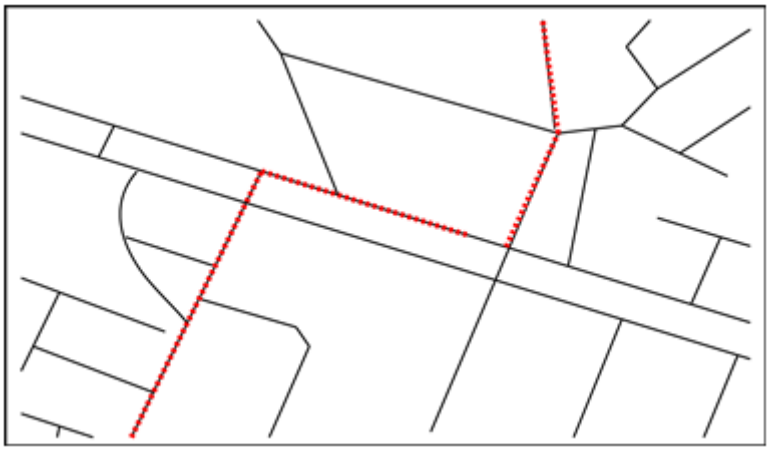

Fig3 After the matching trajectory of aircraft movement

Three is the map building. In the autonomous navigation system, digital terrain height map is a key factor. Can be increased by adding more data of high quality digital terrain height map to increase the information, the purpose is to use this information to reduce the uncertainty in the navigation. Therefore, in order to increase the performance of terrain aided navigation, navigation system requirements with automatic adding the ability to map data, using the latest generation of the map to suppress the inertial drift, namely real-time map building and localization in the map the location of the object.

Four is the storage technology. The autonomous navigation system needs to establish a database and storage of digital map, high quality can imagine, storage mobile target by digital map data region, need large capacity memory. The development of modern large capacity storage technology, to achieve this goal is possible. The memory may have the option of magnetic bubble memory, flash memory, CD etc..

Five is a digital correlator. Digital correlator is one of the key equipment of the autonomous navigation system, mainly used for terrain contour matching and scene matching. Because of the terrain contour matching needs related to processing large amount of data, usually with a single digital correlator or digital correlator array configuration of real time processing system. In order to achieve high speed and parallel processing requirements, the processing systems generally use DSP and FPGA to realize the hardware.

Six is the terrain matching area selection. In the autonomous navigation, the characteristic parameters of terrain is an important factor that affects the positioning accuracy and the matching probability, it mainly includes the terrain elevation data, the standard deviation of the roughness and the correlation length, respectively, reflects the overall fluctuation, the average smoothness and speed of terrain topography changes. Because of the feature parameters of hilly terrain is quite obvious, is often the system is chosen as the matching area.

The seven is data fusion. In the autonomous navigation system, data fusion algorithm of filter output position estimate and system output by the ins position value was used for data fusion of certain data, through the final location data fusion was obtained after estimation of target value, so as to realize the autonomous navigation of mobile target. In the process of moving target motion vector model, INS position error model, autonomous navigation system with adaptive joint particle filter mathematical model.

4. Research of terrain aided navigation accuracy

One is the precision of height measurement of aircraft. In the geographical coordinates of the earth's land surface on any place, can according to the region around the contour map or landscapes to single value determination. When the aircraft crosses a block have been digitized terrain, airborne radar altimeter measured relative to the height of the vehicle from the ground (hr), at the same time the pressure altimeter absolute height and phase INS synthesis measured vehicle (h),h and HR can be obtained by subtracting the terrain height (ht), as shown in figure 4. The height of the terrain ht and digital map correlation analysis, so as to obtain the estimation of the position of an aircraft. During the pressure measuring precision altimeter and radar altimeter is directly related to the size of the terrain height error, thus affecting the accuracy of matching terrain aided navigation[5].

Two is the error of inertial navigation system. INS is a kind of autonomous navigation system, it depends entirely on the airborne equipment in dependently complete navigation tasks, and the outside Ren Heguang, electric contact, therefore, good concealment, work is not affected by meteorological conditions limit. Therefore in the terrain aided navigation system, inertial navigation system as the main navigation system, the characteristics of the positioning error of INS determines the characteristics of the system state equation. Equation of state properties affect the system observ ability, influences the result of state estimation.

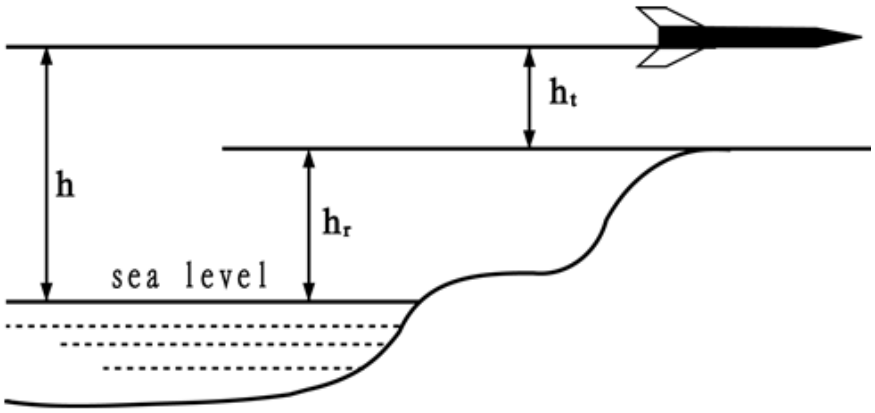

Fig 4 Height measurement

Three is a digital map accuracy. The prerequisite for the realization of terrain aided navigation is to be required to comply with the quality requirements of the reference database, digital elevation map preparation process is mainly to an equivalent to the ground a certain area of the map is divided into many small square, and then entered in the average height above sea level in the small box on the corresponding, results can be used in digital form said digital array the height above sea level. Figure 5 shows the process of making digital elevation map with contour.

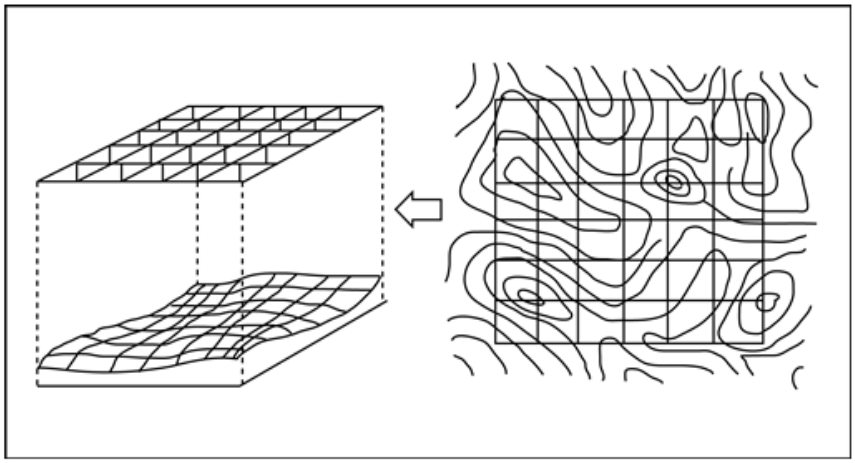

Fig 5 Digital map production

Four is the characteristic of terrain matching area. Characteristic parameters of terrain is an important factor that affects the positioning accuracy and the matching probability, it mainly includes the terrain elevation data, the standard deviation of the roughness and the correlation length, respectively, reflects the overall fluctuation, the average smoothness and speed of terrain topography changes. And these changes affect the height of the terrain matching model observability, thus affecting the height of the terrain matching results.Through the optimization of aircraft flight route, choose suitable terrain area, can improve the matching accuracy of terrain aided navigation.

Five is the matching method of terrain aided navigation. Estimation method essentially matching method of terrain aided navigation is a kind of state, different estimation methods use different estimation criterion, optimal estimation values are not the same. Now in the terrain aided navigation system, is commonly used in TERCOM and SITAN these two kinds of typical algorithm.

5. The ways to improve the accuracy of terrain aided navigation

Hardware to improve aspects, one is the use of high precision inertial device. In the TAN system, an inertial navigation system is the main navigation system, inertial navigation system navigation accuracy directly affects the accuracy of TAN system, and therefore the use of high precision inertial device can improve the navigation precision of inertial navigation system, so as to improve the navigation accuracy of TAN system. Two is the selection of high precision barometric altimeter and radar altimeter. High precision barometric altimeter and radar altimeter system can improve the TAN height precision, which can get closer to the true value of actual terrain height HT, reduce the height of the terrain measurement noise, so as to improve the navigation accuracy. The three is a high precision digital map making. The digital map is the prerequisite for the use of terrain aided navigation system, is the basis of terrain aided navigation system, the. The foundation and now several digital map production are the need of high precision surveying and mapping tool, measured topographic data with high precision, high accuracy in digital map making.

Software to improve aspects, one is to improve the height of the terrain matching method. The height of the terrain matching method refers to the use of real time measurement of terrain estimation method of vector digital map position in the reference coordinates in the sequence data of height value. In the terrain matching each sensor system performance, reference digital map and flight routes have been determined, the height of the terrain matching method determines the performance of the height of the terrain matching system. To improve the performance of the height of the terrain matching method can increase the height of the terrain matching system. Two is to plan flight routes selection of suitable terrain matching area. The parameters of topography obvious terrain usually more suitable for terrain matching area.

6. Conclusions

Auxiliary navigation system has broad prospects in the low altitude aircraft, unmanned aircraft and cruise missiles in the application of high precision. Along with the electronic sea gallery and geographic information system (GIS) improvement, terrain aided navigation is gradually used in submarines, ships and ground vehicles, become a important direction of terrain aided navigation technology research and application. Terrain aided navigation system development quality, are in great demand, improve the precision of the system better development prospect and practical significance.

References

[1] Feng Qing-tang,Shen Lin-oheng,Chang Wen-seng. *Terrain aided navigation using PDAF* [J]. IEEE International Conference on Robotics,intelligent systems and signal processing. 2003, 2(2): 1063-1068.

[2] Kim J, Sukkarieh S. *Autonomous airborne navigation in unknown terrain environments* [J]. IEEE Transactions on Aerospace and Electronic System,2004,40(3):1031-1045.

[3] YANGYuan-xi. *Properties of the Adaptive Filtering for Kinematic Positioning*[J].Acta Geodaetica et Cartographica Sinica,2003,32(3):189-192.

[4] Yu Liu ,*Research of Terrain Aided Navigation Technology* [J].

[5] Dai Guo-feng, *Analysis of terrain aided navigation system precision,Sichuan ordnance Journal.*