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Overview of Application Research on Inertial Navigation Unit

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Abstract

We now widely used in the positioning and navigation system is the global positioning system, but the global positioning system is mainly suitable for outdoor navigation, empty place on the indoor navigation is less satisfactory. Therefore, the main content of this paper is the application of indoor positioning and navigation of inertial measurement unit. Firstly, the basic theory of inertial measurement unit (inertial measurement unit) and its current research status in navigation are reviewed. Then, relevant researches are analyzed and reviewed from the following aspects: its advantages and disadvantages, its combination with other positioning methods, and its application principle. At the same time, it points out the constraints and challenges of inertial measurement unit in navigation application, and puts forward the future prospects.

Keywords

Indoor Navigation; Inertial Measurement Unit; Combined Positioning; Review.

1. Introduction

After entering the 21st century, the development of society has become faster and faster. With the rapid development of Internet of Things technology and mobile phone applications, various industries based on mobile phone applications such as takeaway software, taxi software, and express software have developed rapidly. Life increasingly relies on accurate location positioning. The rise of online payment, express delivery and other industries has brought great convenience to people, and the development of these industries also relies on outdoor positioning and navigation to a large extent. However, with the continuous improvement of people’s living conditions, indoor navigation has become extremely important. For example, indoor navigation can accurately provide location information of victims and firefighters when a fire occurs, and real-time location and status of unattended elderly Update etc. [1] Therefore, the research of indoor navigation provides a great guarantee for people's personal and property safety.

The outdoor navigation systems we use in our lives are basically the Global Positioning System (GPS for short) [2] of the United States, which can help people to complete outdoor positioning and navigation, but it can be used in indoor conditions. Become unsatisfactory. Under indoor conditions, due to the multipath effect, the uncertainty of the indoor environment and the occlusion of the building itself, the propagation of wireless signals indoors becomes weaker and weaker, which greatly weakens the GPS positioning effect , Making the positioning error become particularly large. The development of indoor positioning is still in the early stage of development, many indoor positioning technologies are not mature, and the demand for indoor positioning is very large. Therefore, the research on indoor positioning technology has very important scientific research value and research significance.

The current indoor positioning technology has begun to attract more and more people's attention. As market demand continues to increase, many positioning methods and technologies have also emerged, and they have achieved good development. Such as ultrasonic positioning, ultra-wideband

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positioning, infrared technology, radio frequency identification technology, Bluetooth, Zigbee technology, WIFI technology, Inertial Measurement Unit (IMU)[3], etc., different positioning technologies have their own advantages and disadvantages. Inertial technology has its unique advantages when applied to navigation and guidance, such as autonomy, concealment, anti-interference, global navigation, continuous and complete navigation information. Due to these characteristics, inertial technology has always been valued and developed by various countries, and has been widely used in various fields such as aviation, aerospace and navigation. With the development of microelectronics technology, integrated circuit technology and processing technology, inertial sensors using micro-electromechanical system (mems) technology [4] have excellent advantages such as small size, light weight, low cost, strong impact capability, and high product reliability. The characteristics of it have been widely used in various civil and military fields such as automobiles, electronics, aviation, aerospace, weapon guidance and so on. However, inertial navigation also has shortcomings. Due to the integration of navigation information, the positioning error increases with time, and the long-term accuracy is poor; and it requires a long initial alignment time before each use; at the same time, the current inertial navigation equipment The price is more expensive, and the exact time cannot be given [5].

The purpose of this article is to summarize the application of IMU module in indoor positioning and navigation. Through systematic discussion on the technology and methods involved in related research, readers can understand the application status and existing problems of IMU module in indoor navigation field. The structure of this article is as follows: First, a basic introduction to the inertial measurement module, including the advantages and disadvantages of the module itself, and the necessity of using it in combination with other positioning technologies; then the necessity of IMU research from various aspects of indoor navigation applications; and finally the existing The limitations are summarized and prospects for future development are made.

2. Overview of indoor positioning methods

2.1 Commonly used positioning methods

Indoor positioning refers to a technology that realizes location positioning in an indoor environment. Currently, it mainly uses a set of indoor positioning system formed by base station positioning, wireless communication, inertial navigation positioning and other technologies to realize the indoor environment of people and objects. Under the monitoring. Several positioning technology methods commonly used in the market are WiFi, ZigBee, infrared, Bluetooth, and UWB, but there is no unified standard, and each technology has its own advantages and disadvantages [6]. Figure 1 shows the comparison of the positioning accuracy and scale difficulty of these positioning techniques.

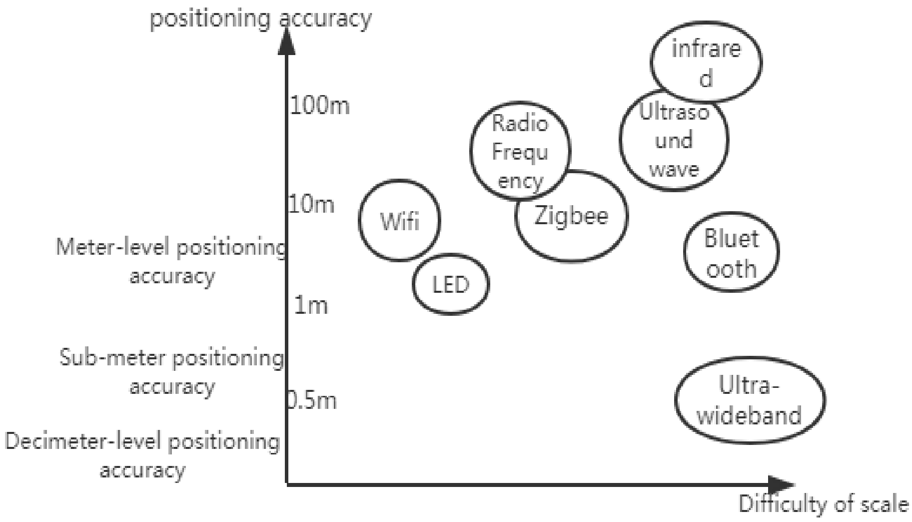

Figure 1. Comparison diagram of indoor positioning technology

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2.2 Commonly used positioning algorithms

At present, the commonly used indoor positioning algorithms are: based on the time difference of arrival (TDOA) positioning algorithm, based on the time of arrival (TOA) positioning algorithm, and based on the radio wave incidence angle (AOA) positioning algorithm Algorithm and positioning algorithm based on signal strength [7]-[9] .

2.2.1 TOA and TDOA positioning algorithms

The TOA positioning algorithm is mainly based on the TOA circle equation, which constructs different positioning equations through the intersection line between the circle and the circle. Assuming that the radio wave is transmitted from the point to be estimated, the propagation speed of the radio wave is c, and the propagation time of the radio wave to the base station is t, then the position of the point to be estimated may be on a circle with the base station position as the center and a radius of c*t. If the wireless signal of the mobile terminal of the point to be estimated can be transmitted to at least three or more base stations at the same time, the position coordinates of the point to be estimated can be determined by three circles with the base station as the center and c*t as the radius.Intersect.Intersect. Figure 2 shows the positioning principle of TOA algorithm.

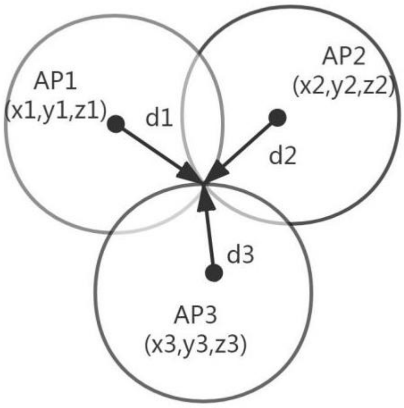

Figure 2. TOA algorithm localization principle

The principle of the TDOA positioning algorithm is mainly to use the time difference for positioning [10]. By measuring the time it takes for the signal to reach the monitoring station, multiply the time by the speed to get the length of the propagation distance. Using the distance from the signal source to each monitoring station, the location of the signal can be calculated through an algorithm. However, in actual situations, absolute time measurement is generally inaccurate and difficult to measure. By comparing and calculating the time difference between the signal reaching each monitoring station, we can make a hyperbola with the monitoring station as the focus and the distance difference as the long axis. The coordinate of the intersection of the hyperbola is the position of the signal. The positioning technology can be applied to various mobile communication systems, so that the system has strong anti-multipath ability. Compared with the TOA positioning algorithm, the advantage of the TDOA positioning algorithm is that the error of the TDOA algorithm is the same for all base stations and the sum is zero. Synchronization error and multipath delay are the main errors [11].

2.2.2 AOA positioning algorithm

In the AOA positioning algorithm, we determine that the focal path from the base station to the mobile terminal is mainly used to measure the incident angle of the radio wave emitted by the terminal at the point to be estimated through the antenna of the receiver [12]. We measure the incident angles of the mobile terminal and multiple base stations at the point to be estimated, and the intersection of these focal diameter lines is the position coordinate of the point to be estimated. The AOA positioning algorithm is easily affected by wireless signal multipath fading, and indoor obstacles are the main factor causing wireless signal multipath fading. Therefore, positioning is more accurate only in an indoor environment with relatively few obstacles. In addition, the equipment required for AOA

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positioning is not only complicated, but also very expensive, so this method is not suitable for indoor positioning of firefighters at the fire rescue site.

2.2.3 RSSI positioning algorithm

RSSI positioning technology is mainly based on the signal strength that will gradually attenuate as the distance increases, and there is a formula to calculate the relationship between the two, so as to determine the distance between the signal receiving end and the signal transmitting source [13]. In general, the smaller the signal strength value received by the signal receiving end, the farther it is from the signal transmitting source, otherwise the larger the signal strength value, the closer it will be. RSSI positioning technology is very convenient to adjust. It does not need to modify the mobile terminal or other equipment, but only needs to change the software. This is the main advantage of RSSI positioning. At present, the two most commonly used methods for RSSI positioning are the strongest base station method and the location fingerprint method. The strongest base station method uses the position of the access point used by the wireless terminal for communication as the estimated position. The accuracy of this method is greatly affected by the coverage of the AP. Although it is simple, the positioning accuracy is not high. The location fingerprint method is mainly divided into offline phase and online phase. The offline phase mainly collects the RSSI value of each AP at each physical coordinate point and stores it in the location fingerprint database. The online phase is performed according to the RSSI value of the received AP and the location fingerprint database. Match, use the corresponding positioning algorithm to calculate the physical coordinates.

3. Indoor positioning method combining IMU and WIFI

3.1 Basic concepts of IMU

IMU (Inertial Measurement Unit): The full name is inertial measurement unit, or IMU for short. It has many applications in inertial navigation [14]. It is mainly used to measure the data needed in inertial navigation and positioning, including the acceleration and angular velocity information of the carrier. The main components include accelerometer and gyroscope. In actual applications, due to the interference of the module itself and the surrounding environment, the accelerometer and gyroscope are inevitably interfered. In this case, the accumulation of positioning with IMU over time will cause Large systematic errors have a great influence on the final positioning results. This is a problem that needs to be solved in inertial navigation and positioning, which is usually assisted by other information for joint positioning. Normally, the IMU module is placed at the center of gravity of the object to be measured, using three independent accelerometers and three gyroscopes. The data collected by the accelerometer is relative to the acceleration of the carrier coordinate system. The gyroscope What is collected is relative to the inertial coordinate system. We first need to convert the coordinate system, and then calculate the attitude based on the angular velocity information.

The system is mainly composed of a 3-axis MEMS gyroscope, a 3-axis MEMS accelerometer, a microprocessor, a Bluetooth sensor module, and a personal computer[15]. As shown in Figure 3:

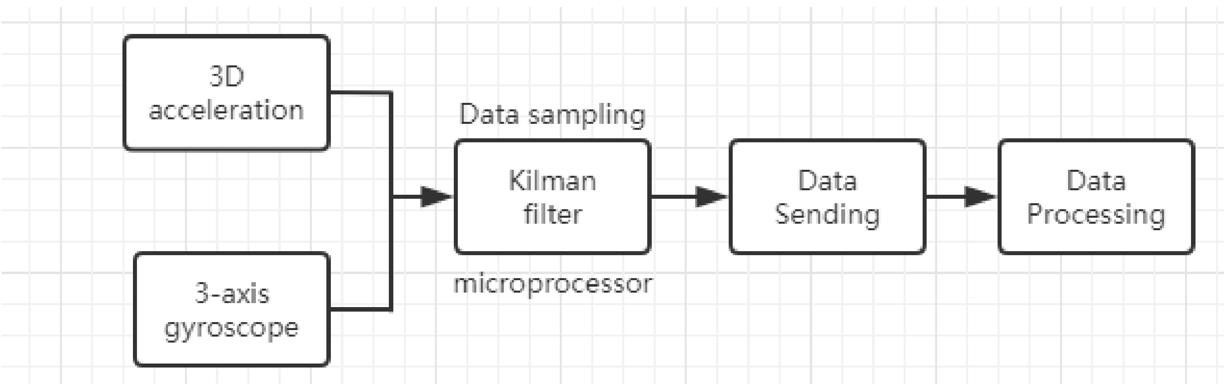

Figure 3. IMU system architecture

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Figure 3 In the IMU system structure, the gyroscope and accelerometer in MPU-6050 use three 16-bit AD conversion modules to convert the measured analog signals into digital signals. First, the microprocessor samples the sensor composed of the gyroscope and the accelerometer, and then compensates and information fusion the data sampled by the sensor through the Kalman filter, and finally we can get the accurate acceleration signal and angle signal.

Inertial navigation system is an autonomous navigation system that does not rely on external information and does not radiate energy[16] to the outside . Its working environment includes not only the air, the ground, but also the underwater. The basic working principle of inertial navigation is based on the laws of Newton's mechanics. By measuring the acceleration of the carrier in the inertial reference system, integrating it over time, and transforming it into the navigation coordinate system, you can get the value in the navigation coordinate system. Information such as speed, yaw angle and position. The inertial navigation system belongs to the calculation navigation method, that is, from the position of a known point according to the continuously measured heading angle and speed of the moving body to calculate the position of the next point, so the current position of the moving body can be continuously measured. The gyroscope in the inertial navigation system is used to form a navigation coordinate system, so that the measuring axis of the accelerometer is stabilized in the coordinate system, and the heading and attitude are given; the accelerometer is used to measure the acceleration of the moving body, after a time Integrate to get the speed, and the speed can get the distance after one time integration.

The current navigation system is mainly divided into: strap-down inertial navigation system (Strap-down Inertial Navigation System, abbreviated as SINS); analytic inertial navigation system (analytic inertial navigation system); semi-analytic inertial navigation system (semianalytic inertial navigation system) [17].

The strapdown inertial navigation system is to install the accelerometer and gyroscope directly on the carrier, and calculate the attitude matrix in the computer in real time, that is, to calculate the relationship between the carrier coordinate system and the navigation coordinate system, so that the accelerometer of the carrier coordinate system The information is converted into the information in the navigation coordinate system, and then the navigation calculation is performed. Due to its high reliability, strong functions, light weight, low cost, high precision and flexible use, SINS has become the mainstream of today's inertial navigation system development. The strapdown inertial measurement unit is the core component of the inertial navigation system. The accuracy of the output information of the IMU determines the accuracy of the system to a large extent.

Gyroscopes and accelerometers are indispensable core measurement devices in inertial navigation systems. Modern high-precision inertial navigation systems place high requirements on the gyroscopes and accelerometers used, because the drift error of the gyroscope and the zero offset of the accelerometer are the most direct and important factors that affect the accuracy of the inertial navigation system. Therefore, how to improve the performance of inertial devices and the measurement accuracy of inertial components, especially the measurement accuracy of gyroscopes, has always been the focus of research in the field of inertial navigation.

3.2 WIFI positioning technology

WIFI positioning technology is currently the most widely used among several indoor positioning technologies. WIFI positioning has the following advantages: (1) Basically all office buildings, shopping malls and other large indoor public places have free WIFI network nodes, and there is no need to deploy other equipment; (2) The cost is relatively low, and people use it now Basically all smartphones have free WIFI function. However, the biggest disadvantage of WIFI positioning is that during the propagation process, the signal strength will attenuate as the propagation distance increases, and the signal is affected by environmental factors, resulting in insufficient positioning accuracy, so only using WIFI positioning still cannot achieve positioning. Accuracy. In this article, IMU human body posture sensor is used to assist WIFI in indoor positioning and improve the accuracy of single WIFI positioning.

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The KNN algorithm is to find the sampling point that is most similar to the target anchor point, and estimate the position of the target anchor point through the position coordinates of this sampling point. Normally, Euclidean distance is used to measure similarity[18][19].

The implementation principle of KNN algorithm positioning is as follows:

1) Collect the location fingerprint data of q sample points indoors and their corresponding location coordinates L, the signal vector of the sample pointRi= (rss1i, rss2i, …, rssni) , RiRi represents the signal strength of n APs collected at the i-th sampling point.The coordinates corresponding to the data Ri in the positioning area are expressed as Li= (xi, yi);

2) The signal vector collected at the anchor point is S= (s1, s2, …, sn);

3) Calculate the distance between S and all sample data in the fingerprint library as:

$$d(S,R)=\sqrt{\sum_{j=1}^{n}(s_j-r_j^i)^2} \tag{1}$$

In formula (1), i is the sampling point and j is the dimension;

4) Sort the results calculated in 3) according to the size, select the first k smallest position fingerprints, and finally estimate the position coordinates of the points to be located as:

$$(x,y)=\frac{1}{k}\sum_{i=1}^{k}(x_i,y_i) \tag{2}$$

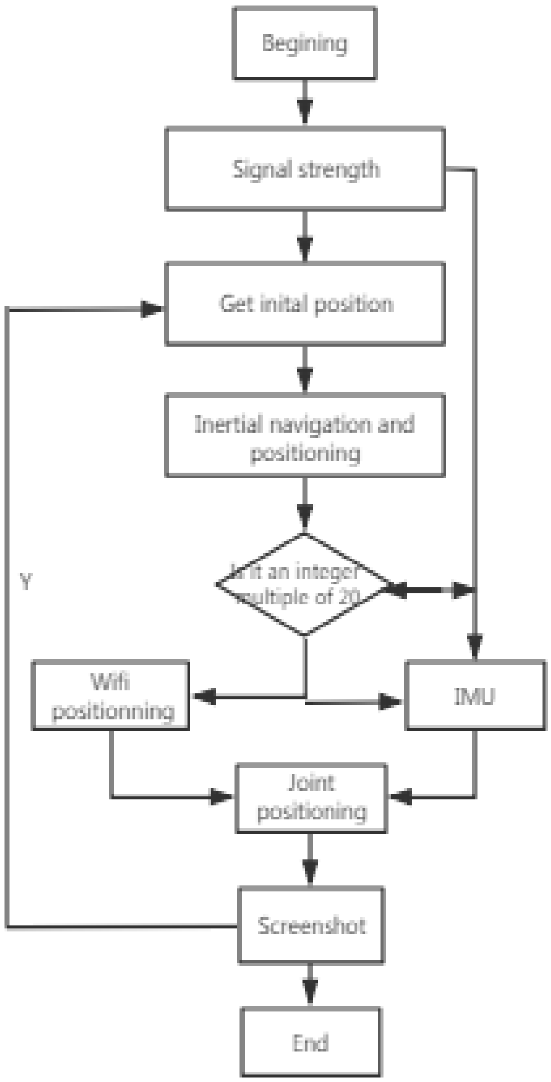

Figure 4. WIFI assisted IMU positioning flow chart

3.3 IMU-WIFI positioning principle

IMU inertial navigation mainly uses inertial sensors such as accelerometers and gyroscopes to measure the movement information of the carrier in the inertial space, and then calculates real-time acceleration, angular velocity and angle values in the three directions of x, y and z through differential equations, and The angle error measured by the IMU inertial measurement device is very small, and the result is very accurate [20].

The figure 4 shows the flow chart of WIFI assisted IMU positioning.

The specific steps of the WIFI-IMU positioning algorithm are as follows:

Step 1: Use the Android App on the mobile phone as a sampling point every 1 meter as a sampling point, take the average value, and take the WiFi signal strength data of several APs with strong signal strength;

Step 2: Build an RSSI fingerprint database based on the collected data, and the location coordinates correspond to the AP node name;

Step 3: In the positioning phase, first use the KNN algorithm to calculate the user's initial position;

Step 4: Use the IMU inertial measurement device worn on the user to detect the change in the direction of the user's movement, and determine and calculate the direction of the user's movement;

Step 5: Divide the RSSI into four quadrants according to the user's current coordinates. For example, if the current coordinates are (x0, y0), then the fingerprint library of the first quadrant is calculated by calculating the physics of the original fingerprint library where x is greater than x0 and y is greater than y0 The fingerprint library regenerated by the AP value corresponding to the coordinates;

Step 6: Combine the coordinates and direction of the previous position, select a suitable fingerprint set, and use the matching algorithm to calculate the coordinates;

Step 7: Repeat the previous operation to obtain a series of positioning coordinates

4. Summary and outlook

Considering that the existing single technology has the problem of low positioning accuracy, this paper studies indoor positioning algorithms based on the fusion of multiple technologies, and proposes a new algorithm for a combined positioning system based on WIFI and IMU in different scenarios, which achieves the improvement of positioning accuracy.

The main work completed in this paper is summarized as follows:

(1) Aiming at the current research status of indoor positioning. Combining the positioning accuracy and the difficulty of scale, IMU and WIFI technology are determined for indoor positioning combined system research.

(2) Aiming at the application scenario of the combined positioning system walking indoors, combined with WIFI technology to assist in correcting the position information, an algorithm for online update of the step length is proposed. Finally, the rationality of the algorithm can be verified through experiments.

In this article, the positioning scheme mentioned in this article can get good results under experimental verification, but there may be significant shortcomings under more complex experimental conditions, such as the threshold setting of gait detection and the determination of dynamic step length parameters. And better deal with the lack of hot spots. The next important task is to consider the improvement of the scalability of the positioning system and the ability to deal with complex environments. The next specific work mainly includes the following aspects:

(1) Expansion of space. The main environment of the original design is two-dimensional space, and there may be a need for three-dimensional space in the real environment, such as the movement state of people when going up and down stairs and the judgment of the floor where the person is located.

(2) Regarding the selectivity of WIFI base stations. Since this article is based on the premise that the WIFI base station is very stable when calculating the distance information based on the signal

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propagation model algorithm, but in actual situations, the WIFI base station will show different performances at different times and different places. In view of this problem, you can consider in-depth study The selectivity of the base station AP.

(3) Accurate acquisition of the initial state. The positioning in this article mainly relies on the WIFI fingerprint positioning to obtain the initial position, and the inertial navigation positioning is carried out on this basis. Because fingerprint positioning itself has certain flaws, there will be certain errors in the initial position. In the future, you can consider introducing other positioning mechanisms to obtain the initial position.

(4) The complexity of the movement state. In the research of this article, the main state is normal walking, but there is still a big gap in the analysis of more complex actions, such as running and jumping. So next, we can analyze a more common action. The model can be adapted to different motion states. It is also possible to analyze the above-mentioned motion model separately to further extend the existing motion model.

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