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Research Article

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Design of Patrol Vehicle Autonomous Tracking System Based on RTK Navigation

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Abstract The design of patrol vehicle autonomous tracking system based on RTK navigation mainly uses RTK to obtain vehicle information such as the latitude and longitude of the vehicle and the heading of the patrol vehicle, and then designs the patrol vehicle autonomous tracking system with the help of mathematical model and MATLAB programming software. The first is the upper computer program design, with the help of MATLAB and RTK message specification manual, the original data obtained by the device is converted into the tracking data we need, mainly including real-time longitude and latitude and real-time heading Angle data. Then calculate the Angle between the patrol car and the target position, that is, the target heading Angle. When calculating the target heading Angle, it should be calculated according to the situation that the target position is in the four quadrants of the patrol car. Finally, according to the calculation and summary, the Angle that the patrol car needs to rotate is obtained. Then is the patrol car lower machine code design, this part is based on the upper computer transmission signal, real-time control of the patrol car steering motor rotation. In the last part, an outdoor tracking experiment is carried out to verify the accuracy of the autonomous tracking system by comparing the actual driving path with the preset path.

Keywords RTK, Patrol Vehicle, Autonomous Tracking, Autonomous Driving

1. Introduction

In the field of autonomous driving, accurate positioning systems are essential to ensure that vehicles operate safely and efficiently. Real-time dynamic differential positioning technology, which provides centimeter-level positioning accuracy, has been widely used in the navigation system of unmanned vehicles. This paper aims to design a patrol vehicle autonomous tracking system based on RTK navigation to improve the navigation ability of patrol vehicles in complex environments.

RTK navigation technology uses the phase information of satellite signal, eliminates errors by differential technology, and realizes high-precision positioning. Compared with traditional global positioning systems, RTK can provide more accurate positioning information, which is crucial for patrol vehicles that need accurate navigation. The design of patrol vehicle autonomous tracking system proposed in this paper includes not only RTK navigation module, but also patrol vehicle autonomous tracking system, control system and other modules. The main method is to obtain the data information related to the patrol car through the host computer, and control the patrol car to track autonomically by setting the tracking code in advance.

The autonomous tracking ability of patrol vehicles is of great significance to ensure public safety. Patrol cars can be used to monitor traffic, patrol streets, and even respond quickly in an emergency. In the industrial sector, autonomous patrol vehicles can carry out material handling inside factories. Therefore, designing an efficient and reliable autonomous tracking system can not only improve the operational efficiency of patrol vehicles, but also reduce labor costs and improve operational safety.

2. Principle of Positioning and Attitude Measurement Based on RTK Technology

Once the longitude, latitude, and velocity are obtained through RTK, they must be converted into plane coordinates. In the current field of geographic information system, the Gaussian Kluge projection method is used to convert coordinates, cut the surface of the ellipse into an ellipse, and call the tangent line intersecting with the central longitude line as the central longitude line, and then project a point in the ellipse onto the ellipse within the spacing specified at both ends of the central longitude line, so as to obtain the Gaussian projection of the point. Because the absolute value of the horizontal coordinate Y after the conversion is relatively small, in order to prevent it from becoming negative, the converted Y value is multiplied by 500 kilometers, so that although the result is a large gap, it does not interfere with the navigation data. The forward Gaussian projection of longitude and latitude B,L is used to solve the plane transverse and longitudinal values (X,Y), where L is the longitude of the patrol vehicle and its current position, B is the average longitude and latitude of the patrol vehicle, $L0$ is 120°, as shown in the following formula:

$$X = X_0 + \frac{1}{2}Ntm_0^2 + \frac{1}{24}\left(5-t^2+9h^2+4h^4\right)Ntm_0^4 + \frac{1}{720}\left(61-58t^2+t^4\right)Ntm_0^6 \quad (1)$$

$$Y = Nm_0 + \frac{1}{6}Nm_0\left(1-t^2+h^2\right) + \frac{1}{120}\left(5-18t^2+t^4-14h^2-58h^2t^2\right)Nm_0^6 \quad (2)$$

In the formula：

$$\begin{cases} l = L - l_0 \\ m_0 = l\cos B \\ t = \tan B \\ h^2 = e^2\cos^2 B \end{cases} \quad (3)$$

e stands for eccentricity, e' stands for second eccentricity

$$\begin{cases} e^2 = \dfrac{a^2-b^2}{a^2} \\ e^{\prime 2} = \dfrac{e^2}{1-e^2} \end{cases} \quad (4)$$

Based on the world geodetic coordinate system defined in 1984, the length of the ellipsoid semi-axis is used in this study, where the major axis a is 6378137.0m and the minor axis b is 6356752.2.3 m.

N is the radius of curvature of the prime unitary circle through this point:

$$N = \frac{a}{\sqrt{1-e^2\sin^2 B}} \quad (5)$$

X_0 is the arc length of the longitude of the central meridian from this point to the equator:

$$X_0 = C_0B - \cos B\left(C_1\sin B + C_2\sin^3 B + C_3\sin^5 B\right) \quad (6)$$

The value of C_0、C_1、C_2、C_3 in the formula is only related to the ellipsoid parameter:

$$\begin{cases} \{C_0 = a(1-e^2)(1+\frac{3}{4}e^2+\frac{14}{65}e^4+\frac{175}{256}e^5+\frac{11025}{16384}e^8+...) \\ \{C_1 = a(1-e^2)(\frac{3}{4}e^2+\frac{14}{65}e^4+\frac{525}{512}e^5+\frac{2025}{2048}e^8+...) \\ \{C_2 = a(1-e^2)(\frac{14}{65}e^4+\frac{105}{256}e^6+\frac{2025}{2048}e^8+\frac{10395}{16384}e^{10}...) \\ \{C_3 = a(1-e^2)(\frac{35}{512}e^6+\frac{315}{2048}e^8+\frac{31185}{13072}e^{10}+...) \end{cases} \quad (7)$$

The calculation process is complicated if calculated according to the formula. In order to ensure the accuracy, the calculation process is simplified in this paper. The principle of attitude measurement is to determine the position relationship between the target point and the actual point by measuring the longitude and latitude of the actual position point, the degree of the actual heading Angle and the longitude and latitude value of the target course. Then using the inverse tangent function of the inverse trigonometric function to calculate the target heading Angle. Then make the difference between the actual heading Angle and the target heading Angle, and determine the next turning and steering Angle of the vehicle by judging the positive and negative of the difference and the absolute value of the difference.

3. Design of Autonomous Tracking System

3.1 Hardware platform of autonomous tracking system:

The autonomous tracking system is composed of drive motor, RTK, STM32 microcontroller and steering motor. In this system, the deviation of the target heading Angle detected by RTK in real time is compared with the actual heading Angle, and the steering and Angle signals that need to be adjusted are obtained. The steering motor is controlled according to the calculated steering Angle through data transmission.

3.2 RTK message parsing program:

The main steps of code design are to find the protocol header of the required data in the first step, extract the corresponding valid data in the second step, and read and output the valid data in the third step. Here is a partial code demonstration:

The first step is to find bits 14 to 26 of GNRMC and bits 30 to 44 of GNRMC.

```
data_index1 = strfind(data, protocol_header1) + 13;
data_index2 = strfind(data, protocol_header1) + 29;
```

The second step extracts data from bits 14 to 26 and 30 to 44.

```
data1 = data(data_index1:data_index1+12);
data2 = data(data_index2:data_index2+14);
```

Step 3 Output bits 14 to 26 and 30 to 44.

```
disp(['Data1: ', num2str(data1)]);
disp(['Data2: ', num2str(data2)]);
```

Similarly, the protocol header is GNHDT second to eighth data output, the implementation of RTK data parsing.

Table 1: RTK parses data tables

Name	Format	Example	Unit	Instructions
$GPHPD	string	$GPHPD		HPD message protocol header
GPSWeek	numeric	1451		Number of weeks since 1980-1-6 to current (receiver time)
GPSTime	numeric	368123.30		Milliseconds per week
Heading	numeric	90.01	degree	Yaw angle 0~360
Pitch	numeric	0.132	degree	Pitch angle-90～90
Track	numeric	90.11	degree	The angle of ground velocity relative to true north（0-359.99）
Latitude	numeric	34.1966004	degree	Latitude（WGS84）
Longitude	numeric	108.8551924	degree	longitude（WGS84）
Altitude	numeric	394.98	meter	Altitude（WGS84）
Ve	numeric	0.157	Meters/second	Eastward velocity

3.3 Path tracking program:

The tracking program is a key part of the autonomous tracking vehicle, which determines how the vehicle travels along a predetermined path. This time, we use the real-time data of RTK to judge the position relationship between the target point and the actual point and use mathematical methods to interpret the steering and Angle of the vehicle, so as to control the vehicle to drive.

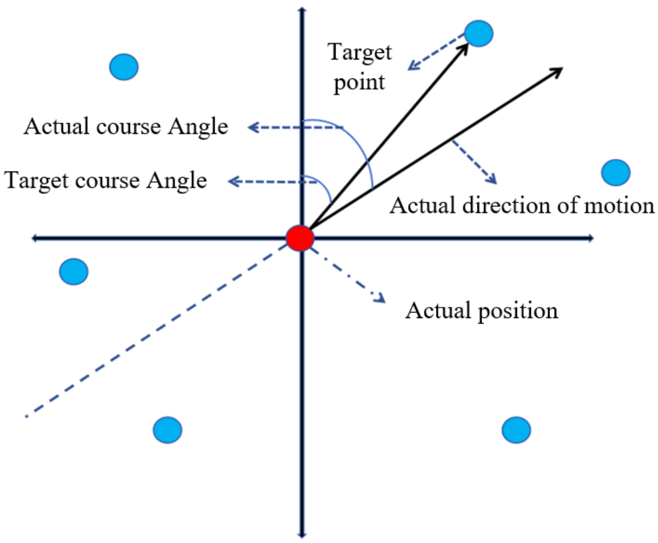

Figure 1: Multi-case discussion diagram in coordinate system

The code design of the tracking system in this paper mainly uses the trigonometric function model in the mathematical model and realizes the precise control of the autonomous vehicle through accurate mathematical calculation and effective communication.

First of all, the upper computer determines the actual position information of the patrol car through the data analyzed by the real-time motion positioning system. This data includes the vehicle's heading Angle and the associated latitude and longitude data. On this basis, the host computer establishes a rectangular coordinate system, assuming that the patrol car is located at the origin of coordinates, the x axis represents the latitude, the y axis represents the longitude. Through this coordinate system, the host computer can calculate the difference between the longitude and latitude of the target heading point and the actual position point of the patrol car.

Next, using the trigonometric function, the host computer calculates the Angle between the patrol car and the target location, that is, the target heading Angle. This step is accomplished by measuring the difference between the longitude and latitude of the target heading point and the actual position point of the car. Then, the host computer compares the target heading Angle with the actual heading Angle and calculates the required turning Angle and turning direction.

In different position situations, the target point may be located in the first, second, third or fourth quadrants, and the patrol car will need a steering strategy to turn the minimum Angle. For example, if the target point is in the first quadrant and the car's current heading Angle points to the second quadrant, the host computer calculates a positive steering Angle, indicating that the car needs to turn right. Conversely, if the target point is in the third quadrant and the car's current heading Angle points to the fourth quadrant, the host computer calculates a negative steering Angle, indicating that the car needs to turn left.

Finally, a variety of cases are summarized, the result is that the difference between the target heading Angle and the actual heading Angle determines the steering direction of the patrol car, and the absolute value of the difference determines the steering Angle. These calculations are converted into control instructions, which are sent to the lower computer via data communication. After receiving the instruction, the lower machine controls the motor to run according to the specified steering and Angle, so as to adjust the driving direction of the vehicle.

4. Autonomous Tracking Test and Analysis

In order to verify whether the patrol car can accurately execute the tracking algorithm, a tracking experiment is set up according to the set trajectory, and the experiment site is selected to be carried out on the south lawn of the library of Shandong University of Technology West Campus. In the experiment, the researchers need to observe the driving of the vehicle and record whether the vehicle can accurately follow the predetermined path. The latitude and longitude information obtained by RTK is recorded, and the latitude and longitude coordinate map is drawn to more intuitively verify whether the patrol car is driving according to the preset trajectory. The performance of the tracking algorithm can be evaluated by comparing the actual motion latitude and longitude data of patrol vehicle with the preset trajectory latitude and longitude data.

In the test, an approximate square track was selected on the south lawn of the library of the West Campus of Shandong University of Technology, and the longitude and latitude of several points were measured. The vehicle was driven according to the preset path, and the longitude and latitude values measured during the running of the vehicle were derived. The actual driving path of the patrol vehicle could be obtained by tracing the points into lines, and then the degree of fitting between the preset point and the actual running track was compared. Figure 2 shows the relationship between the longitude and latitude data of the actual running track and the preset points, and the accuracy of vehicle tracking can be analyzed. It is obvious from the figure below and the data table that both the latitude and longitude data and the operation diagram can be seen that the accuracy of vehicle operation is relatively high.

Table 2: Actual driving track points

latitude	longitude
36.80632114	117.9992806
36.80640275	117.999302
36.80666904	117.9993289
36.80683655	117.9993557
36.80712647	117.9993718
36.80735196	117.99942
36.80751087	117.9994308
36.80750658	117.9993557
36.80749369	117.999302
36.80746792	117.9991947
36.80745933	117.9990445
36.8074894	117.9988461
36.80749799	117.9987602
36.80751946	117.9986744
36.80756241	117.9985886
36.80759248	117.9985027
36.80763113	117.9984223
36.80735196	117.9983364
36.80639415	117.9981862
36.80623524	117.9981433
36.80616651	117.9987549
36.80613215	117.9992484
36.80640275	117.9992913

Table 3: Target track point

latitude	longitude
36.80632123	117.9992798
36.80683646	117.9993562
36.80751092	117.9994312
36.80746787	117.9991952
36.80748947	117.9988470
36.80749804	117.9987608
36.80751949	117.9986752
36.80735203	117.9983359
36.80639408	117.9981871
36.80623519	117.9981440
36.80616647	117.9987553
36.80613238	117.9992478

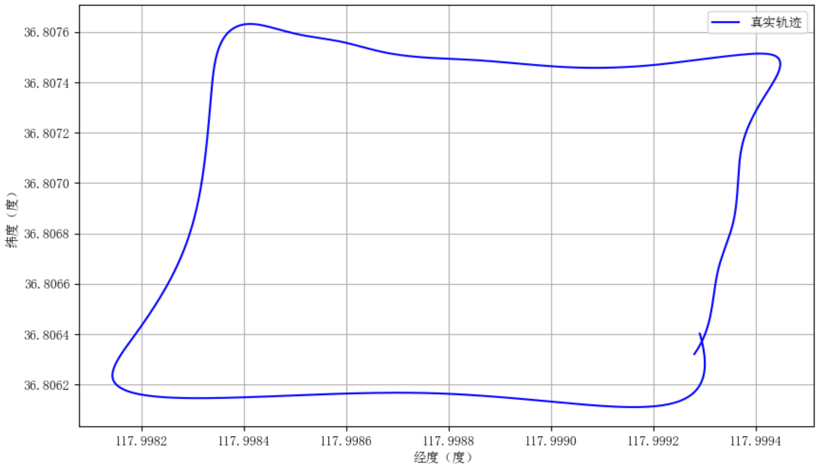

Figure 2: Actual driving track diagram

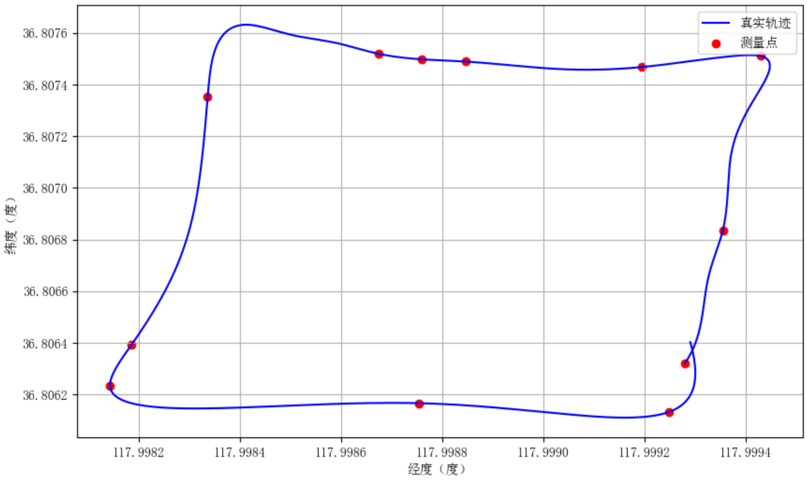

Figure 3: Comparison diagram between actual driving track and preset track points

5. Conclusion

The patrol vehicle autonomous tracking system based on RTK navigation can make the patrol vehicle navigate along the preset path without manual intervention. The key of the system is to use RTK receiver for accurate positioning, combined with related algorithms, to achieve accurate control of patrol vehicles. In this system, the main code design mainly includes three parts: RTK data analysis part, tracking system part, the lower computer code part. Among them, the RTK data analysis part is mainly based on the RTK protocol to write code to obtain relevant information, the tracking system part is mainly based on the patrol car data information to use mathematical models to discuss the patrol car heading Angle under various circumstances, and the lower computer design part is mainly based on the command sent by the upper computer to control the patrol car motor to run according to the requirements. Finally, the accuracy of the patrol vehicle tracking system is verified by comparing the actual trajectory and the preset trajectory of the patrol vehicle through an outdoor test.

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