

Research Article

Positioning Control Algorithm of Vehicle Navigation System Based on Wireless Tracking Technology

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To improve the accuracy and reliability of the on-board navigation system positioning, the positioning control algorithm of vehicle navigation system based on wireless tracking technology is proposed. By using modern information fusion technology, the accurate positioning of vehicle integrated navigation is realized, and the design goal of omnidirectional, all weather, and self-contained positioning function is realized. Finally, the test shows that the accuracy and reliability of the positioning control algorithm of vehicle navigation system based on wireless tracking technology are improved than existing point system, speed measurement accuracy can reach 0.02 m/s, and positioning accuracy is about 18 meters. The vehicle operation efficiency and safety are greatly improved, and the traffic capacity is improved. And the traffic congestion is effectively alleviated, which provides reliable guarantee for the realization of traffic management automation and intelligent vehicle driving.

1. Introduction

With the acceleration of social development, there are many problems in road traffic in recent years, which makes intelligent transportation system get widespread attention. As an important part, intelligent vehicle is a comprehensive intelligent vehicle system which integrates many functions such as environmental perception, planning, decision-making, and auxiliary driving and is the future development direction. The further study of it can help to reduce the incidence of traffic accidents, and to some extent, it can effectively alleviate the current traffic situation. Real-time acquisition of high precision navigation and positioning information is an important part of intelligent vehicle system and also the primary goal to ensure its safety. Vehicle navigation and positioning technology has achieved some scientific research results as one of the key technologies of intelligent vehicle system. Lin and Liao [1] proposed a design scheme of Beidou/GPS-based vehicle positioning monitoring system, which receives satellite positioning information via dual-mode positioning module, analyzes and displays it on the LCD (liquid crystal display) screen, and uses 4G wireless communication to upload monitoring data to the monitor-

ing center for remote monitoring management. The positioning system is relatively stable, but the positioning accuracy is not high. Su et al. [2] analyzed three common satellite navigation and positioning methods. Key research on differential techniques is performed. After the comparison analysis, it is found that the carrier phase difference positioning accuracy can reach the cm level positioning, and this technology is applied to the on-board navigation terminal equipment. The positioning of this method is better reliable, but the speed measurement accuracy cannot meet the actual needs. Hu et al. [3] proposed the combined navigation scheme in the vehicle combined navigation system. Using the zero lateral and celestial velocity of the vehicle during normal driving, the combined navigation filter measurement equation is obtained when the satellite signal fails; considering the difficulty to obtain the measured noise covariance matrix during the Kalman filtering, a new adaptive Kalman filtering (ADKF) algorithm is derived, which calculates the actual covariance of the new interest sequence, and adjusts the noise covariance matrix size using the fuzzy inference system (FIS) to adjust the noise covariance to navigate the vehicle position. The navigation method is highly adaptable to the environment, but the positioning accuracy

is not ideal enough. Based on this, it is of great significance to develop a complete navigation and positioning system which is suitable for intelligent vehicle platform and existing laboratory equipment.

In order to improve the accuracy and reliability of the navigation positioning system, the vehicle navigation system positioning control algorithm based on wireless tracking technology is designed. The positioning control algorithm of vehicle navigation system is the core of this paper, including lane tracking algorithms and lane departure algorithms.

The innovation point of this paper is that it does not rely on one kind positioning and navigation system control algorithm, but instead combines multiple algorithms to make the positioning more accurate. Based on the equipment configuration of the current intelligent vehicle platform, the paper designs a new algorithm based on loose combination and decentralized extended Kalman filter, which makes full use of the complementary characteristics of GPS and inertial system in navigation and positioning information; second, in order to make the navigation and positioning of intelligent vehicles more accurate, a more detailed GPS coordinate conversion algorithm is adopted to replace the traditional GPS localization protocol used in the document [1], and the information preprocessing mechanism of GPS positioning system and inertial system is introduced; third, in order to realize the visualization effect of intelligent vehicle navigation and positioning, the software integrates the secondary development of MapX map control and draws the vehicle position and driving path in real time by using the dynamic layer principle and map matching algorithm; finally, the above algorithm is tested in the intelligent vehicle platform [4]. The feasibility of the algorithm is verified by real vehicle control, and the whole design intention of establishing a complete navigation and positioning system is achieved. Experiments also demonstrate that the present design has higher system accuracy and reliability compared to existing literature methods.

2. The Positioning Control Algorithm of Vehicle Navigation System

2.1. Positioning Function Optimization of Vehicle Navigation System. With the increasing number of urban vehicles, how to effectively command, dispatch, and manage public service vehicles and some special vehicles in the city has become an important problem faced by transportation departments and urban planning departments. Therefore, vehicle navigation and positioning system have attracted more attention. With the development of wireless communication and mobile communication network, vehicle navigation and positioning technology are developing rapidly [5]. The basic function block diagram of modern vehicle navigation and positioning is shown in Figure 1.

At present, the main application types of vehicle navigation and positioning technology are automatic navigation system, fleet management system, consultant navigation system, information storage system, and portable system [6]. There are three types of vehicle navigation and positioning system: autonomous, nonautonomous, and combined. The

autonomous vehicle navigation and positioning system uses the inertial principle of navigation; uses the distance sensor, direction sensor, and other sensors to measure the displacement and heading information of the vehicle; and calculates the position of the vehicle. In the research of intelligent vehicle safety assistant driving system, navigation and positioning module is one of the most important parts [7]. It is responsible for providing accurate location information for the vehicle and informing the vehicle of the path and direction to be driven. After obtaining the information, it is transmitted to the information processing module through various interfaces. Only when the components in the navigation and positioning module work stably and reliably, the functions of auxiliary driving and vehicle control can play a role [8]. In this paper, the differential GPS and inertial navigation elements are used to provide relevant information for the vehicle, and the vehicle position is informed in real time, so that it will not be lost in the road. This chapter will mainly introduce the working principle and characteristics of differential GPS and inertial navigation system, as well as the integrated navigation and positioning mode as Figure 2.

The basic positioning principle of GPS is the satellite sends its own ephemeris parameters and time information continuously [9]. After receiving the information, the user calculates and calculates the three-dimensional position, three-dimensional direction, motion speed, and time information of the receiver. Suppose that the GPS time and satellite clock time of satellite signal are expressed in t , respectively. The GPS time and receiver clock time when the receiver receives the satellite signal are expressed by T_G and T_R , respectively [10]. Therefore, the satellite clock deviation Δt_S^j and the clock deviation of the receiver Δt_R can be calculated as follows:

$$\begin{cases} \Delta t_S^j = t_S^j - t_G^j, \\ \Delta t_R = T_R - T_G, \\ \tau_R^j = (T_G - t_G^j) + \Delta t_R - \Delta t_S^j. \end{cases} \quad (1)$$

In formula (1), t_S^j expresses the satellite time when the receiver receives the satellite signal j , t_G^j expresses the GPS time when the receiver receives the satellite signal j , τ_R^j expresses the GPS time deviation of the receiver receiving the satellite signals.

Inertial navigation system (INS) is a kind of navigation method which uses the internal information of vehicle to calculate the position and attitude information of vehicle through inertial sensors, such as gyroscope, accelerometer, and angle sensor [11]. Navigation and positioning system mainly provides accurate vehicle position and attitude information for vehicle navigation control, such as vehicle position coordinates, heading angle, front wheel angle, and driving speed [12]. In this study, the Futian Ou Bao 4040 tractor is taken as the research object. The heading angle sensor, the angle sensor, and the speed sensor are installed on the tractor, respectively. The angle sensor is a multicircle

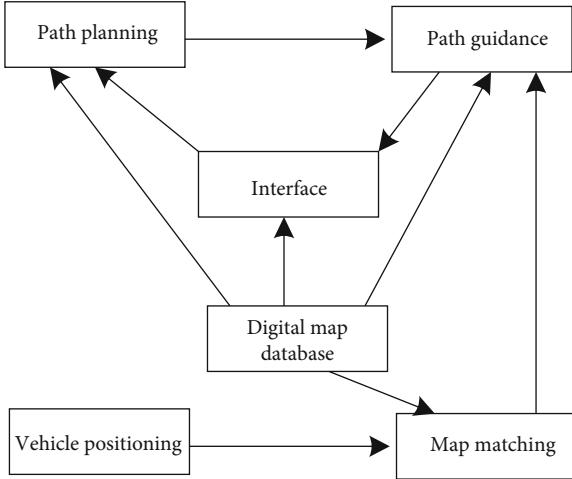


FIGURE 1: Functional block diagram of vehicle navigation and positioning.

hollow angle sensor, using Witterson technology “magnetic-Angle displacement detection.” Even if the mechanical displacement is generated after power loss, a high-reliability measurement of the real-time absolute angle can be achieved after recharging. The speed sensor has embedded precision integrated circuit for equipment fault absolute vibration speed measurement. The vehicle status information detected by the sensor is input into the computer through a certain interface, and the vehicle position coordinates are calculated by the computer [13]. The hardware structure of the test system is shown in Figure 3.

The heading angle sensor is the MTI (“MTI” is the brand name of the US sensor) type sensor produced by *x* sense company of the Netherlands. The sensor is a microelectro mechanical system integrating gyroscope, acceleration sensor, and geomagnetic sensor. Its internal low-energy signal processing system can provide zero drift 3D (3-Dimension) direction information, 3D acceleration, and 3D angular velocity information, which can be used in robot, aerospace, navigation, and other fields. There are good application prospects in the fields of navigation and autonomous vehicles.

The sensor is suitable for the PC equipped with serial port. By integrating the 3D acceleration signal, 3D angular velocity, and 3D geomagnetic field signal detected by the internal sensor, three Euler angles of the sensor dynamic coordinate system are obtained: roll, pitch, and yaw. The sensor base is bolted to the tractor, and the measured yaw angle is the vehicle heading angle. The sensor is equipped with geomagnetic sensor. Because the earth magnetic field is weak and the sensor and it is easy to be affected by the surrounding magnetic field, the sensor should be far away from the strong magnetic field as far as possible and suitable position shall be selected for installation [14]. The selected heading angle sensor has an angular resolution of 0.050, a static precision of less than 0.50, and a dynamic precision of less than 20. It can measure all the angle values in the 3D range. The sampling frequency can be adjusted to 120 Hz at the maximum according to the needs of the user. When measuring vehicle speed, the sensor is installed on the engine fly-

wheel housing, and the sensor is kept at a proper distance from the flywheel [15]. When the engine is rotating, the concave and convex changes of the tooth on the flywheel make the output voltage of the sensor change. Through the internal amplifying and shaping circuit, the sensor outputs a square wave signal with stable amplitude, and the engine speed n_1 can be obtained by measuring the frequency P of square wave high and low voltage change in a certain time R interval of T_4 . If the throttle is kept constant, the transmission ratio K_1 of engine speed n_1 and wheel speed n_2 remains basically the same [16]. Without considering the vehicle sliding, the sensor obtains engine speed, and wheel speed and vehicle speed are calculated as follows:

$$\begin{cases} v = 2n_2\pi R, \\ n_2 = n_1K_1, \\ n_1 = \frac{\Delta tz}{p}. \end{cases} \quad (2)$$

The course deviation measured in eight directions is made into a curve, and the output course angle of the sensor is corrected by using the curve to obtain the accurate course angle value, as shown in Table 1.

According to the geometric relationship between the virtual front wheel angle and the real front wheel angle, the functional relationship between them can be obtained as follows:

$$\text{ctg}\alpha = \text{ctg}\beta + \frac{B}{2L}, \quad (3)$$

where B is the center distance between the left and right front wheels, and L is the distance between the front and rear axles of the tractor. Using the formula, the virtual front wheel angle can be calculated according to the detected right front wheel angle. The measurement of vehicle speed is realized through the detection of engine speed:

$$v = 2\pi RK_1 n_1. \quad (4)$$

If the tire pressure is constant, the rear wheel radius R of the vehicle remains unchanged. In the same gear, K is the constant value, so that $K = 2\pi zRK$, K are also fixed values, the calculation formula of vehicle speed can be obtained as follows:

$$v = Kn_1. \quad (5)$$

Let a linear time invariant continuous time system be

$$\begin{cases} \dot{x} = Ax + Bu, \\ y = Cx. \end{cases} \quad (6)$$

After discretization, the difference equation of the system is obtained as follows:

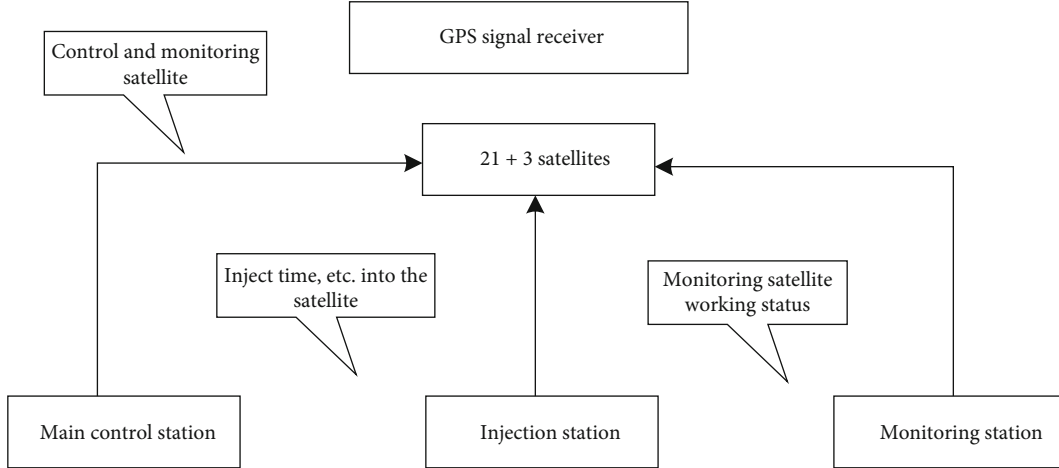


FIGURE 2: Composition of GPS positioning system.

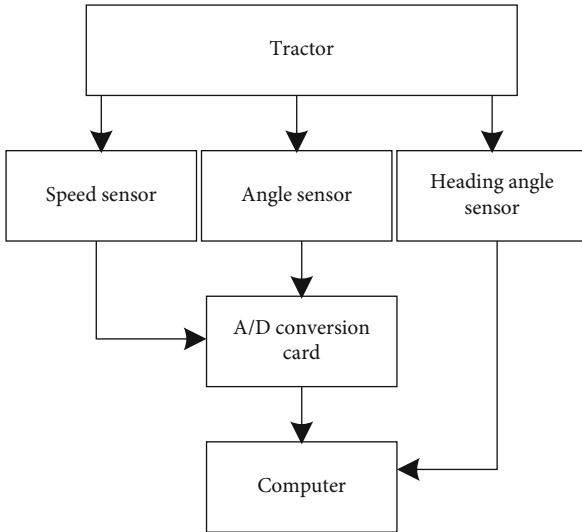


FIGURE 3: Composition block diagram of navigation and positioning system.

$$\begin{cases} x_k = G_d x_{k-1} + H_d u_{k-1}, \\ y_k = C x_k. \end{cases} \quad (7)$$

According to the above formula, as long as the initial state of the system is known, the state parameters and output values at any time can be predicted, but there are always interference and noise in practice, which makes the calculated values deviate from the actual state. Considering the system input noise and measurement noise, the equation can be rewritten as

$$\begin{cases} x_k = G_d x_{k-1} + H_d u_{k-1} + \omega_{k-1}, \\ y_k = C x_k + v_{r,k}. \end{cases} \quad (8)$$

2.2. Positioning Data Processing Algorithm of Vehicle Navigation System. The processing of vehicle navigation

and positioning data plays an important role in the navigation and positioning system. It is not only the basis of map matching but also the data source of the whole positioning process, which affects the effect of map matching to a large extent. The current navigation and positioning system mainly include GPS positioning system and Dr positioning system, but each of them has its advantages and disadvantages. A single positioning system cannot guarantee good positioning effect [17]. Therefore, how to make it better and make up for short is the key problem to solve the problem of vehicle navigation and positioning data processing. GPS is a passive ranging system. In passive ranging system, users measure the propagation delay by comparing the received satellite signals and local reference signals; if the satellite clock and the user clock are synchronized, that is, the two clocks are synchronized in the same frequency or known difference, the measured propagation delay t is proportional to the distance d between the satellite and the user, i.e., the distance d between the satellite and the user:

$$d = ct. \quad (9)$$

In fact, there is an unknown clock difference $4t$ between the user clock and the satellite clock. At this time, the measured propagation delay t and the corresponding distance P are not the real radio wave propagation delay T and the distance d from the satellite to the user. At this time, P is called pseudorange:

$$\rho = d + c\Delta t. \quad (10)$$

To minimize the localization distance bias caused by the aforementioned signal propagation time delay, lateral auxiliary control of the lane deviation is required. The premise and basis of lateral assistant control of lane departure are to judge whether the vehicle has lane departure or not, that is, to judge whether the error between the vehicle trajectory and the expected track is less than the allowable threshold of vehicle safe driving [18]. The process of lane departure judgment is mainly divided into two stages: lane line recognition

TABLE 1: Secondary calibration data of sensor (unit: degree).

	1	2	3	4	5	6	7	8
Actual heading angle	0	40.4	88.7	143.1	178.5	217.1	269.7	316.3
Sensor output	1.1	37.2	86.1	141.5	176.8	215.9	272.2	320.2
Deviation value	1.1	-3.2	-2.6	-1.6	-1.7	-1.2	2.5	3.9

and tracking, and lane departure judgment. The following is a detailed analysis.

The first stage task is lane recognition and tracking.

Lane departure means that vehicles are not within the range of lane line, so lane line recognition and tracking are very important [19]. The specific process of lane recognition and tracking is as follows:

Step 1. Arrange cameras on the vehicle to collect sequence image information.

Step 2. Preprocess the acquired image sequence, including graying, image filtering, and lane edge point filtering.

Step 3. Vanishing point detection, that is, to detect the lane feature points from the lane feature map.

Step 4. According to the detected vanishing points, the image is clipped to obtain the region of interest.

Step 5. In the region of interest, collect the four points in the lane edge line.

Step 6. Make the confidence judgment and lane width information to supplement the lane line under the condition of fuzzy, shadow, or vehicle occlusion, so as to realize the detection of lane line.

Step 7. Lane tracking. According to the identified lane line, the lane line is recognized again in the next frame, namely, lane line tracking. In this link, the Kalman filter tracking method is used to realize the lane tracking operation.

Second stage task is deviation judgment.

In this stage, a lane departure algorithm is selected to judge the lane departure and realize the departure warning. At present, lane departure algorithms mainly include the following, as is shown in Table 2.

According to the above table, each lane departure algorithm has some shortcomings [20]. Therefore, the algorithm based on the current position of the vehicle and the algorithm based on the time of vehicle crossing the lane line are combined to judge the lane departure. The principle formula is as follows:

$$S = S_{CCP} \cup S_{TLC} = \begin{cases} 1, S_{CCP} = 1 \text{ or } S_{TLC} = 1, \\ 0, \text{ other.} \end{cases} \quad (11)$$

Among them:

$$S_{CCP} = \begin{cases} 1, d_L \leq T_{CCP} \text{ or } d_R \leq T_{CCP}, \\ 0, \text{ other,} \end{cases} \quad (12)$$

$$S_{TLC} = \begin{cases} 1, t_{TLC} \leq T_{TLC}, \\ 0, \text{ other,} \end{cases} \quad (13)$$

where S_{CCP} represents the output result of the algorithm based on the current position of the vehicle; S_{TLC} represents the output result of the algorithm based on the time of vehicle crossing the lane line; d_L represents the lateral distance from the left wheel of the vehicle to the left lane line; d_R represents the lateral distance between the right lane and the right lane of the vehicle; T_{CCP} represents the distance threshold; t_{TLC} represents the time to cross the lane line; T_{TLC} represents the time threshold. When there is deviation trend, it will send early warning signal to the control system in time to trigger the lateral control procedure of lane keeping and correct the deviation in time to make it return to the safe range and ensure the safety of vehicles.

2.3. Realization of Positioning Control in Vehicle Navigation System. In the lateral assistant control of vehicle lane departure, the algorithm depends on vehicle system model and driver model, so it is necessary to establish appropriate vehicle model and driver model before the implementation of the control algorithm. The former is to determine the desired vehicle motion state, and the latter is to obtain the required optimal steering wheel angle. The formula of the model equation is as follows:

$$\begin{bmatrix} \dot{\beta} \\ \dot{\omega} \end{bmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{bmatrix} \beta \\ \omega \end{bmatrix} + \begin{bmatrix} (2 \cdot C_f / m \cdot v) \\ 2 \cdot C_f \cdot l_f / I_z \end{bmatrix}, \quad (14)$$

where

$$a_{11} = -\frac{2(C_r + C_f)}{m \cdot v}, \quad (15)$$

$$a_{12} = -1 + \frac{2(l_r C_r - l_f C_f)}{m \cdot v^2}, \quad (16)$$

$$a_{21} = \frac{2(l_r C_r - l_f C_f)}{I_z}, \quad (17)$$

$$a_{22} = -\frac{2(l_r^2 C_r + l_f^2 C_f)}{I_z \cdot v}. \quad (18)$$

TABLE 2: Comparison of lane departure algorithms.

Algorithm	Definition	Characteristic
Algorithm based on vehicle current position	According to the distance between the vehicle tire and the left and right lane lines, it can judge whether the vehicle deviates	The advantages are high precision; the disadvantage is that the reserved reaction time is short
Algorithm based on future preview offset	By comparing the lateral position of the vehicle in the forward-looking time with the virtual boundary, the deviation problem can be judged	The advantage is that the structure of the algorithm is simple; the disadvantage is that the virtual lane is difficult to determine
Algorithm based on vehicle crossing lane time	According to the time of the vehicle crossing the lane line to judge whether the vehicle touches the boundary	The advantages are simple algorithm, easy parameter measurement, low false alarm rate, long reserved reaction time, and low accuracy.
Algorithm based on prediction trajectory	The evaluation is based on the deviation between the predicted trajectory and the target trajectory after a period of time	The advantage is that the algorithm is easy to implement; the disadvantage is that it is more suitable for straight deviation judgment

Driver control model:

$$\delta_d = \arctan \left[\frac{2L}{L_p^2} (\Delta y_p - L_p \beta) \right], \quad (19)$$

$$L_p = uT_p. \quad (20)$$

In the formula, the parameters of vehicle system model and driver model are shown in Table 3.

Both electric power steering control and differential braking control are important algorithms for lateral auxiliary control of vehicle lane departure. Among them, the former control idea is to determine whether the deviation problem occurs through deviation detection. In case of deviation, early warning is given and control signal is output to automatically control the steering wheel rotation of the vehicle, so as to maintain the lateral position deviation of the vehicle within the specified range and turn the vehicle back to the right track of the lane. In this process, the key lies in the role of BP (back propagation) neural network PID (proportion integral differential) controller. The optimal steering wheel angle is obtained through the driver model, and then it is input into the BP neural network PID controller. After the BP neural network PID controller operation, the target auxiliary torque is obtained. The specific calculation formula of the target auxiliary torque is as follows:

$$J = \frac{1}{2} \sum_{k=1}^n [r(k) - r_d(k)]^2. \quad (21)$$

In formula (21), $r(k)$ expresses the ideal pendulum velocity in the input PID controller, $r_d(k)$ expresses the actual pendulum angle velocity, and k indicates the wheel-base of the vehicle [21].

Finally, the man-machine coordinated control is realized by combining the actual operation torque of the driver and the lateral position deviation of the vehicle relative to the lane centerline. The latter control idea is to first determine the desired vehicle motion state, that is, the ideal yaw rate, based on the driver model, and then take the ideal yaw rate

as the input of BP neural network PID controller. After calculation, the ideal yaw moment is obtained. Finally, this parameter is reasonably distributed to the four wheels of the vehicle, and the braking system controls the vehicle to return to the normal lane.

Although both of the above methods can realize the control of vehicle deviation, both methods are difficult to meet the control requirements under various conditions. The electric power steering control is more suitable for the deviation correction in straight road, and differential braking control is more suitable for deviation correction in curve. Therefore, this chapter combines the two and proposes an extension joint lateral auxiliary control method. The method is based on the road adhesion coefficient and the initial steering wheel angle. The extension set is divided into four regions, namely, classical domain, extension domain, and nondomain. Different control strategies are adopted for each area as shown in Table 4.

The principle equation of extension joint lateral auxiliary control is as follows:

$$u(t) = \begin{cases} u(DBC), K(S) \geq 0, \\ (1 + K(S))u(DBC) - K(S)u(EPs), -1 \leq K(S) < 0, \\ u(EPs), K(S) < -1, \end{cases} \quad (22)$$

where $u(t)$ represents the controller output; $u(DBC)$ represents the output of differential braking control; $(1 + K(S))u(DBC) - K(S)u(EPs)$ represents the output under the cooperative operation of differential braking control and electric power steering control; $u(EPs)$ represents the control output of electric power steering; $K(S)$ represents the value of the correlation function obtained by the characteristic state S . GPS/DR integrated navigation mode. When GPS signal is lost and cannot be located, the GPS position calculation system can continue to work and the reliability of the system is improved. However, when the vehicle is in the urban area with dense roads, it is impossible to use the digital map matching technology to further correct the GPS

TABLE 3: Parameter description of vehicle system model and driver model.

Parameter	Meaning	Parameter	Meaning
m	Vehicle mass	L	Wheelbase
v	Vehicle longitudinal speed	L_p	Preview range
I_z	Moment of inertia of vehicle around vertical axis	β	Sideslip angle of mass center
C_f, C_r	Equivalent cornering stiffness of front and rear tires	Δy_p	Lateral deviation at preview point
l_f, l_r	Distance from the center of mass of the whole vehicle to the front and rear axles	T_p	Preview time
δ_d	Optimal steering wheel angle	u	Vehicle longitudinal speed

TABLE 4: Extension joint lateral auxiliary control strategy.

Extension set	State characteristics	Control strategy
Classical domain	The road adhesion coefficient is large and the initial steering angle is small	Differential braking control
Nondomain	When the road adhesion coefficient is small and the initial steering wheel angle is large	Electric power steering control
Extension field	Between nondomain and classical domain	Coordinated operation of differential braking control and electric power steering control

positioning information and the positioning information of the GPS positioning system, as is shown in Figure 4.

GPS/DR/M integrated navigation mode. It overcomes the disadvantages of GPS/MM and GPS/DR, which is an ideal independent combination. But the matching map must have high precision, so it can achieve high positioning accuracy and navigation system reliability. Although it is possible to apply all the positioning technologies to vehicle positioning, due to the cost and coverage, the low-cost GPS receiver and the inertial sensor with the increasing performance price ratio and the increasingly widespread digital map make GPS/DR/MM technology become the mainstream of vehicle combination positioning technology.

3. Analysis of Experimental Results

Taking CarSim as a tool and based on the collected information, the system model and driver model of intelligent vehicle are built by using simulation software CarSim and MATLAB. The basic data required are shown in Table 5.

In order to further explain the characteristics of integrated navigation positioning mode, the test of sports car is carried out by using the designed system proposed by Lin and Liao [1], the designed system proposed by Su et al. [2], and GPS/GLONASS/mm integrated navigation (design of this article) to verify the accuracy and reliability of integrated navigation positioning. GPS/GLONASS integrated navigation and positioning has 24 parallel channels and simultaneously receives 24 satellites from GPS/GLONASS two systems. The two systems backup each other and are no longer subject to the constraints and control of the U.S. military. The coverage of satellites is expanded, and the number of satellites that can be used for positioning calculation is increased, so that the strength of satellite geometry is better. Moreover, GLONASS satellite system has no SA impact,

GPS/GLONASS does not need difference, and the accuracy of single machine positioning can be about 15 m, which can get rid of the trouble of SA or differential communication. The speed measurement accuracy can be as high as 0.02 m/s, even better than that of differential GPS. This is because the system designed in this paper combines multiple systems to make full use of the complementarity of GPS and inertial systems in navigation and positioning information, using a more detailed GPS coordinate conversion algorithm, using dynamic layer principle and map matching algorithm in real time, thus, has higher system accuracy and reliability. In this way, it is more conducive to uninterrupted positioning in multiocclusion environment and realize full field tracking measurement. At the same time, RAIM is enhanced, which can benefit from two independent global positioning systems, increase the geometric strength of satellites and the number of positioning combinations, and effectively judge the health status of satellites, so as to improve the integrity of the whole system. GPS/GLONASS/mm three integrated navigation and positioning can make up for the inherent defects of GPS and GLONASS single system, eliminate the problem of perfection, and use digital map matching technology to further correct GPS/GLONASS integrated positioning information, so as to improve the accuracy of its navigation and positioning. The performances of the designed system proposed by Lin and Liao [1], the designed system proposed by Su et al. [2], and GPS/GLONASS/mm integrated navigation (design of this article) are tested, respectively. Roadcar test curves result for three navigation systems as shown in Figure 5.

From the graph and curve, the positioning accuracy of GPS/GLONASS integrated navigation is higher than the designed systems proposed by Lin and Liao [1] and Su et al. [2], especially when driving at the corner and under the overpass, the positioning accuracy of GPS/GLONASS

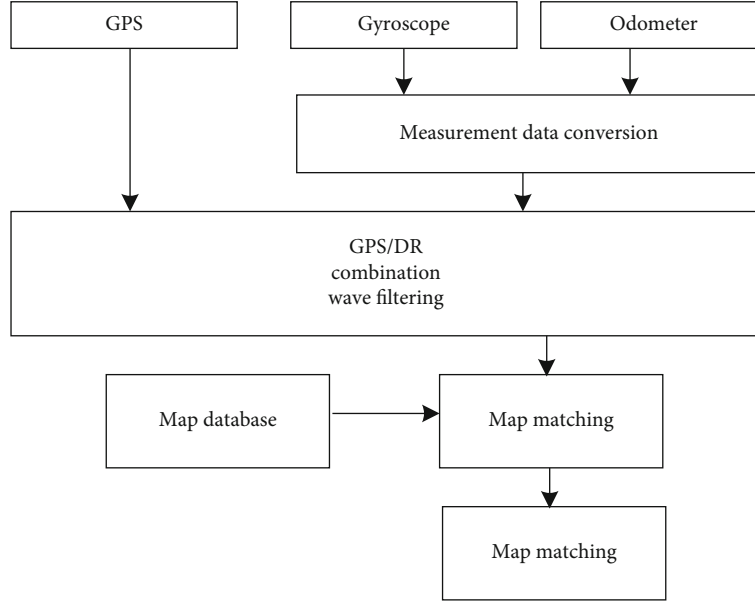


FIGURE 4: GPS/DR/M integrated navigation and positioning control steps.

TABLE 5: Intelligent vehicle information.

Parameter name	Numerical value	Parameter name	Numerical value
Vehicle mass (kg)	1231	Front wheel track (mm)	1481
Sprung mass (kg)	1111	Rear wheel track (mm)	1486
Vehicle width (mm)	1695	Kingpin inclination (deg)	13.7603
Car height (mm)	1535	Caster angle (deg)	3.000056
Wheelbase (mm)	2600	Left and right front wheel brake pressure (Nm/MPa)	250
Distance from centroid to front axle (mm)	1040	Left and right rear wheel brake pressure (Nm/MPa)	150
Distance from centroid to ground (mm)	540	Tire size	185/65R15
Wheelbase (m)	2.6	Sideslip angle of mass center	35°
Preview range (m)	16	Lateral deviation at preview point (m)	0.5
Preview time (s)	0.5	Vehicle longitudinal speed (m/s)	100

integrated navigation is more obvious than the designed systems proposed by Lin and Liao [1] and Su et al. [2], and its positioning accuracy is generally about 18 m. This is because this paper designs a new algorithm based on loose combination and decentralized extended Kalman filtering, using a more detailed GPS coordinate conversion algorithm, replacing the traditional GPS localization scheme, and the software design integrates the secondary development of MapX map control, which significantly improves the positioning accuracy of the system. The figure shows the test curve of GPS/GLONASS/mm three integrated navigation for sports car, as is shown in Figure 6.

The scale of digital map is 1:6000. In the GPS/DR/mm integrated navigation mode, digital map is not only a digital traffic map, behind the digital map is a geographic information database, which should contain all the geographic codes. These geographic information should be corresponding to the two-dimensional or three-dimensional coordinates, because GPS positioning adopts the coordinate mode, and people often only know the destination of the

vehicle rather than the coordinates. The matching accuracy of coordinate point and address should be within 15 m, so that the driver can easily and accurately find the target. When the coordinate value of the positioning system deviates from the road chain of the digital map, the digital map should find the nearest road chain according to a certain algorithm and match the vehicles back. With the driving of the vehicle, the shape of the route should be determined according to the change of the direction of the vehicle and the journey, and it should match with the road network on the map. Map matching algorithm requires high accuracy of the map itself, and map matching is also used to smooth the noise of positioning sensor or positioning system. The system should also be able to determine the best driving route according to the best route algorithm, driving time, driving distance, and other special criteria based on the digital road map. The determination of the best route is not a simple calculation of the shortest route; it needs a lot of map information. The digital map must contain the driving direction and turning limit of each road chain, so as to avoid

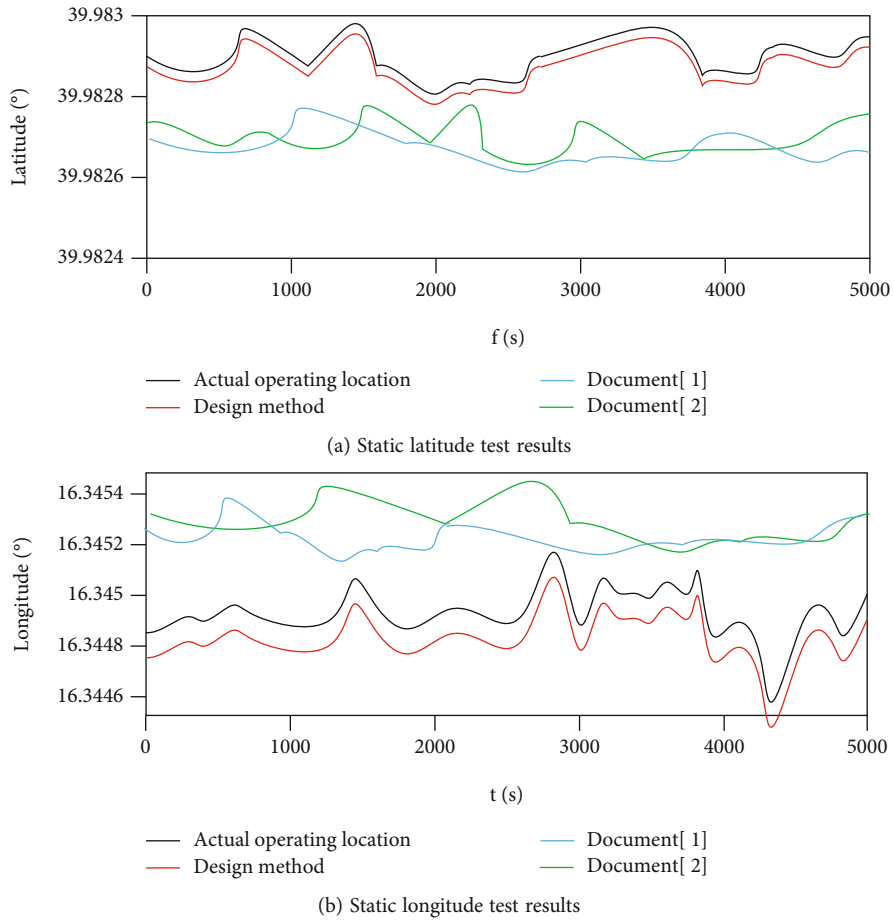


FIGURE 5: Static control test results of GS/GLONASS integrated navigation system.

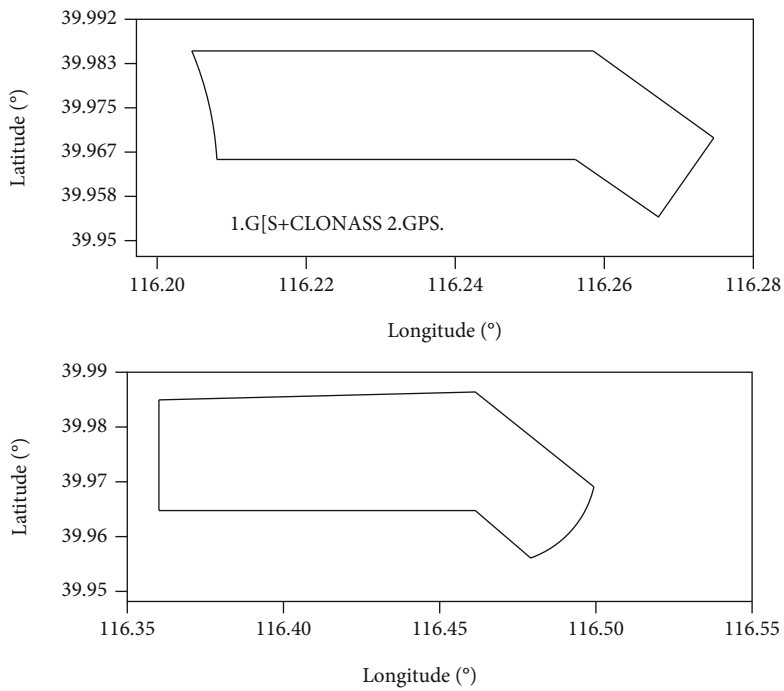


FIGURE 6: Positioning control test curve of GPSGLONASSMM integrated navigation sports car.

the consequences of illegal turning and entering one-way road. The display of the map should have the display function of general graphics, such as local magnification, roaming, and layering. The position of the vehicle shall be indicated on the screen with a certain symbol. For the vehicle positioning and navigation system, the realization of many functions depends on some special features of the geographic information in the digital map, which also shows that the success of vehicle positioning and navigation is directly related to the accuracy and integrity of the digital map and its information.

4. Conclusions

To enhance the positioning accuracy of the vehicle positioning control system, in this paper, the navigation and positioning technology of intelligent vehicle is studied, and the common methods of vehicle positioning and the configuration characteristics and functional characteristics of existing intelligent vehicle navigation and positioning sensors are analyzed. A combined localization algorithm based on loose combination and decentralized extended Kalman filter is designed and matched with the map to display the accurate driving route in the map in real time. According to the function of each module, the communication mode between each module is set, and the positioning information is shared with other control terminals. Finally, through MATLAB simulation and real vehicle test, the design method can improve the accuracy and reliability of the vehicle positioning control and further improve the vehicle operation efficiency and safety. However, due to the limited conditions, the localization system studied in this paper mainly improves the localization accuracy and reliability, but does not significantly improve the localization speed, and future studies can further reduce the localization time.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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