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Research Article

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Design of intelligent vehicle tracking system based on GPS / IMU

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Abstract The realization of unmanned driving of intelligent vehicles requires fast and high-precision positioning and tracking of vehicle positions. Therefore, in this paper, the GPS / IMU combined navigation is used for the highprecision positioning of the vehicle. First, the reference target road is determined, the latitude and longitude data of the road is collected using GPS equipment, and the data is imported into MATLAB to draw the reference trajectory map. Secondly, combined with the non-linear characteristics of the actual working environment of the car, the extended Kalman filter is used to integrate the data of GPS and IMU, and the EKF trajectory is generated in MATLAB and compared with the reference trajectory to show the fusion effect, so as to prove the feasibility of the GPS / IMU combined navigation system designed in this paper. Finally, an automatic tracking control system based on MPC algorithm is designed to analyze the MATLAB / Simulink-CarSim joint simulation to verify the reliability and effectiveness of the control system.

Keywords unmanned driving, combined navigation, automatic tracking control, joint simulation

1. Introduction

Although a single navigation system has its own advantages, it also has its own shortcomings. Such as GPS positioning system positioning speed, powerful, good confidentiality, but because it is through the radio signal information, so there are many disadvantages, such as can be wall reflection block, not indoor positioning, at the same time, GPS due to satellite clock error, calendar error in navigation will produce a lot of error, has certain influence on navigation accuracy [1]. Inertial navigation system can provide position, speed heading, attitude Angle information, navigation information update speed and concealment, but the error of integration will become larger and larger as time goes by.

By combining the navigation system with different characteristics, the multi-functional system with excess degree, high precision and high reliability can be obtained after the specific algorithm calculation. The combined navigation system can not only cover the performance of each subsystem, but also be compatible with a single system mode, so that the information of each subsystem can be fully utilized to obtain the performance [2] beyond the subsystem. At the same time, the combined navigation system integrates the data of each subsystem to expand the application scenarios and improve the accuracy. Positioning technology is a key step in achieving driverless driving. Referring to the algorithm introduced by Jing [3], Kamal [4] and Song [5] and Haitao [6], the work of this paper is to design a tracking system based on combined navigation. Through the construction of the hardware system and the preparation of control procedures, the real-time driving data of the vehicle is accurately identified and calculated, and finally the intelligent vehicle can reach the destination safely according to the prescribed route.

2. Data acquisition and visualization

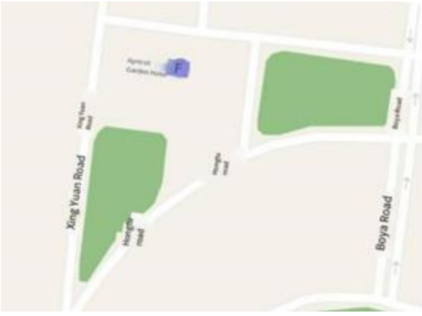


Figure 1: Real path plots of the reference trajectory

Figure 2: *Equipment diagram*

GPS / IMU combination navigation equipment fixed on the electric vehicle platform, correctly put the position of the computer and equipment, using the movement of the tram instead of smart car in the campus to get the target reference road longitude and latitude information, then convert the longitude and latitude information into the corresponding plane coordinates, part of the latitude and converted plane coordinates such as table:

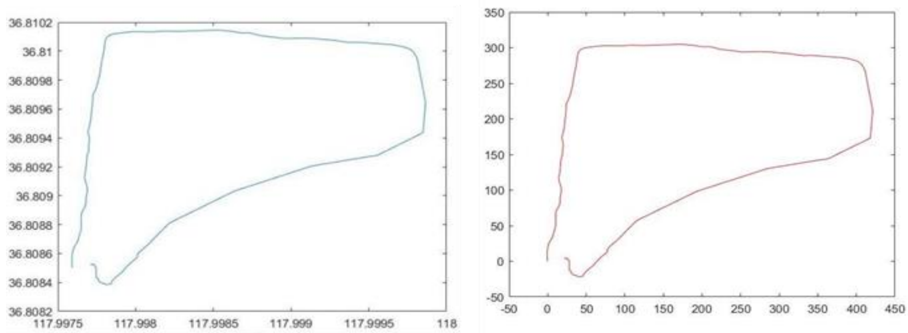
Table 1: Longitude and latitude information of the road section

Longitude	Latitude
117.9975942	36.80850233
117.9975942	36.80850233
117.9975935	36.8085035
117.9975935	36.8085035
117.9975935	36.8085035
117.9975935	36.8085035
117.9975935	36.8085035

Table 2: Part of the converted plane coordinates

X(m)	Y(m)
33189765.805718	7091928.319158
33189765.805718	7091928.319158
33189765.727755	7091928.21696
33189765.727755	7091928.21696
33189765.727755	7091928.21696
33189765.727755	7091928.21696
33189765.727755	7091928.21696

The acquired data are processed using MATLAB software as shown in the figure:



(a) (b)

Figure 3: Reference track diagram (a)Reference trajectory diagram obtained from longitude and latitude (b) Reference trajectory diagram obtained by coordinate transformation

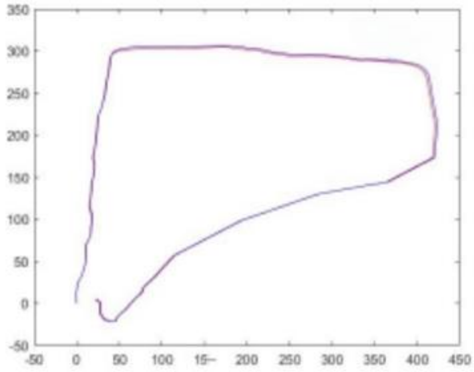


Figure 4: Comparison diagram ofthe trajectory

3. Methods

The automatic tracking control of the car refers to the tracking of the car according to a predetermined route, which includes two aspects of lateral tracking and lateral tracking of the car. Currently, the most used control algorithms are MPC control, PID control, sliding mode control, and neural network control, etc. [7]. In this paper, the MPC control will be used for the design of the automatic tracking control system. MPC mainly consists of three parts: model (establish simulation prediction model), prediction (put forward accurate and reasonable assumptions and constraints), control (implement decision making and verification correction processing).

Model prediction control is a time-related control algorithm, which uses the current state and control amount and the historical state and control amount of the system to realize the control of the future state of the system. The future state of the system is uncertain, so in the control process, the future control amount should be constantly adjusted according to the system state. Model predictive control is a kind of optimization control problem dedicated to the longer time span, even infinite time, decomposed into a number of shorter time span, or finite time span, and still pursues the optimal solution to a certain extent. The schematic diagram is shown below.

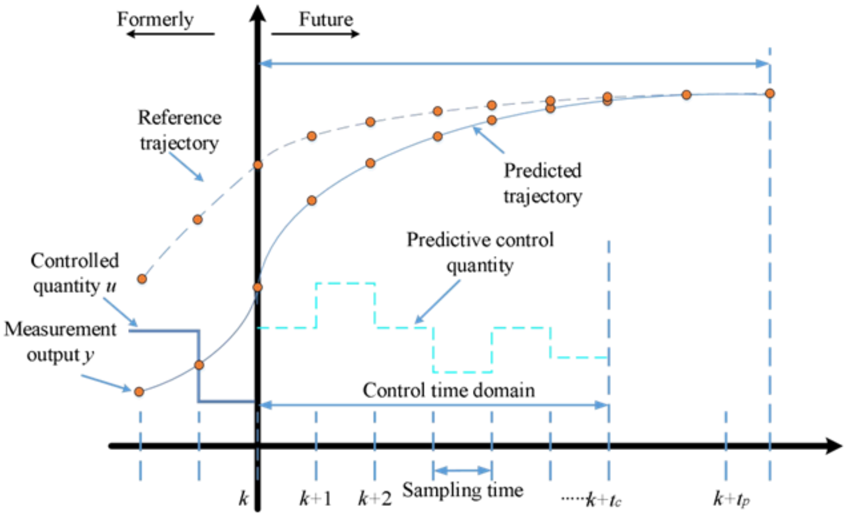


Figure 5: Schematic diagram of model predictive control

In the above figure, the meaning of each curve has been marked. The control amount of the controlled object isμ, and the measured output of the controlled object is y. For the current moment state k, the left side of the k axis is the historical moment state, and the right side of the k axis is the future moment state+1、+2 + +.

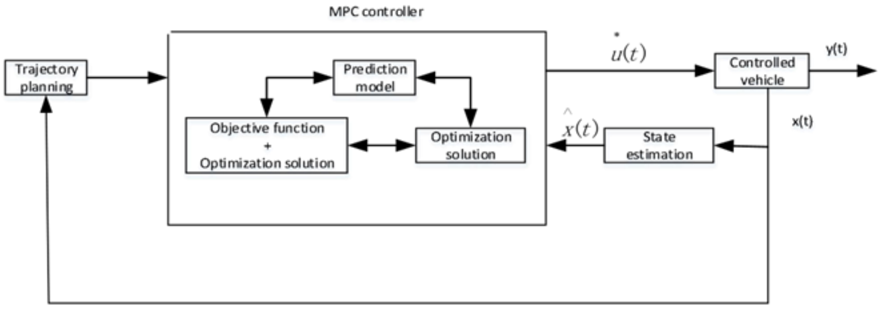


Figure 6: MPC control principle structure diagram

The symbols in the figure are the state quantity at the *t* time, which *() is the optimal control solution settled by the MPC controller at the time, () is the system output state of the controlled vehicle at the time, () is the observed state of the vehicle at the time, but () is the estimated state of the vehicle at the time.

The working steps are briefly described, including as follows:

1) In this structure, the MPC controller establishes a prediction model combined with the current state information and the historical state information.
2) In the case of meeting the constraints, the objective function ∗() is designed to calculate the optimal control solution at this time, and input it into the controlled vehicle, move under this control amount, and output the motion state of the vehicle at the later time.
3) Then the vehicle state () at this time is obtained on the controlled vehicle, and it is input into the state estimator ()to estimate these observed states, and then the estimated state ∗(+1) is input to the MPC controller for optimization solution, so as to obtain the optimal control solution at the next moment.
4) Finally, the above process is repeated at t+1 time, and the continuous control of the controlled vehicle is realized by using the rolling optimization.

4. Experiment and analysis

4.1Simulation model building

Vehicle parameters are set in the CarSim software, the vehicle type selected in this paper is C-class vehicle, and the simulation speed is 36 km/h. Vehicle parameters are as shown in the figure:

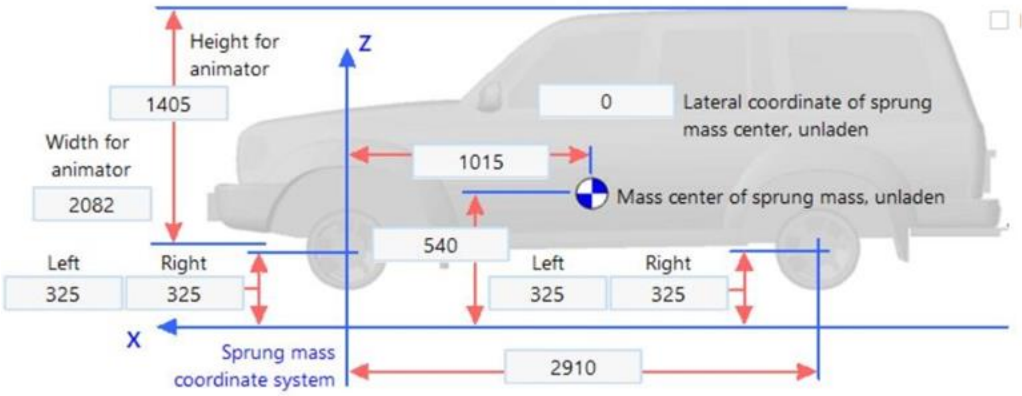


Figure 7: Schematic diagram of vehicle parameters

Table 3: Carsim Description of parameters

Parameter name	symbol	value	unit
Vehicle mass	M	1520	kg
Distance from center of mass to front axis	A	1.455	m
Distance from center of mass to rear axis	B	1.455	m
wheelbase	D	2.910	m
Moment of inertia of the center of mass about the Z axis	I_Z	1520	Kg-m^2
Wheel radius	R	0.330	m
Height of center of mass	H	0.540	m

Simulink-CarSim joint simulation, the actual verification process of double moving curve and circular curve are established and used to verify the feasibility of automatic tracking control system based on MPC algorithm.
CarSim The simulation model is shown in the figure below:

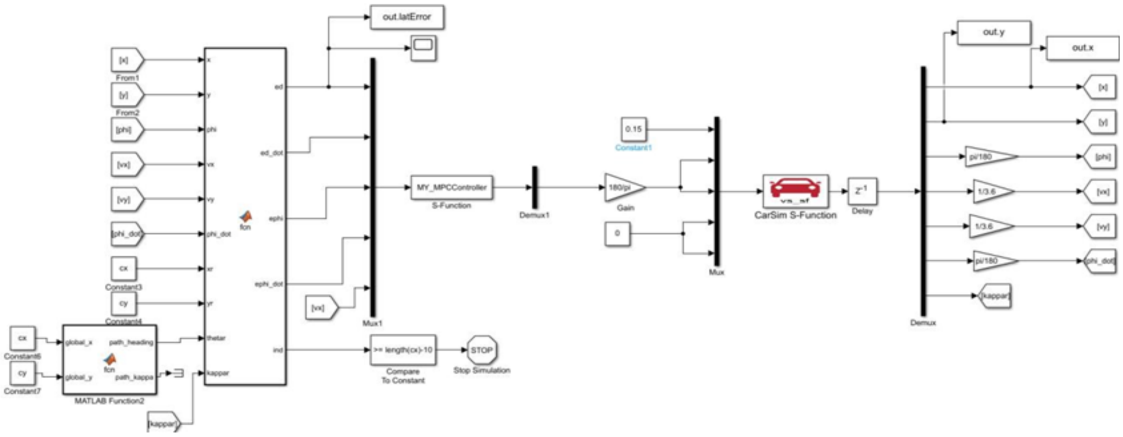


Figure 8: MATLAB/Simulink-CarSim simulation model

1) The left side of the model diagram
The left part of the building principle is to run the abscissa *cx* and ordinate *cy* of the global reference track in MATLAB. Then import it into the established function function module and calculate the heading angle *path_heading* accordingly. In determining the reference road environment, the road curvature of the road may be determined, which may be determined by CarSim Export, and it can also be calculated by itself. At the same time, the moment of the vehicle body abscissa *x* and ordinate *y*, the transverse speed *vx* and longitudinal speed *vy*, the vehicle pendulum *phi* and pendulum velocity *phi_dot* and other parameters input another function function to get the lateral error *ed*, heading error *ephi*, lateral speed error *ed_dot*, heading speed error e*phi_dot*, after the digital information transmission to the MPC control system, analyzed and processed by the MPC algorithm.
2) The middle part of the model diagram
The middle part is the control system part of the whole simulation model. In order to improve the safety and accuracy of the intelligent vehicle in the driving process, the vehicle dynamics model is introduced in this part. The MPC Controller part receives the vehicle posture state information and reference trajectory information from the left side and processes and analyzes it. The control system is to track the reference track coordinate points and control the vehicle based on the vehicle dynamics model, so as to realize the control and tracking of the vehicle in the driving process.
3) To the right side of the model diagram
In the car simulation tracking running, by the control system in the process of the car at every moment movement information, in the model of the output state information as the next moment input into the left model, after calculation and into the MPC controller for correction, cycle makes the system constitutes a closed loop state, feedback adjustment and optimization processing in the ring.

4.2 The analysis of simulation result

1) Set the double shift reference track

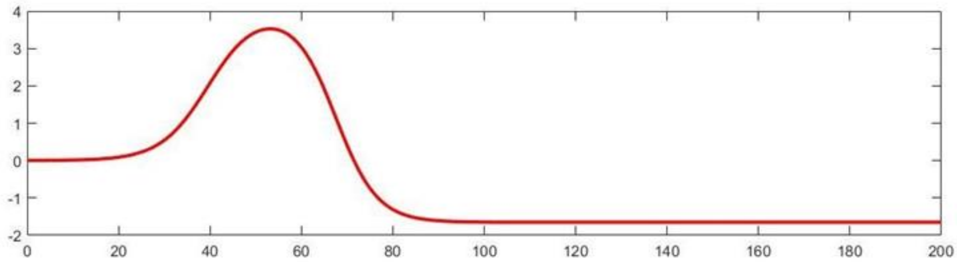


Figure 9: Double shift reference track

2) Actual dual-shift track

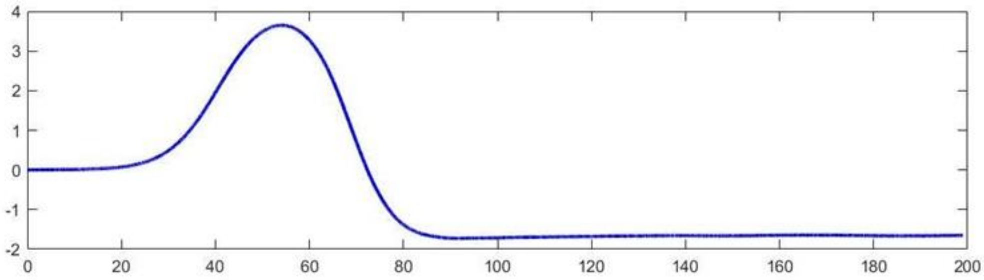


Figure 10: Actualdouble shifttrack

3) Trajectory comparison diagram

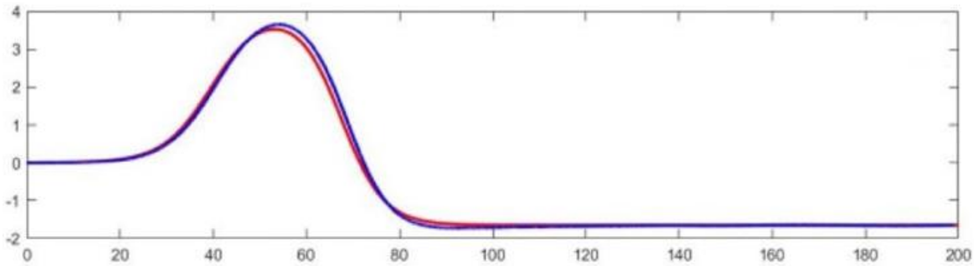


Figure 11: Comparison diagram ofdouble line movingtracks

With the same double shift line track principle, the circular curve track comparison diagram is as follows:

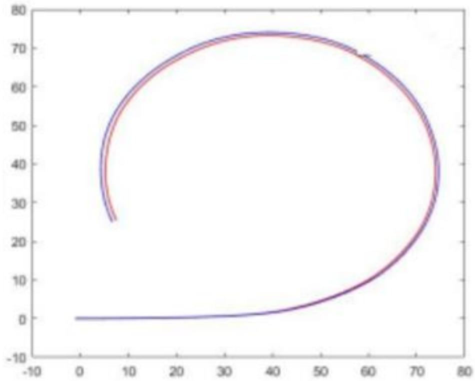


Figure 12: Comparison diagram of classcircle trajectories

The gap between the reference trajectory and the actual trajectory is small. It can be concluded that the automatic tracking control system based on MPC algorithm can effectively control the vehicle tracking, which verifies the feasibility of MPC algorithm in this tracking design.

5. Conclusion

This paper designs a tracking system based on combinatorial navigation. The longitude, latitude and pose information of the reference track are collected by GPS and IMU, and the coordinate transformation is completed. The Kalman filter is used to analyze in MATLAB and verify the feasibility of Kalman filter in data fusion. The joint simulation model of MATLAB / Simulink and Carsim is established, and the corresponding input parameters are set in CarSim. The feasibility of MPC algorithm is verified by visualization. This study is verified through simulation, which lays a foundation for the subsequent real vehicle test.

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