Research on Trajectory Tracking Control of Driverless Vehicle Based on MPC

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Abstract: In the vehicle-human-road traffic, the role of human is the most prominent. However, people often cause traffic accidents because of driving fatigue, drunk driving, driving experience, poor road conditions and other reasons, so people are the most likely to make mistakes in the driving environment. Research on intelligent driverless vehicles not only conforms to the current automotive development trend, but also enables people to get rid of the complex driving environment and reduce traffic safety risks. This thesis mainly studies the trajectory tracking of driverless vehicle.

Keywords: Driverless Vehicle; Trajectory Tracking; Model Predictive Control

Introduction

After entering the 21st century, due to the improvement of people's living standards, the development speed of the automobile industry becomes faster. On the one hand, the continuous growth of automobile annual output shows the high quality and high-level development trend of China's automobile industry at present, and also makes people's life more convenient and comfortable. On the other hand, the increase of motor vehicle also has a great impact on urban traffic and environment, such as the increase of motor vehicle emissions, road congestion, traffic accidents and so on. In order to solve the current complex road transportation problems, the development of driverless vehicle and intelligent transportation system has become the main task of the automobile industry. Driverless vehicle is a comprehensive research field, covering vehicle, machinery, computers, materials and other aspects, including three aspects: environmental perception, path planning and trajectory control.

1. Setup of preview controller

An intelligent vehicle trajectory tracking control system based on forward - looking control is established. First of all, we select in CarSim, determine the vehicle parameters, set the simulation parameters, then set the file specified path in CarSim, input/output interface, and transfer CarSIMs-Function to Simulink. So, a Carsims-function module was added to the Simulink library, which was pulled into and connected to the pre-established track control model. It should be pointed out that the input and output interfaces of the trajectory control mode correspond to the output interface of CarSim one by one, so special attention should be paid to establishing the connection interface. The steering control model was established by using the pre-view algorithm, and the longitudinal speed control model was established by using the model [1]. The MPC model predictive control system can control the longitudinal and lateral forces of the vehicle by using the method of vehicle dynamic limitation. In this way, the driving stability of the vehicle can be improved and the deviation between the real track and the reference track can be reduced.

2. Longitudinal velocity control

2.1 The establishment of longitudinal velocity controller based on PID

On the basis of PID, the longitudinal speed controller is established, and a unified accelerator concept is introduced, through a control quantity to represent the acceleration pedal signal and the brake pedal signal, on the consistent accelerator, when accelerating, when braking. In the aspect of longitudinal speed, the application of PID control technology, the acceleration and deceleration of the car need to take into account the difference between the actual speed of the car and the expected speed. If the actual speed of the vehicle is greater than the expected speed, the vehicle accelerates, and when the actual speed is lower than the required speed, the deviation is negative, at which point the vehicle have to brake. The PID controller takes the speed deviation as the input, and determines the acceleration of the car through the deviation value, so that the car can accurately track the required speed. Speed control is achieved by the accelerator and the brake pedal.

When the actual speed is significantly lower than the required speed, the acceleration mode should be opened to increase the throttle opening, so as to achieve the appropriate acceleration tracking required speed, and when the actual speed is close to the expected speed, it is necessary to reduce the throttle opening to avoid excessive speed and keep the speed constant. In the case that the actual speed is much higher than the expected speed, certain braking power must be applied based on the current speed, road conditions and ride comfort to ensure that the vehicle speed is within the expected speed range [2]. When actual drivers control the longitudinal speed of a vehicle, they usually use fixed acceleration control method to track the required speed to ensure the stability of the vehicle.

2.2 Design of lateral tracking control method based on preview LQR and feedforward

Lateral tracking refers to the use of the front wheel Angle to track the planned trajectory, while the lateral tracking control is based on the current actual position, speed, attitude and other conditions and the expected state information of the planning level, to find the corresponding front wheel Angle, so as to accurately track the planned trajectory. Based on LQR and feedforward theory, a lateral tracking controller based on two-degree-of-freedom model was established. The controller fully considered the dynamic characteristics of the vehicle and realized stable tracking at medium and low speeds.

2.2.1 Design of stable yaw moment control layer based on synovium control

When the vehicle tracks the planned track, it should not only ensure the track tracking accuracy, but also minimize the deviation from the planned track. In addition, the stability of the vehicle is also very important in track tracking, especially under extreme driving conditions, such as in slippery road surface, slippery road surface, high speed and emergency steering, the vehicle is prone to sideslip, tail rejection and rollover. In order to ensure the ride comfort and safety of vehicle in track tracking, stability control must be carried out. Therefore, it is necessary to design a kind of sliding film variable structure controller for controlling the vehicle mass center and yaw angle. The ideal yaw angle and the roll angle of the center of mass of the vehicle are calculated by using the two-degree-of-freedom model, so that the actual yaw angle and the roll angle of the center of mass of the vehicle tend to be ideal, so as to ensure the smoothness of the vehicle.

2.2.2 Variable structure control of synovium

Synovial variable structure is a nonlinear control method, which is mainly manifested as discontinuity of control. Compared with the PID control of the synovial membrane variable structure, it has better robustness and accuracy. The key of the control is to establish a sliding surface according to the control object. On the sliding surface, the sliding surface occurs “synovial motion” near the sliding surface, and the current control method is mainly used to control the lateral torque.

2.2.3 Selection of stability control variables

Vehicle center of gravity roll Angle and yaw Angle speed is an important index of vehicle stability. The yaw Angle and the inclination of the center of mass add up to the inclination of the vehicle. When the yaw angle of the center of mass is small, it can reflect the steering performance of the vehicle, while too large yaw angle will lead to excessive steering of the vehicle. Under extreme conditions such as in low adhesion road surface, vehicles are prone to sideslip and other unstable phenomena. In the process of sideslip, due to the large deflection angle of mass center, it is particularly important to study it

[3]. If the center of mass deflection of the vehicle is large, the yaw moment of the vehicle cannot be controlled by using the front wheel angle under unstable conditions. That is, lateral control is no longer effective. In order to ensure the stability of mass roll angle and yaw angle, the longitudinal direct swing moment controller is used to realize the additional yaw moment. By selecting the combined control of the center of mass and yaw angle velocity, the center of mass and yaw angle velocity can meet the predetermined requirements, so as to obtain the optimal yaw moment required by the smooth running of the vehicle. The combined control method of center of mass and yaw angle can overcome the effectiveness of single control method.

3. Model predictive control principle

An optimal control algorithm for industrial production is proposed in Europe and America. After several years of development, has been widely used in industry, intelligent control and other fields. Due to the continuous improvement of algorithm theory, it has been widely used in industry. Although in different fields, different algorithms are used differently. But they all follow the basic principles of predictive modeling, rolling optimization and feedback correction.

3.1 Predictive model

The predictive model is based on the prediction of the real-time state of the controlled platform. The model can make real-time prediction of the current state of the controlled platform and compare it with the control input in the future. There is no definite formal requirement for the model form, so state space equation, transfer function, impulse response model, fuzzy model and so on can be adopted. Based on the control objective and the required prediction, the state space model is suitable to select an appropriate predictive model.

3.2 Rolling optimization

Compared with the general discrete optimal control method, the optimal solution of predictive control is a rolling finite time domain optimization method. At each sampling time point, the optimal control rate is calculated based on the optimal performance index at the time point. In this method, only the control action is calculated, and the optimal control rate is calculated again in the next sampling time. This means that the optimization process is not done offline once, but online again and again, at each sampling point, the optimal performance index includes only a limited period of time from that moment into the future, and then the optimal cycle will advance synchronously at the next sampling point. On this basis, the rolling optimization method can not only consider the optimization in the finite time domain, but also effectively solve the uncertain problems in reality. This method is more practical and effective than traditional optimal control under ideal conditions.

3.3 Feedback correction

The open loop optimization problem is the solution of predictive control. In terms of predictive control, it is the most ideal method to use predictive model to predict, but in actual production, due to the existence of nonlinear, time-varying, model mismatch, interference and other unstable factors, the model prediction results can not accurately reflect the actual situation. In predictive control, the prediction error is obtained by comparing the prediction result with the forecast estimate of the model, and then the prediction result is corrected by the prediction error to obtain more accurate future output. MPC controller combines prediction model, objective function and constraint conditions to achieve the optimal solution. On this basis, the optimal control sequence is obtained, and it is input to the controlled platform, which completes the received control command, and then the state quantity observation value of the current time is input to the state estimator. State estimators estimate states that cannot be directly observed, such as the coefficient of surface adhesion. By inputting state quantity to MPC controller, the optimal solution is carried out, and the control parameters required by the control system at the next time are obtained. Thus, a complete predictive control process is formed.

4. Conclusion

To sum up, trajectory tracking control of driverless vehicle based on MPC can achieve better trajectory tracking. In this paper, a relatively simple two-degree-of-freedom kinematic model of vehicle is adopted in the process of vehicle model selection. However, with the deepening of research, we should consider the vehicle dynamics factors, because in the process of vehicle driving, its dynamics factors will also have a relatively large impact on the vehicle driving state, so it is very necessary to consider the dynamics factors.

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Project Name：

1. Project supported by the foundation of the natural science of universities in jiangsu province,
project number :22KJB120002.

2. Jiangsu University Students Innovation and Entrepreneurship Program, Research on Automobile safety early Warning System based on machine vision.