Collaborative vehicle steering and braking control system research

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Abstract. The vehicle steering and braking conditions, braking systems and steering systems there are complex coupling between each other, the security and stability of the vehicle will have a dramatic effect when, in order to improve the stability of the vehicle you must brake system and steering system for joint control. Firstly, the establishment of a vehicle model of the vehicle, wheel model, steering model for analysis in the simulation environment and research vehicles both steering and braking condition of the vehicle dynamic performance and usability verification controller design basis; and then were in the braking system and steering system for the study, with no model control method, designed single-wheel antilock vehicle brake controller, the vehicle antilock brake controller; and finally, based on model free control method, design coordination collaborative vehicle steering control systems and braking systems, successfully resolved the vehicle coupling phenomena of the two systems, designed to improve the effectiveness of the braking condition of the vehicle steering and braking and steering stability, ensure the steering while the vehicle is in a stable shorten the braking distance.

Introduction

With the rapid development and theoretical research level of vehicle technology in depth, people for steering stability of the vehicle, driving safety and ride comfort and other requirements are increasing, prompting a variety of electronic control technology is widely used on the vehicle .Braking performance and steering performance in handling stability of the vehicle is particularly important. Both mutually influence each other constraints, but both stability is an important index of the vehicle chassis stability, thus making essential to achieve a synergistic effect on improving vehicle performance and stability between the two. Therefore, steering and braking condition of the vehicle stability control study is necessary. Due to the rapid development of computer technology, computer simulation is playing an increasingly important role in the controller design and research. Computer simulation study on vehicle stability can draw comparisons and is very close to the actual results, the performance indicators able to study the stability of the vehicle for proper evaluation.

Design of vehicle model

As the vehicle control system is more complex, and do not use a real car experiment into this high and very risky, so the design of the vehicle control is usually achieved through computer simulation. Matlab software based on the subject vehicle Simiulink module model. Using Simulink module easy to use, you can not perform any programming, connected only by the direct use of transfer functions and block diagrams, dynamic simulation, will be able to achieve the desired control system model is established, simulation and analysis, can be directly observed and various parameters required changes.

Establishment of vehicle model.

Establishment of a whole vehicle model has nine degrees of freedom in modeling ignored the vehicle suffered during the drag and rolling resistance of the tire, according to the vehicle dynamics can build the vehicle model vehicle, vehicle model vehicle cross swing direction of balance equations, based on kinetic analysis can be obtained:

$$I_s\dot{\gamma} = [F_{xt}(2) - F_{xt}(1)]\cdot\frac{d}{2} + [F_{xt}(4) - F_{xt}(3)]\cdot\frac{d}{2} + [F_{yt}(1) + F_{yt}(2)]\cdot l_f - [F_{yt}(3) + F_{yt}(4)]\cdot l_r \quad (1)$$

The angle between the forward direction of the vehicle vehicle model vehicle ox axis coordinate system is:

$$\beta = \arctan\frac{v}{u} \quad (2)$$

Establish wheel model.

An important part of the vehicle wheels are connected vehicle contact with the ground, it plays a role as a bridge to connect the mechanical transfer vehicle and ground vehicles. The simulation model based on the wheel, the wheel can be established around the spin axis of the model is:

$$J_{Tx}\dot{\omega}_x = F_x r - T_b \quad (3)$$

among them:

J_{Tx} - Moment of inertia about the spin axis of the wheel; $\dot{\omega}_x$ - the wheel angular acceleration about the spin axis;

F_x - Longitudinal forces suffered tire; r - wheel radius; T_b - wheel braking torque suffered.

Modeling of the steering.

Vehicle steering herein are also important research object, so set up a steering vehicle model is also very necessary. To facilitate the study, the subject of two degrees of freedom called linear input to the steering system model is described. The model front wheel steering angle additional angle as input, the output of the vehicle sideslip angle and yaw rate, and taking into account the sliding of the vehicle.

Linear two degrees of freedom angle input model:

$$\dot{x} = Ax + Bu \quad (4)$$

Controller design

Vehicle brake controller design goal is to design a vehicle anti-lock brake controller, so that the vehicle has a good braking effect, while maintaining the performance of the vehicle steerable.

Single-wheel brake controller design model.

To facilitate the study of this topic, only the single-wheel anti-lock brake controller models are designed and studied. Brake controller design using model free control method. In the control process, the information collected by the processing process, estimate the model in which the state of the wheel, and then use the general method of model-free control of the model control, namely the modeling method side edge control. When the anti-lock brake controller design a single on the model does not consider the transfer of vehicle steering and load, and the road conditions seen unchanged. For a single wheel, its pan-model can be written as:

$$y(k) - y(k-1) = \varphi(k)^T[u(k-1) - u(k-2)] \quad (5)$$

But the single wheel anti-lock brake controller is not directly used to control the vehicle model, because it is only a partial role, not taking into account the situation with four wheels, this part of the design but proved no model controlled anti-lock brake controller design feasibility applications.

Vehicle brake controller design model.

Vehicle model for the design of anti-lock brake controller, considering only brake the vehicle when driving straight, without regard to the steering, while the vehicle is assumed that the surface of the open road, namely the road as the vehicle four wheels . When designing the controller uses the same model free control method. The vehicle's anti-lock brake controller by changing the role of the four wheels to control braking torque on the vehicle, so that the four wheels are always in the vicinity of the optimum slip rate the slip rate to shorten the braking distance and to maintain the stability of the vehicle, while the four-wheel yaw rate to zero with so stable driving purposes.

Thus, the Pan-model system can be written as:

$$\begin{bmatrix} S_1(k) \\ S_2(k) \\ S_3(k) \\ S_4(k) \\ V(k) \\ \gamma(k) \end{bmatrix} - \begin{bmatrix} S_1(k-1) \\ S_2(k-1) \\ S_3(k-1) \\ S_4(k-1) \\ V(k-1) \\ \gamma(k-1) \end{bmatrix} = \varphi(k)^T \left(\begin{bmatrix} T_{b1}(k-1) \\ T_{b2}(k-1) \\ T_{b3}(k-1) \\ T_{b4}(k-1) \end{bmatrix} - \begin{bmatrix} T_{b1}(k-2) \\ T_{b2}(k-2) \\ T_{b3}(k-2) \\ T_{b4}(k-2) \end{bmatrix} \right) \quad (6)$$

No model antilock brake controller designed in this paper is by adjusting the braking torque distribution over all four wheels to achieve control of the vehicle. By influencing the brake torque to change the face of the force of each wheel, thereby controlling the movement of the body. In order to ensure the maneuverability and stability of the vehicle in the process, prevent slippery drag phenomenon, we must make the four wheel slip ratio in the stable area, preferably near the optimum slip ratio.

Design collaboration Controller.

Under ideal conditions, with no model control when the basic form of the design of the brake controller works well alone suppress external interference, stable and timely control purposes. But the vehicle system is a complex system, linkages between the various subsystems, mutual influence and mutual restriction. Especially between steering and braking systems, the presence of complex dynamic relationship, mutual coupling phenomenon is very serious.

Coordinated controller designed herein is not a brake controller and the steering controller in the upper system controller separately control the two work together, but the design of the two controllers, the two controllers to enhance their robustness, thus avoiding interference by coupling with each other, to achieve the purpose of the two systems work together.

No model brake controller function module constructed as follows:

$$k_s(S_{ik-1}^{k-n}) = \frac{\sum_{j=k-n}^{k-1}(j(S_{i0}-S_i(j))) - \frac{1}{n-1}\sum_{j=k-n}^{k-1} j \sum_{j=k-n}^{k-1}(S_{i0}-S_i(j))}{\sum_{j=k-n}^{k-1}(S_{i0}-S_i(j))^2 - \frac{1}{n-1}(\sum_{j=k-n}^{k-1}(S_{i0}-S_i(j)))^2} \quad (7)$$

The idea is that when the actual amount charged and the amount of the difference between the ideal accused steep slope, the control effect is obvious, when the slope is small, control action is reduced, so that timely and accurate steering vehicle tracking ideal steering track and maintain robust.

Vehicle Simulation Design

Single-wheel brake simulation model.

In order to verify the control effect model free control brake controller, first we analyze in the case of single wheel braking, the braking effect of the controller. Speed single-wheel model with initial velocity 20m / s traveling on the road is better on the road, set the road adhesion coefficient of 0.8. T = 0s at the moment to send commands to the automatic brake controller, start braking. Analysis using model-free brake braking effect classic PID controller and brake controller.

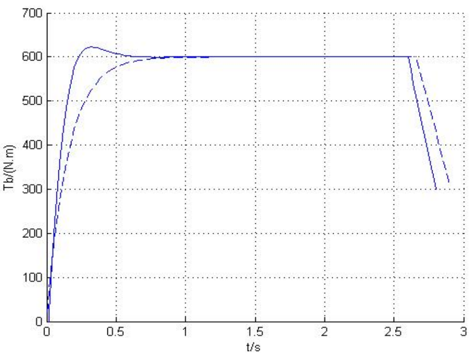


Figure 3

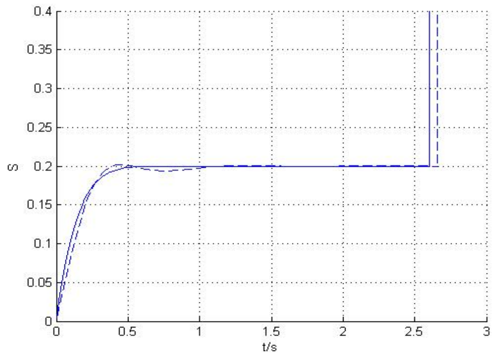


Figure 4

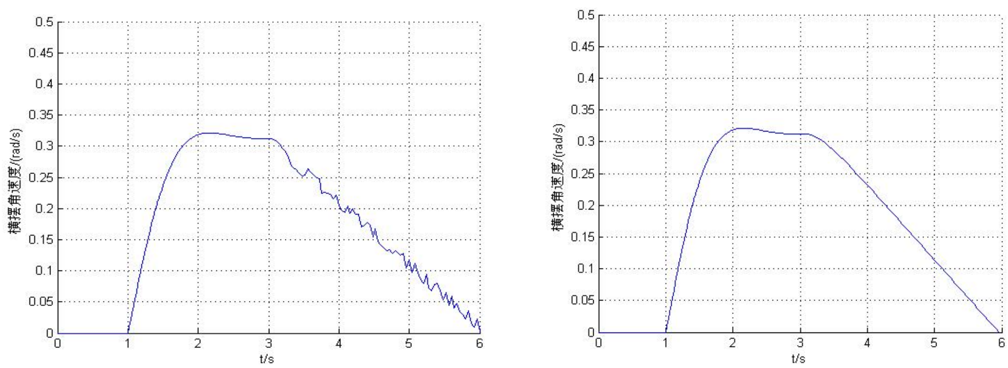
Figure 3 is a result of both the controller generates braking torque. The solid line in response to non-model brake controller lose braking torque, dashed brake PID controller output in response to the braking torque. As can be seen from the figure, the response speed without braking control model than classic PID brake controller slightly faster.

Figure 4 is at two brake control when braking a single wheel model change of the slip rate. The solid line in the absence of changes in the model single-wheel brake controller model slip rate, the dotted line is in the brake PID controller changes the role of a single wheel slip ratio model. Through the analysis shows that in the absence of models brake controller, single-wheel slip ratio model is relatively stable, maintaining optimum slip ratio at 0.2, while in the brake PID controller, single wheel slip ratio model basically stable, but there are slight fluctuations.

From the above simulation results, the single wheel model simulation experiments verify the control effect when the two models, two models can be used to stabilize the vehicle stopped, to achieve the desired braking effect, the control model free brake controller braking effect is slightly better than PID controller. Since the single-wheel model the environment is ideal, suffered constant load, so in this case the advantages of model-free brake controller does not fully reflected. To take advantage of model-free controller, we have to continue to experiment.

Collaborative Control Simulation.

Vehicle steering conditions, the steering and braking systems interaction and mutual coupling can cause interference with each other. In the two systems co-steering and braking conditions, to stabilize the vehicle driving is necessary. In this section we will analyze the steering and braking conditions, the use of model-free method of controlling cooperative effect of two in order to design a good system of control.



(a) (b)

Figure 5 yaw rate

Figure 5 is a vehicle steering and braking condition of the vehicle yaw angular velocity curve. Wherein Figure (a) is the absence of coordinated control of vehicle yaw rate change, when the time t = 3s after starting the braking, the yaw angular velocity of the vehicle received a strong interference, which is due to the braking system for the steering system influences. Figure (b) is added after coordinated controller yaw rate of change, it can be seen from the figure, in the role of co-controller of the vehicle steering is possible to suppress interference from the braking system, so that the vehicle can be stabilized steering, to control the effect.

Through simulation results, in the vehicle steering and braking conditions to join the coordinated controller, significantly enhanced braking stability, braking distance was shortened over the steering while the ability to track the trajectory, can achieve the purpose of stable steering. Coordinated controller can well coordinate braking and steering systems work, to lift the mutual interference between the two systems.

Conclusion

In the braking system and steering system of the vehicle for the study, the use of model-free control design methods were designed single wheel antilock brake control, the vehicle antilock brake control; in the end analysis and brake systems After turning the system interaction coupling factor, re-use model free control method, the brake controller and the steering controller has been improved and amended to improve the robustness of the two systems, and finally the two systems can work together to achieve the purpose, enabling the vehicle steering and braking conditions, both steady with steering, brake in time but also shorten the braking distance. This is the first model free control method will be applied to the brake control of the vehicle and steering controller designs, while using two methods to improve the robustness of the system are two systems to work together to achieve the purpose of steering and braking of the vehicle stability control .

Simulink platform to build on the vehicle model, for a single wheel braking of the vehicle, the vehicle steering and braking conditions a simulation experiment, and each performance of the vehicle carried out a detailed analysis of viable verification controller designed in this paper and effectiveness.

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