OPTIMAL PATH FOLLOWING ROAD VEHICLE STEERING CONTROL

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Summary

Previous work in which the theory of the linear quadratic Gaussian regulator was applied to path following steering control of a car is applied to determine differences between drivers with different priorities and vehicles of different configurations. A new criterion for optimising a vehicle is introduced.

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In a previous paper [1], the theory of the Linear Quadratic Regulator was applied to minimum error path following control of an automobile. The car "driver" was represented as able to preview the path to be followed, in discrete time, and to convert the previewed path data samples, relative to the car, into steering control inputs which cause the car to follow that path with precision. The solution to the optimisation problem accepted was the time invariant steady state one, implying optimality over infinite time if the road disturbance is a Gaussian white noise process. It also implied that the control law is of state feedback form, which means that the control can be determined off-line. It was argued that the preview control was, to some extent, an inverse of the vehicle lateral dynamics. The cost function minimised contains weighted contributions from path error, attitude angle error and steer angle utilisation, such that different driving strategies can be examined and compared. Simulations showed the path following of the optimally controlled neutral steering simplified vehicle to be excellent, over several variations of path type.

Using the same theoretical basis, new results are here generated to show optimal preview controls for cars with different front to rear balance and with different natures (touring and sports). Tight and loose controls are demonstrated by the control laws themselves, Fig. 1, and by path following simulations.

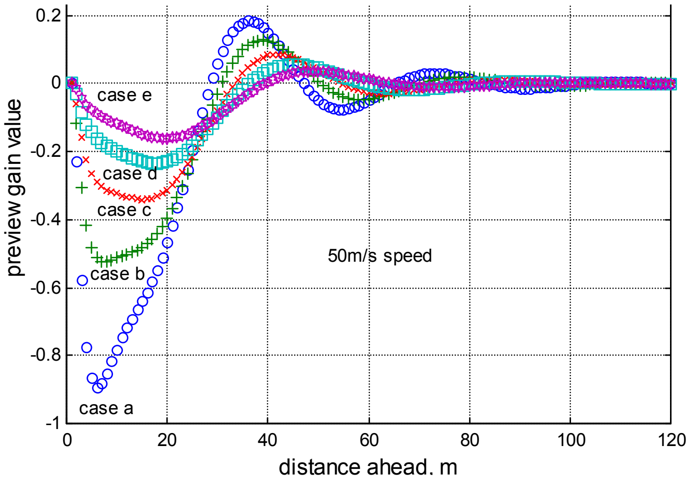

Fig. 1 Preview control gain sequences for a representative car at 50m/s with variations in control authority. Case (a) involves the highest cost on path errors relative to the control power while case (e) involves the lowest.

As can be observed in Fig. 1, the use of the preview data involves diminishing returns. Further away from the car, the path information is of little value. This gives rise to the notion of a required preview distance, which is a function of the vehicle design and the speed, for full path following performance. This notion is quantified and a new car performance criterion is set up, involving the minimisation of the required preview distance. The car is specified by only six basic parameters; the mass, M; the yaw inertia, Izz; the distance from the mass centre to the front axle, a; the corresponding distance to the rear axle, b; the front axle cornering stiffness, Cf and the rear axle cornering stiffness, Cr. The sensitivities of the required preview distance to variations in the car design parameters are calculated, Fig. 2. According to the criterion, it is advantageous to raise b and Cr and to lower Izz and M. The performance, in the current sense, is less sensitive to a and Cf.

The influence on the required preview distance of steering the rear wheels in proportion to the front steering is also shown, Fig. 3. Steer angle ratios up to 0.5 do not have a big influence but from 0.5 to 0.7, the necessary preview distance is reduced substantially and the preview gain sequence is simplified, Fig. 4, suggesting two separate sources of advantage to real drivers. Oscillatory steering control ahead of a uni-directional turn for a rally car at high speed on loose ground, as commonly observed in practice, is demonstrated using the theory. The results yield new insights into driver steering control behaviour and vehicle design optimisation. They lead to some important conclusions about the way ahead for driver modelling from a steering control viewpoint.

[1] Sharp, R. S. and Valtetsiotis, V., Optimal preview car steering control, Supplement to Vehicle System Dynamics, **35** (P. Lugner and K. Hedrick eds), May 2001, 101-117.

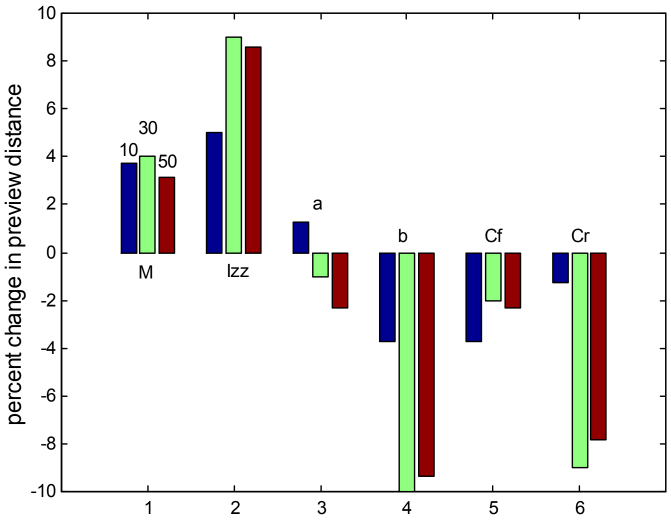

Fig. 2 Sensitivities of required preview distance to design parameter changes for 10, 30 and 50m/s speeds.

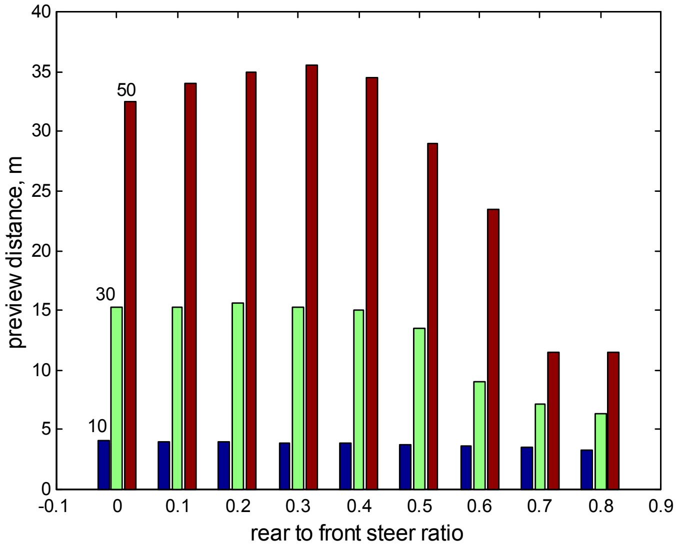

Fig. 3 Required preview distance as function of ratio of rear to front steer angle for 10, 30 and 50m/s speed.

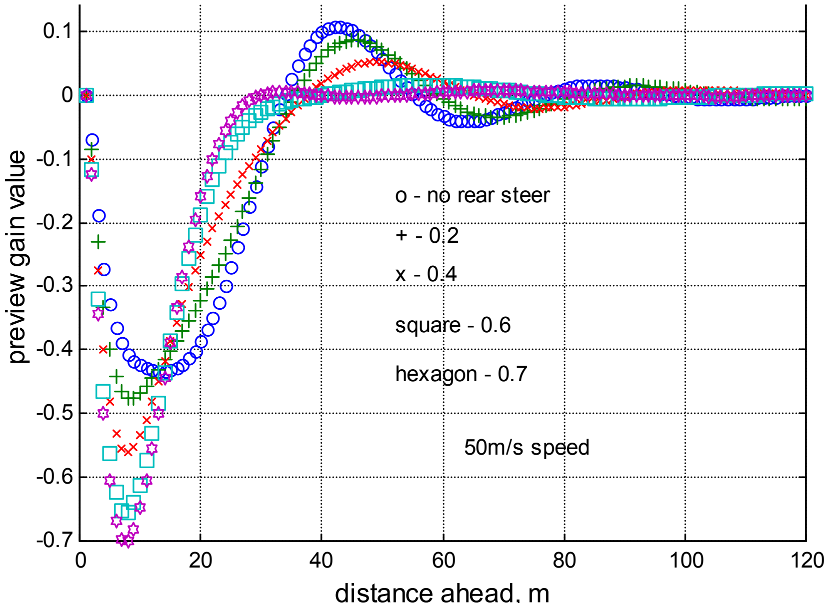

Fig. 4 Preview gain sequences for car with variations in rear to front steer ratio for 50m/s speed.