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Rider control of a motorcycle near to its cornering limits

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Abstract

In previous work [1, 2, 3, 4, 5, 6, 7, 8], skilled riding of single-track vehicles has been depicted as involving optimal control with full preview of the path to be followed. Linear optimal preview control theory has been developed and applied to the separate representations of steering and speed control and it has been argued that the full range of feasible vehicle motions can be covered by adaptation of the controls to the running conditions.

General well-ordered vehicle motions are seen as entailing small perturbations from trim (dynamic equilibrium) states. At any particular time, an appropriate trim state is chosen as a reference state for the motions occurring and the linear optimal preview control scheme belonging to that trim state is employed temporarily. Gain scheduling by interpolation allows the controls to adapt to the changing running state.

In the present case, the separate representations of steering and speed control for a high-fidelity and well-documented motorcycle [9, 10] are combined into simultaneous path and speed (x, y, t) control. Optimal throttle, steering and rider-lean controls are generated for trim states with variations in speed and lateral acceleration, and they are used to illustrate how the controls change as the running conditions alter. In particular, as the lateral acceleration increases towards the limit of physical possibilities, the control authority decreases towards zero and these influences are reflected in the optimal controls. Exemplary preview control gains, with sampling interval 0.05 s and 10 s preview time, are shown in figure 1 as functions of lateral acceleration for a fixed speed of 30 m/s. Similar figures show throttle position to x-error gains and cross-coupling effects when the motorcycle is cornering.

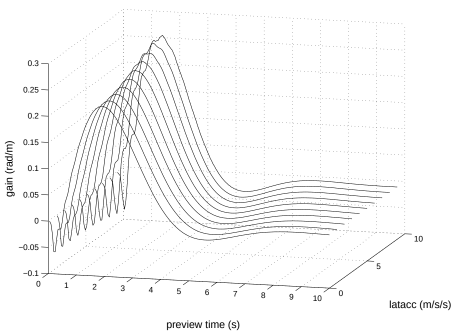

Figure 1. Optimal preview y-error to steer torque gains as functions of lateral acceleration for a speed of 30 m/s, for 10 s preview.

Other new results available comprise frequency-responses of rider-controlled systems, indicating tracking capabilities, and path-tracking simulations. These simulations include a lane-change manoeuvre with speed variation and control adaptation over speed and lateral acceleration by bilinear interpolation, figure 2, and constant speed clothoid manoeuvres up to the lateral acceleration limits. Results to be shown in the paper will be selected from this library.

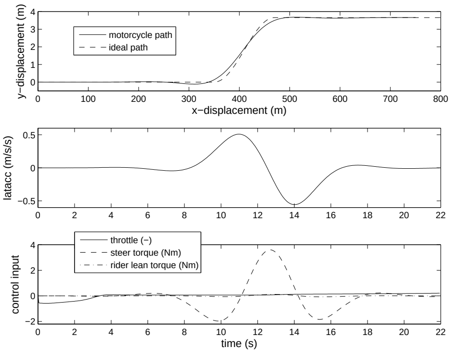

Figure 2. Motions occurring in a lane-change with bilinear gain scheduling by speed and lateral acceleration. The speed starts at 50 m/s, decreases to 30 m/s after 3.5 s and builds up to 47 m/s again from 13 s on.

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