EVS35 OSL2022

Optimizing Torque Delivery for an Electric Race Car Using Model Predictive Control

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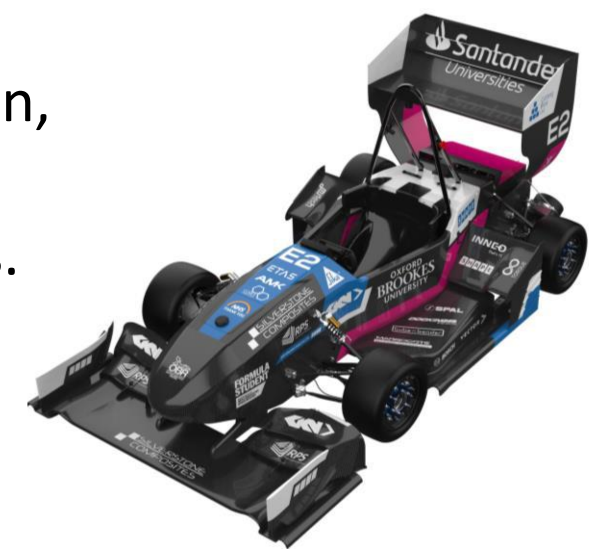
Summary

Limited battery capacity requires energy management to minimize race time while managing overall energy consumption to finish the race. A novel energy-managing model predictive torque control algorithm was developed to optimize lap time performance and manage energy consumption.

Introduction

In order to minimize lap time and simultaneously reduce energy consumption, the controller must use energy when it contributes most to acceleration. As drag forces square with velocity, energy use is most efficient at lower speeds. Simultaneously, the race car must finish the race, and with the minimum energy left in its battery. A dynamic optimization problem was created to control this Single Input Multi Output plant.



Methodology

The longitudinal dynamics of the vehicle were represented by a linearized first-principles model. A Simulink-based Model Predictive Controller (MPC) architecture was created to balance energy use requirements with optimum lap time. This controller was then tested against a hardware-limited system as well as a torque-limited system in a constant torque request and varying torque request scenario.

Setpoints and Weighting

An energy use trajectory was created to depict the preferred energy spend strategy for the race. Weighting for each input was determined on an experimental basis, weighting towards the driver's torque request. As velocity increases, a greater cost is incurred. Similarly, as energy spend exceeds the predetermined trajectory, energy use is further penalized.

Results

The controller decreased the elapsed time to complete a 150m straight line acceleration by 11.4% over the torque-limited solution, and 13.5% in a 150m representative Formula Student manoeuvre.

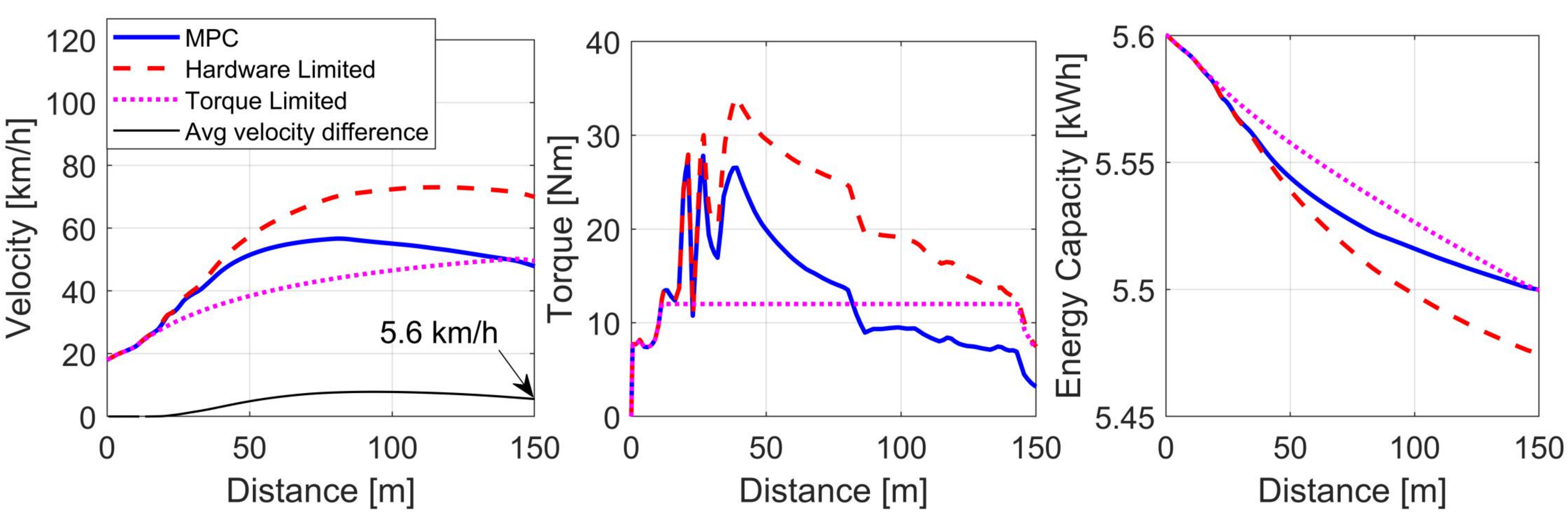


Figure 1: From left to right, Formula Student manoeuvre torque request scenario. Speed profile, torque request and energy remaining in the battery.

Future Development and Applications

While energy use limits were used in the single-input multiple-output (SIMO) model, thermal and State of Power (SOP) limits can also be introduced. Though a motorsports derived application demonstrates the technology, this energy expenditure control strategy easily transfers to known-mission industrial applications such as mining and agriculture. Further developments include a higher level energy/mission hypervisor, with lower level controllers for thermal and SOP limits.

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