

Vehicle Dynamics and Control 2015

A one-day seminar to explore recent developments in the design and analysis of road vehicle dynamic behaviour

Programme and Registration

Tuesday 17 March 2015

Murray Edwards College, Cambridge, UK

www.vehicledynamics.org



UNIVERSITY OF
CAMBRIDGE
Department of Engineering

Vehicle Dynamics and Control 2015

A one-day seminar to explore recent developments in the design and analysis of road vehicle dynamic behaviour will be held at Murray Edwards College, Cambridge on **Tuesday 17 March 2015**. The seminar will be of benefit to engineers working in many branches of vehicle and component engineering including research, design, development, testing and competition. The topics covered are relevant to a broad range of vehicles including road and racing cars, bicycles and trucks. Fifteen presentations in four sessions will cover steering control, control at limits of adhesion, tyre and vehicle dynamics, and racing. Each presentation will be followed by audience questions. Refreshment breaks and lunch will offer opportunities for further discussion.

The cost of attending the seminar is £80 inclusive of lunch and refreshments (exempt from VAT). Register and pay by following the link at www.vehicledynamics.org. The closing date for registrations is **Monday 9 March 2015**. Note that the total number of delegates is limited to 120 so registration may close before this date. Delegate names may be changed at any time.

One author of each presentation may attend free of charge. Current staff and students of Cambridge University may attend at reduced rate. Please contact Claire Whitaker (cw535@cam.ac.uk) if you wish to take up one of these options.

For enquiries about the programme please contact Dr David Cole, djc13@cam.ac.uk. For enquiries about registration or overnight accommodation please contact Claire Whitaker, cw535@cam.ac.uk.

Vehicle Dynamics and Control 2015
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Outline Programme (may be amended)

09.30 Registration and refreshments
10.00 Session 1 – Steering control
11.00 Refreshments
11.25 Session 2 – Control at limits of adhesion
12.45 Lunch
13.55 Session 3 - Tyre and vehicle dynamics
15.15 Refreshments
15.40 Session 4 - Racing
17.00 Close

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Programme (content and timing may be amended)

9.30 Arrival and refreshments

Session 1 – Steering control

10.00 Assessing vehicle handling quality.
David Cole (University of Cambridge)

Active steering and other chassis control technology provide great freedom for tuning the response of a vehicle to driver inputs (steering/accelerator/brake). In the motorsport world, mathematical simulation enables vehicle parameters to be optimised to minimise laptime. Despite these advances in technology and simulation, much remains to be understood about subjective vehicle handling quality. In this presentation recent developments in theoretical understanding are reviewed and future directions of research are discussed.

10.20 Modeling and compensating friction in electric power steering.
Robert Fuchs, Frédéric Wilhelm and Tsutomu Tamura (JTEKT R&D)

In electric power steering, friction affects both the vehicle performance (objective) and the driving feel (subjective). Compensating the effects of friction is motivated by the benefits gained from simpler tuning of the EPS control. Here, a model-based control strategy is presented for the compensation of the friction in a mass-produced column EPS. It relies on a reduced physical model of the column. Experimental results demonstrate the performance and the robustness of the control, which forces the column response close to that of a linear, frictionless system.

10.40 Rider optimal control identification in bicycling.
Arend Schwab (TU Delft)

Rider control in bicycling is modeled by first adding the rider as a passive mechanism to the Whipple bicycle model. Next, a linear PID controller with and without delay is assumed, where the control inputs are the bicycle roll and steer angle with their higher derivatives, and the control output is the torque applied by the rider at the handle bars. Experimental data is obtained from riding a bicycle on a narrow treadmill. The experiments are conducted in both the stable and the unstable forward speed range. A parametric control model is fitted to the data, and the gains of this control model are used to identify LQR cost function which the rider is using.

11.00 Refreshments

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Session 2 – Control at limits of adhesion

11.25 Simultaneous braking and steering of articulated heavy vehicles

Graeme Morrison and David Cebon (University of Cambridge)

Compared to a conventional anti-lock braking system, wheel slip control can substantially reduce the stopping distance of a heavy vehicle. However, this may be at the expense of directional performance in simultaneous braking and steering maneuvers. A model-based approach to stabilize the vehicle under such conditions is demonstrated. Nonlinear simulations indicate that the system can restore the directional performance of a tractor-semitrailer under heavy braking to that achieved with a conventional anti-lock braking system, while sacrificing less than 10% of the braking improvement given by slip control.

11.45 Integral sliding mode for the torque-vectoring control of fully electric vehicles.

Tommaso Goggia, Aldo Sorniotti, Patrick Gruber (University of Surrey)

An integral sliding mode formulation for the torque-vectoring control of a fully electric vehicle with multiple motors is presented. The performance of the controller is evaluated in steady-state and dynamic conditions, including the analysis of the controller performance degradation due to the drivetrain dynamics, signal discretization and vehicle communication buses. The controller is experimentally assessed on a prototype electric vehicle demonstrator, in the worst-case conditions in terms of drivetrain layout and communication delays. The results show a significant enhancement of the controlled vehicle performance in the whole range of manoeuvres.

12.05 MPC based torque vectoring for electric vehicles near the limits of handling.

Efstathios Siampis, Efstathios Velenis and Stefano Longo (Cranfield University)

In the past few years it has been recognised that in the limits of vehicle handling, active control of the vehicle's velocity is not only a very effective strategy but also crucial in cases of terminal understeer behaviour. Based on this observation, in this work we propose a Model Predictive Control (MPC) strategy for combined yaw, sideslip and velocity regulation to stabilize the vehicle during cornering near the limit of handling using the rear axle electric torque vectoring configuration of an electric vehicle.

12.25 Friction-limited path and speed control without the use of a reference path.

Tim Gordon (Lincoln University)

In cases where chassis control supports or overrides the driver, for example in automatic collision avoidance, it is common to define a reference trajectory before control is applied. This begs many questions, especially whether the reference trajectory is feasible, overly conservative or "optimal" in some sense. Here it is proposed that decoupling between reference planning and path/speed control can be both unnecessary and undesirable, especially when controlling at the limits of friction. Algorithms and examples are presented.

12.45 Lunch

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Session 3 – Tyre and vehicle dynamics

13.55 Development of an efficient off-road tyre model aimed at full vehicle simulations.
Thomas Lewis (Jaguar Land Rover) and Georgios Mavros (Loughborough University)

Accurate simulation of tyre behaviour on soft, deformable terrains presents a number of unique challenges. Tractive/braking as well as lateral forces depend primarily on the local shear strength of the soil, which is in turn dictated by the local pressure. A hybrid analytical-numerical tyre model is developed that uses recent formulations to describe soft soil material behaviour. The model incorporates a fairly advanced tread whereby tread pattern properties such as tread/void ratio and proportion of longitudinal/lateral grooves are identified from real tyres using digital photography and image processing.

14.15 Tyres, roads, rubber friction and circuit racing.
Robin Sharp (University of Surrey)

Observation of contemporary circuit racing indicates that rubber friction depends on the track texture and temperature, the tyre temperature and the state of tyre wear. An understanding of what is happening is desirable. From the classic experiments of Grosch, it can be deduced that friction derives from the visco-elasticity of rubber, which will be illustrated with some rubber properties. Some results and conclusions from Grosch will be exposed and they will be related to Persson's theory of hysteretic friction.

14.35 Active variable geometry suspension robust control for improved vehicle ride comfort and road holding.
Simos Evangelou (Imperial College)

The design of robust H_∞ control for a novel road vehicle mechatronic suspension is investigated. The objective is to improve ride comfort and road holding, while guaranteeing operation inside existing physical constraints. The study utilizes a nonlinear quarter car model that represents accurately the vertical dynamics and geometry of one quarter of a high performance car with a double wishbone suspension. Simulation results for a range of road disturbance inputs demonstrate that effectiveness of the designed control scheme.

14.55 Vehicle dynamic analysis using a computer vision system.
Andrew Bradley and Denise Morrey (Oxford Brookes University)

This study has used a 4-post rig to excite a vehicle, and an optical tracking motion capture system (more commonly used for computer animation) to record the vehicle's response to known vibration inputs. A methodology has then been developed to estimate vehicle suspension parameters including; tyre stiffness, spring rate, damping curves, roll stiffness and chassis rigidity, for use in vehicle optimisation or lap-time simulation. A novel method of estimating basic tyre performance parameters has also been developed.

15.15 Refreshments

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Session 4 – Racing

15.40 Lap time simulation of racing vehicles.

Roberto Lot (Southampton University)

Lap time optimization of racing motorcycles and cars is a challenging task that requires the solution of non-linear optimal control problems. This talk will illustrate an indirect approach to the problem and its implementation for racing two and four wheels vehicles. Techniques for an efficient formulation of problems and fast numerical solution will be discussed, correlation between simulations results and experimental data collected on track will be shown.

16.00 Optimising the aero-suspension interactions in a Formula One car.

David Limebeer (University of Oxford)

The interactions between the multi-link suspension system of an open-wheeled race car and the vehicle's aerodynamic performance are studied. It is shown that the car's suspension motion can have a significant impact on the aerodynamic performance of the vehicle. Optimal control calculations are used to illustrate the impact of aero-suspension interactions, and adjustments, on the lap-time performance of the car.

16.20 Optimal control of motorsport differentials.

David Purdy (Cranfield University) and Anthony Tremlett (University of Oxford)

Modern motorsport Limited Slip Differentials (LSD) have evolved to become highly adjustable, allowing the torque bias that they generate to be tuned in the corner entry, apex and corner exit phases of typical track manoeuvres. The task of finding the optimal torque bias profile under such varied vehicle conditions is complex. A nonlinear optimal control method is used to find the minimum time optimal torque bias profile through a demanding set of manoeuvres. Varying track friction levels and tyre wear metrics are also considered in the analysis. The methodology is designed to provide a practical basis on which to configure passive LSD setup parameters, or in the formulation of semi-active LSD control algorithms.

16.40 A crashing time with an electric vehicle.

Mat Hubbard (Technical Director, Anthony Best Dynamics)

AB Dynamics have designed a low profile electric vehicle for ADAS development applications that enables prototype cars to be crashed into another moving vehicle on the test track with 2cm impact precision and without damage. An overview will be given of the design of the suspension, brakes, and powertrain, as well as showing applications of the vehicle.

17.00 Close