Volvo Car Corporation

Master thesis proposal (Feb. 2014)

Vehicle’s Entry Speed Maximization in a Double-Lane Change Manoeuvre

* Location	* Category
Göteborg	**96560: Vehicle dynamics: Optimal control**

Description of thesis work

Background:

The modern vehicle development process dictates the objective assessment of the car's safety potentials. Independent organizations such as the EuroNCAP perform safety rating and publish reports on new cars based on a variety of tests. EuroNCAP assesses Electronic Stability Control (ESC) systems by performing a series of tests in which steering and yaw behaviour can be simultaneously evaluated [1]. These tests are based on an actual double-lane change (DLC) manoeuvre, carried at 80 km/h with sudden steering wheel rotations up to 270 degrees (sine with dwell). A car will pass the “sine with dwell” test when it has met the criteria, of achieving a lateral displacement more than 1.83 m and stay stable after the steering manoeuvre is completed [1]. Still, the ESC and the vehicle's handling are also rated subjectively [2] using tests such as ISO 3888 DLC. The ISO 3888 course (c.f. Fig. 1) was developed to observe the way vehicles respond to handwheel inputs drivers might use in an emergency situation [2]. Although the aforementioned methods are often used for handling rating, they are sometimes characterized unsuitable for objective assessment of the vehicle’s performance because the driver is involved in the control loop [3]. Objectivity can be ensured by examining solely the vehicle’s behaviour. Substituting test drivers by a controller which would generate the optimal steering inputs for achieving maximum entry speed would enable the definition of an objective performance metric [4] and a tool to assess the vehicle's handling, early in the development process. A tool for generating the optimal steering control input for maximizing the vehicle’s entry speed has already been developed at Volvo Cars [5] (c.f. Fig. 2).

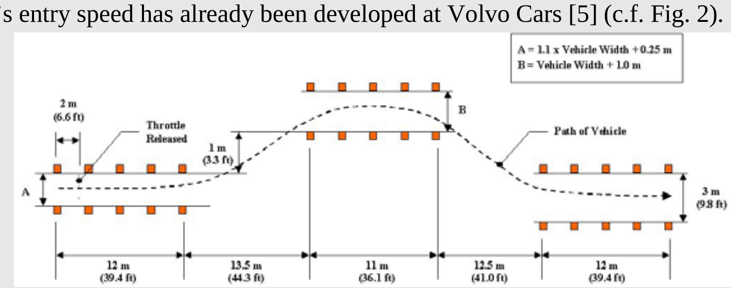

Fig.1. ISO 3888: Passenger cars Test track for a severe lane-change manoeuvre, Part 2: Obstacle avoidance.

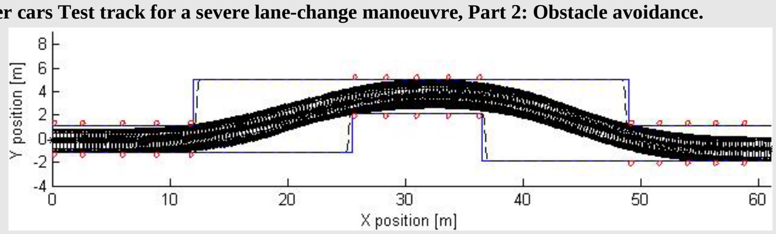

Fig.2. General vehicle trail. The thickness of the outer black lines is proportional to the vehicle slip angle [5].

Scope:

This research thesis aims to extend the work of [5]; optimal steering input that maximize the vehicle's entry speed in a DLC manoeuvre with the vehicle operating in conjunction with ESC. Although the vehicle model in [5] captures details regarding the tires, the vehicle’s suspension characteristics as well as the ESC functionalities, the final judgement of the vehicle is with physical testing; the ultimate goal of this thesis is to utilize the optimal steering input generated in [5] in a feed-forward manner and create a feedback controller which will compensate for the modelling errors and external disturbances during physical testing.

The thesis will constitute upon:

- Literature study:
    - Control theory for dynamical systems (optimal, robust).
    - Existing control methods for vehicle steering control ([5] [6]).

    - Vehicle dynamics and vehicle mechatronics.
    - ESC and its functionalities.
- Goals/ milestone definition:
    - Define the steering control approach to be followed; study the optimal control approach developed in [5] and decide the feature that can extend the functionality by investigating the system's robustness.
- Steering controller development and validation:
    - Develop the first working controller using the optimal control output of the quasi-realistic vehicle dynamics model and ESC from [5] in a high fidelity simulation environment.
    - Combine the feed-forward optimal steering control input [5] and create a feedback controller which will compensate for the modelling errors and external disturbances during physical testing.
    - Evaluate the robustness of the controller system in physical testing; perform DLC test using closed-loop vehicle control. Study the effects of vehicle's setup in the DLC entry speed.
- Documentation: document the results in a thesis report and make a final presentation.

Risks & Limitations:

The problem is rather complex; the optimization solution may be a global optimum in simulation but not in physical testing. The feedback controller should be robust to compensate discrepancies between simulation and physical testing.

Prerequisites:

- Car enthusiast, interested to further work in the automotive industry. The results can be applied into racing.
- Interested in vehicle dynamics with strong understanding of dynamical systems.
- Background in control systems.
- Highly motivated students for research. The current research thesis has potentials to evolve to a strong tool for Volvo Cars. Upon successful completion of the work, the outcome will be explored to derive scientific publications.

References:

[1] Euroncap, "How the ESC is tested," Available: http://www.euroncap.com/Content-Web-Page/bf07c592-4f87-404e-bb06-56f77faee5a2/esc.aspx

[2] G.J., Forkenbrock , W.R. Garrott, M.H., B.C. O'Harra, "An Experimental Examination of J-Turn and Fishhook Maneuvers That May Induce On-Road, Untripped, Light Vehicle Rollover," *SAE paper*, 2003-01-1009.

[3] J. J. Breuer, "Analysis of Driver-Vehicle-Interaction in an Evasive Manoueuvre - Results of Moose Test Studies," *Proc. of the 16th ESV Conference*, 1998, Paper No: 98-S2-W-35.

[4] D. Katzourakis, C. Droogendijk, D. Abbink, R. Happee, E. Holweg, "Force-feedback driver model for objective assessment of automotive steering systems," *Proc. of the 10th International Symposium on Advanced Vehicle Control*, AVEC10, 2010, pp. 381–386.

[5] S. Angelis, M. Tidlund, M. Lidberg, D. Katzourakis, "Optimal Steering Control Input Generation for Vehicle's Entry speed Maximization in a Double-Lane Change Manoeuvre," to be submitted, Volvo Car Corporation, Göteborg, 2013.

[6] E. Velenis, D. Katzourakis, E. Frazzoli, P. Tsiotras and R. Happee, "Steady-State Drifting Stabilization for RWD Vehicles," *Control Engineering Practice Journal*, vol. 19, no. 11, Nov. 2011, pp. 1363-1376, 2011.

The duration of the thesis work is 20 weeks and the work will be carried out at the Volvo Car Corporation, Göteborg.

Suitable Student background

Good knowledge of automotive/mechanical engineering.

Starting date	Number of students
February 2014	1 or 2

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