MSc Thesis proposal in Vehicle Dynamics:

A model library for operating cycle simulation of longitudinal dynamics and transport efficiency

Version, modified 2018-10-23 13:50

Background

Driving cycles have been the dominating way of describing vehicle use in simulations of transport efficiency, CO_2-emission and fuel consumption. A conventional driving cycle describes a target speed as a function of time. Recently it has been highlighted that such a description is oversimplified. For example, it does not allow predictive systems, such as choice of gear or kinetic energy buffers, to influence vehicle motion and their contribution to the increase in efficiency disappears. Thus, a conventional description does not allow a fair comparison between different vehicles.

A new description, the operating cycle-format (OC) [1,2], that was suggested earlier this year avoids many of the problems. It includes the essentials of the road, weather, traffic and mission that are needed to describe the physics of the road-vehicle interaction.
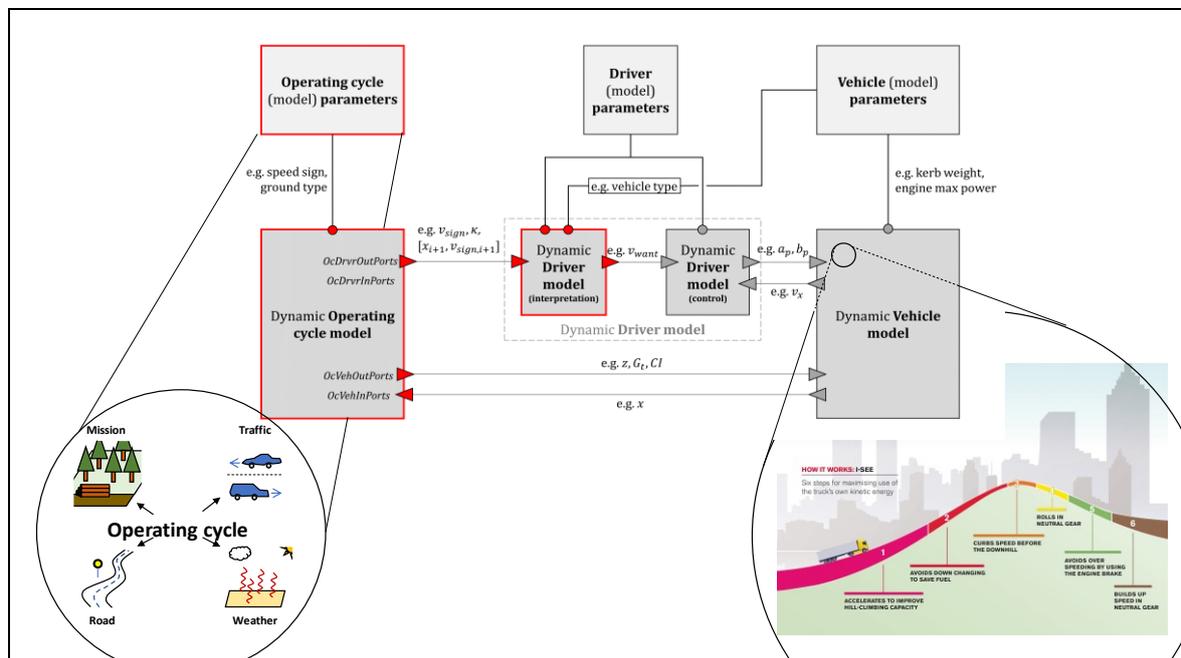
However, being a more realistic and complex description, it renders many of the methods for conventional driving cycles obsolete and new ones are needed. The format is primarily aimed to aid simulations by providing a comprehensive description of the road and the environment to feed realistic, and often complex, vehicle models with meaningful input. Hence, simulation models and their accuracy are of vital importance in this context.

Many characteristics of today's vehicles cannot be addressed using simulation models and conventional drive cycles. One such example is vehicles equipped with road ahead prediction/estimation and speed adaption based on this information. Other examples are the more refined influence of dynamic properties that are inherently impossible to capture with quasi steady-state driving cycles. The capabilities and flexibilities introduced by extra power sources, as in hybrid electric drivelines, are yet another field that is highly limited by conventional descriptions. There is a need to develop vehicle models that can utilize the OC-format fully, to meet an increasing requirement on precision in predicting e.g. fuel consumption, CO_2-emission and transport efficiency.

This problem is an active research subject that combines understanding of the format, its underlying mechanisms, driver and vehicle modelling, as well as dynamic simulation that involve all parts. The project at Chalmers is called COVER [3] and involves Volvo GTT, Scania, Volvo Car Group, RISE, VTI and Chalmers. The project is currently seeking a PhD candidate, which enable a possible continuation for a successful master thesis student.

Problem motivating the project

For successful vehicle development, it is important to represent the usage and vehicle in a realistic way. A fair comparison of components, functions and strategies rely on the underlying road and mission description to be suitable and accurate, and the same goes for the involved simulation models.

Therefore, a library of models needs to be developed to enable a study of component influence. However, the required level of detail in the models, to fully utilize the new way of describing the simulation input, is unknown.

Sketch of work

Successful candidates will work on developing models with the intention to illustrate the OC-format. Example of components that could be modelled are:
- Gearboxes with prediction-based gear choice strategies.
- Hybrid electric powertrain component (batteries, electric machines) as well as predictive power selection strategies.
- Speed planning algorithms based on e.g. topography, speed signs or stops, to use inertia as an energy buffer.

The model should be used in a simulation study to investigate the influence of prediction on e.g. fuel consumption, and possibly benchmark against established simulation tools like VECTO.

Research Question

- What is the defining level of details in the simulation models to fully utilize the OC-format?
- How can this level be found and tested?
- What are the benefits and weaknesses with the use of the OC-format?

Deliverables

- A set of models that can be used to study the influence of vehicle components using the OC-format.
- Evaluation on how well the models together with the OC format can predict e.g. real-life fuel consumption.

- A technical paper suitable for presentation at an international conference. The paper should preferably be a part of the thesis, to avoid redundant documentation.

Limitations

- The OC-format is considered given and no focus is given to the development of it.
- The driver model is given and not part of the study unless it is inevitable.

Sketch of activities

- Literature study on modelling of powertrain components.
- Implementation of a set of components to form a variety of powertrains, preferably including hybrid electric components (batteries, electric machines etc.) and functionality that uses prediction of the road ahead.
- Select one (or a few) mission(s) for evaluation and corresponding OC-file(s) for that (those) mission.
- Comparative simulation studies.
- Write one conference paper.

Academic subject / pre-requisites:

- Modelling and simulation skills with automotive interest.
- Particularly students from fundamental physics, engineering physics, engineering mathematics, mechatronics/control or mechanical/automotive.
- At least a basic course in dynamic modelling/simulation.
- Fundamental understanding of longitudinal vehicle dynamics.
- Intermediate skills in DAE-modelling, especially hybrid systems, and numerical solution methods.
- Knowledge of basic mechanics.
- An interest in PhD studies in the field is a merit.

Administrative

- Number of credits: 30 points per student (nominally 20 weeks).
- Starting date: January 2018 or earlier.
- Resources/Stakeholder: Volvo GTT (the thesis will be within VGTT but in close cooperation with Chalmers.).
- Responsible subject/research group at Chalmers:
  - Examiner: Bengt Jacobson.
  - Supervisors:
    - Academic: Fredrik Bruzelius/Pär Pettersson.
    - Industrial: Sixten Berglund/Anders Eriksson (Volvo GTT).
- Application to: Fredrik or Pär, *{fredrik.bruzelius,parp}@chalmers.se, 070-979 62 43, with CV and transcripts.*
- Physical location: Volvo GTT (Lundby, Göteborg) and Chalmers.

References:

[1] Pettersson, P., Berglund, S., Jacobson, B., Fast, L., Johannesson, P., Santandrea, F., A proposal for an operating cycle description format for road transport missions (2018), European Transport Research Review 10:31, pp 1-19.

[2] Pettersson, P., On numerical descriptions of road transport missions (2017), licentiate thesis, Chalmers Univ. of Tech, Göteborg, Sweden.

[3] Chalmers project page, Real world CO2 assessment and vehicle energy efficiency (COVER), url: https://research.chalmers.se/en/project/?id=8239 (sep 2018)