MSc Thesis proposal in Vehicle Dynamics:

A method to map high to low level descriptions of usage of vehicles

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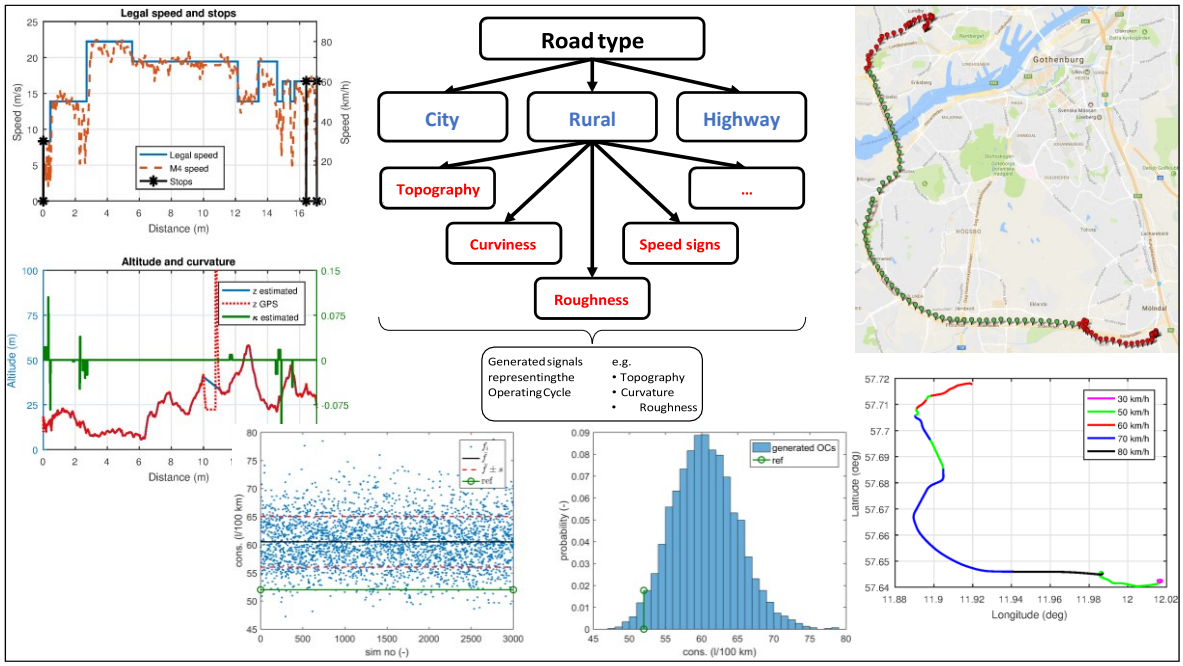
Background

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. The exact speed profile of a drive cycle is the outcome a specific vehicle performance. Hence, there is an inherited connection between a specific driveline and the drive cycle. This makes conventional drive cycles less suitable for describing e.g. transport mission independent of the vehicle.

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. For example, comparing different driving cycles is relatively straight-forward and uses obvious (and some not-so-obvious) measures such as mean speed, duration, mean positive and mean negative acceleration, mean traction force etc., see [3-5]. The OC-format has few such measures and comparing two missions becomes a challenging problem.

A possible approach is to look at each underlying phenomenon as a stochastic process and try to find models that describe the physical properties well [6,7]. The parameters of those models have interesting statistical characteristics and are useful for many things, for example

as measures to compare OCs. In addition, a stochastic model offers the interesting advantage that it can generate new missions, which enables a wealth of theoretical and numerical studies. However, the stochastic description is still an abstract construction with many parameters. If log files of previous missions are available, they can be converted into the OC format and a statical description can be estimated based on these.

In many other situations, such as in a sale situation of a truck, the customer might not have detailed mission description available. For this situation, the truck manufacturer has developed a high level description for the intended use of the vehicle to be sold. Examples of these are the "GTA" at Volvo and the "User factors" at Scania. The aim of this project is to bridge the gap between the high level description and the stochastic operating cycle format sOC, [9]. This would enable a complete tool chain from a high level description of use to simulation and optimization of the best possible vehicle for that use.

This problem is an active research subject that combines stochastic modelling, data analysis, driver, and vehicle modelling, as well as dynamic simulation that involve all parts. The project at Chalmers is called COVER [8] and involves Volvo GTT, Scania, Volvo Car Group, RISE, VTI and Chalmers.

Problem description

The aim of the thesis project is be able to start from an example high level description of usage to generate operating cycles that can be used for simulation and optimization of vehicles and their performance via the stochastic description. This transfer between high to low level description should be in a way that no information from the high level description is lost in the process.

Research Question

- How can a high level description of usage be used to obtain precis description expressed in parameters of stochastic models?
- Is the high level description sufficient to uniquely define a stochastic operating cycle?
- How can we measure of the transformation was good or bad?

Deliverables

- A set of algorithms, implement in matlab
    - automatically obtain a sOC from a high level description (for a set of parameters such as topography, curves, speed signs)
    - evaluate how well the obtained sOC manage to capture the high level description
- A report that describe the methods and illustrate them to a set of examples

Tentative plan

- Start with a set of descriptions of typical missions in the GTA format. Obtained from interviews of real operators.
- Transfer the GTA description to sOC using heuristics, machine learning, modelling or any other tool.
- Simulate the missions by generating dOC and utilizing existing toolchains
- Compare with real vehicle from a real operator.

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 stochastic processes.
- Understand the fundamentals of mathematical statistics.

Administrative

- Number of credits: 30 points per student (nominally 20 weeks).
- Starting date: January 2021 or earlier.
- Resources/Stakeholder: Volvo GTT, Chalmers, RISE, VTI, Volvo cars and Scania (the thesis will be strongly connected to the COVER project).
- Responsible subject/research group at Chalmers: Vehicle dynamics
    - Examiner: Fredrik Bruzelius.
    - Supervisors:
        - Pär Johannesson (RISE & Mathematics Chalmers/GU)
        - Industrial: Rickard Anders (Volvo GTT).
- Application to: Fredrik Bruzelius, *fredrik.bruzelius@chalmers.se, with CV and transcripts.*
- Physical location: at Volvo GTT or possibly at 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] Nyberg, P., Evaluation, generation and transformation of driving cycles (2015), PhD-thesis, Linköping University, Linköping, Sweden.

[4] Zaccardi, J.M., Le Berr, F., Analysis and choice of representative drive cycles for light duty vehicles – case study for electric vehicles (2013), Proceedings of the Institution of Mechancial Engineers, Part D: Journal of Automobile Engineering, 227:4, pp. 605-616.

[5] Lee, T., Filipi, Z., Synthesis of real-world driving cycles using stochastic process and statistical methodology (2011), Int. J. Vehicle design, 57:1, pp. 17-36

[6] Johannesson, P., Podgórski, K., Rychlik, I., Shariati, N., AR(1) time series with autoregressive gamma variance for road topography modeling (2017), Probabalistic engineering mechanics 43, pp. 106-116.

[7] Maghsood, R., Johannesson, P., Detection of steering events based on vehicle logging data using hidden Markov models (2016), Int. J. Vehicle design 70:3, pp. 278-295.

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

[9] Pär Pettersson, Pär Johannesson, Bengt Jacobson, Fredrik Bruzelius, Lars Fast, Sixten Berglund. A statistical operating cycle description for prediction of road vehicles' energy

consumption. Transportation Research Part D: Transport and Environment 73, 205-229, 2019.

The following is not for the announcement:

Plan for definition/planning and announcing of the thesis

It is often good to use this part of document to agree between university and industry stake-holder:

- A thesis needs to be anchored at a **specific research group** at the university, before industry should take it for granted that it can be run as a thesis. This is for both for engineering content and for manning of examiner and supervisor from academy.
- Each research group at the university has to be selective with what topics to agree to. Normally, there has to be some **synergies** with on-going research projects or, at least, strategic areas where future research projects are planned.
- Will the thesis be a **"full" industry thesis**, i.e. including desk at industry, daily supervisor at industry, payment to student from industry, … It is something most students would like to know relatively early in the application/recruiting process.
    - Industry need to understand the annual cycle of finding students:
        - Starting a thesis with industry stakeholder is a 3 part agreement: student, industry, university. It is normally the students that apply for specific thesis. So, industry/university need to announce proposals, else they are not found by the students.
        - Most students look for thesis around Oct-Dec, and carry out the thesis during Jan-June. So, it is important to look over that the right theses are announced in Sept-Oct, each year.
        - But there are a lot of free-floating students, often from other universities, that look for thesis anytime of the year. So, it is a good idea to announce whenever a topic is identified as interesting enough.
- Where to **announce** the thesis. Either both at industry web and Chalmers web or, at least, at Chalmers web. Explanation: If not announced at Chalmers web, it is very likely that one (Bengt) forgets to promote the thesis proposal for interested students.
    - In some cases, there can be a **certain student** selected before defining the thesis. If so, announcement is of course not needed, but instead a "start-registration" can be started directly with the selected student. The student can then, suitably, be involved in the actual definition/planning of the thesis.