MSc Thesis proposal in Vehicle Dynamics:

Range estimation of heavy electric vehicles

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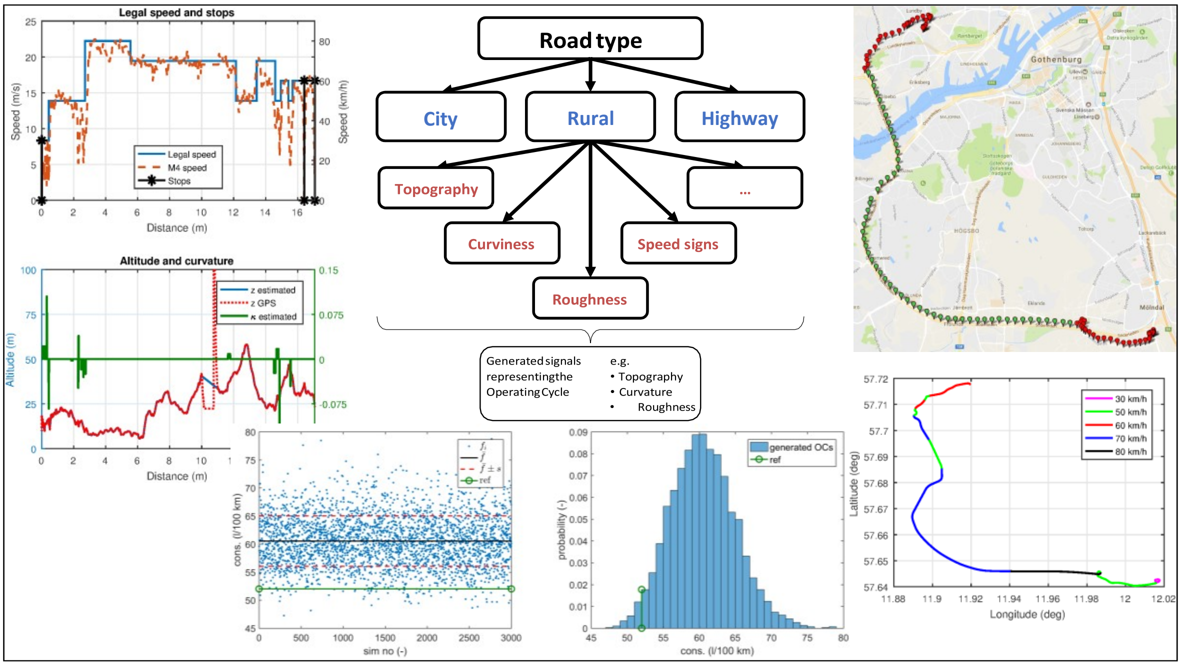
Background

Understanding what influence and estimate the range of vehicles is an important matter. The range estimate can serve, when estimated online, as guide for when to stop for re-fuelling. In an offline situation, a similar estimate may be used to plan routes, which vehicle to use etc. The importance will increase with the introduction of electric propelled vehicles, where the range is a limiting factor, and the charging is time consuming and require planning. For heavy-duty vehicles, the conditions may vary more than for cars depending on the operating cycle. This potentially represent an even more challenging estimation problem.

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 last 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 dOCs. 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 dOC format and a statistical description sOC can be estimated based on these, see [9].

The OC format, and the sOC format in particular, could very well serve as a basis to include the operating cycle variations into the range estimation problem. This holds for both offline and online estimation of the range.

The format itself 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 estimation of range problem would add estimation theory to the list. 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 to formulate and implement estimation of range that takes the OC format into account. The focus will be on the external loads, and a pragmatic standpoint will be taken to the specific driveline. This implies that focus will be on rolling resistance rather than battery technology to give one example. Both offline and online estimation should be investigated.

Research Question

- How could we make use of the sOC format when designing an estimator for range/energy consumption?
- How should the external loads (air drag, rolling resistance, road slope etc) be modelled in the estimator to balance complexity vs accuracy of the estimate?
- How can we assess the performance of the estimator?

Deliverables

- Theoretical derivation and implantation of the estimator in MATLAB environment.
- A report that describes the methods and illustrate them to a set of examples and assessments.

Tentative plan

- Formulate estimation problems for the online (unknown route) and the offline (known route) cases.
- Investigate model from the literature that are relevant to describe the external loads.
- Implement and assess the performance of the estimations on numerical examples.

Academic subject / pre-requisites:

- Preferably students with Control theory, Mechatronics, or similar backgrounds.
- Modelling and simulation skills with automotive interest.
- At least one basic course in estimation theory.
- The student(s) undertaking this thesis project must be capable of working independently as well as under supervision and be self-driven and highly motivated.

Administrative

- Number of credits: 30 points per student (nominally 20 weeks).
- Starting date: January 2021 or as soon as possible.
- Resources/Stakeholder: Chalmers (the thesis will be strongly connected to the COVER project and the partners within this consortium.).
- Responsible subject/research group at Chalmers:
  - Examiner: Fredrik Bruzelius.
  - Supervisors:
    - Luigi Romano
    - 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: Chalmers and possibly also at Volvo GTT

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

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[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.

[10] Erik Nordström Advanced Modelling and Energy Efficiency Prediction for Road Vehicles, Masters thesis Umeå University, 2020.