

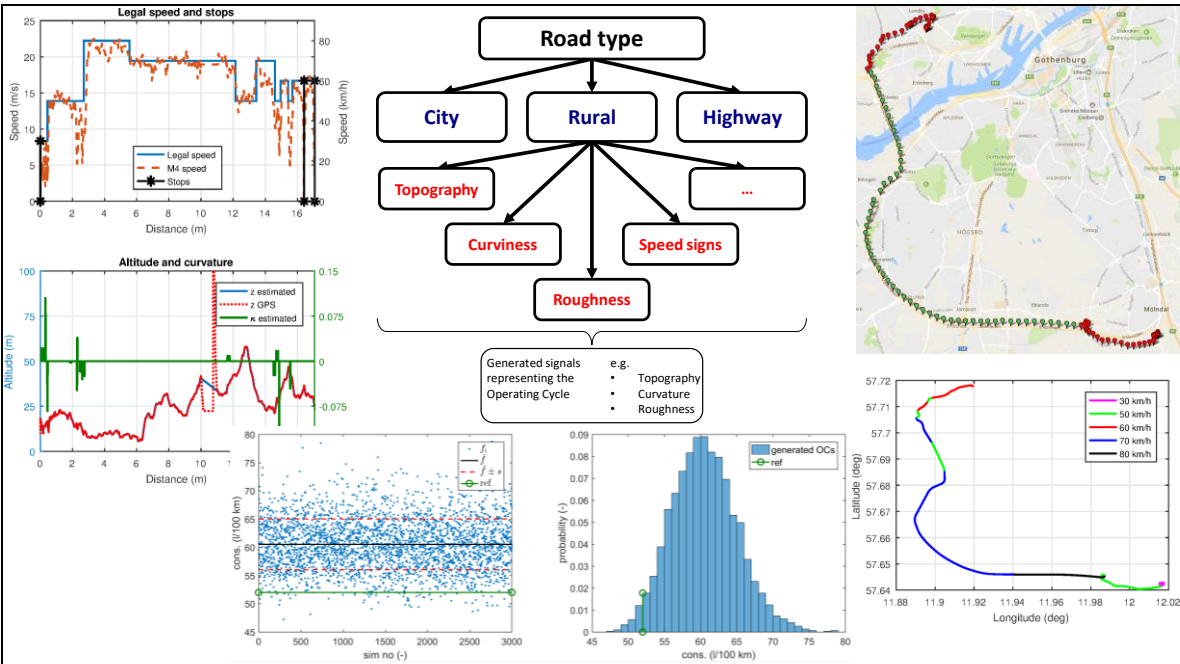
Optimal Battery Management of BEVs considering low temperatures and road conditions

Background

Battery electric vehicles (BEVs) may be regarded as one of the most promising alternatives to conventional IC-engine systems. BEVs’ performance is reported to be very sensitive to environmental stimuli. Combined with the well-known phenomenon of range anxiety, this implies a fundamental need for minimising energy consumption during real road operations. In this context, optimal thermal management of battery electric vehicles (BEVs) in low-temperature conditions is a crucial factor, where battery climatization is necessary [1, 2]. Moreover, apart from the external temperature, these strategies must also account for other physical quantities, including road topography and curvature along the road for efficient energy usage.

Whilst conventional driving cycles do not directly consider these features, the Operating Cycle (OC) representation [4-6] makes use of stochastic models to describe the road and weather properties, allowing for taking into account their effects on vehicles’ energy performance in a very general and intuitive manner.

The objective of this thesis is to investigate optimal strategies for battery management in low-temperature operating conditions, considering the additional effect of road properties. The analysis will be focussed on the combined influence that these parameters have on the energy efficiency of BEVs, and on the development of ad-hoc control strategies for optimal battery management. Simulations will be carried out either in MATLAB/Simulink environment or in GT-Suite.



Problem motivating the project

Optimal battery management of BEVs requires detailed inputs from the surroundings where the vehicles operate. These include weather conditions, but also road properties like topography, elevation, and curviness. While conventional driving cycles fail to incorporate this information, the OC description may be successfully employed to develop control strategies for thermal management during real-world operations.

Envisioned solution

The OC representation provides an adequate framework to investigate the combined effect of weather and road properties on BEVs' energy performance. Using stochastically-generated models of the environment, energy consumption can be calculated more accurately, and different thermal management strategies can be implemented based on the characteristics of the surroundings.

Research Objectives

- Investigate the combined influence of low temperatures, road topography, and curvature on the energy performance of BEVs.
- Investigate different battery climatization methods based on weather conditions and road topography.

Deliverables

- Evaluation of BEVs' energy performance on a vast combination of low-temperature, topography, and road curviness conditions.
- Theoretical development and implementation of control strategies for battery thermal management depending on the operating conditions.
- Improvements to existing road, driver, and vehicle models.
- Possibly, a scientific paper suitable for presentation at an international conference or for journal publication. The paper can be a part of the thesis, to avoid redundant documentation.

Limitations

- Only one vehicle specification will be studied, possibly with minor variation.
- Only one driver model will be studied, possibly with minor variation.

Sketch of activities

- Stochastic modelling of different environments, including temperature and road conditions.
- Generate realisations and run simulations in MATLAB/Simulink or GT-Suite environment.
- Investigate the combined influence of temperature, road topography, and different battery climatization methods on the energy efficiency of BEVs.
- Develop an optimal strategy for thermal battery management.
- Write one conference/journal 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.
- Preferably a course in basic stochastic processes and optimal control/model predictive control.
- Knowledge of MATLAB/Simulink or GT-Suite.
- Some knowledge of vehicle dynamics and heat transfer is advantageous.
- An interest in PhD studies in the field is a plus.

Administrative

- Number of credits: 30 points per student (nominally 20 weeks).
- Starting date: January 2023 or earlier
- Number of students: 1 or 2
- Responsible subject/research group at Chalmers:
 - Examiner: Fredrik Bruzelius and Simone Sebben.
 - Supervisors:
 - Academic:
 - Luigi Romano (VehDyn),
 - Anandh Ramesh Babu (VehAero)
- Application to: Luigi Romano and Anandh Ramesh Babu, luigi.romano@chalmers.se, [070-979 62 43](tel:070-9796243), with CV and transcripts.
- Physical location: Chalmers University of Technology.

References:

- [1] Ramesh Babu, A.; Andric, J.; Minovski, B.; Sebben, S. System-Level Modeling and Thermal Simulations of Large Battery Packs for Electric Trucks. *Energies* **2021**, *14*, 4796. <https://doi.org/10.3390/en14164796>
- [2] Ramesh Babu, A. Battery thermal management for electric vehicles operating in cold climates. Licentiate Thesis. Chalmers University of Technology (2022).
- [3] P. Pettersson, P. Johannesson, B. Jacobson, F. Bruzelius, L. Fast and S. Berglund, "A statistical operating cycle description for prediction of road vehicles' energy consumption", *Transportation Research Part D: Transport and Environment*, vol. 73, pp. 205-229, 2013. DOI: 10.1016/j.trd.2019.07.006.
- [4] Pettersson, P. Operating cycle representations for road vehicles. PhD Thesis. Chalmers University of Technology (2019).
- [5] L. Romano, P. Johannesson, F. Bruzelius and B. Jacobson, "An enhanced stochastic operating cycle description including weather and traffic models", *Transportation Research Part D: Transport and Environment*, vol. 97, pp. 102878, 2013. DOI: 10.1016/j.trd.2021.102878.
- [6] Romano, L. Mathematical modelling of operating cycles for road vehicles. Licentiate Thesis. Chalmers University of Technology (2021).