Using Virtual Test Driving to Analyze Weather-Dependent Energy Consumption in Electric Vehicles

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Motivation
Energy consumption of the powertrain for representative driving scenarios (Renault Zoe)

Data Source: Stadtmobil Carsharing GmbH & Co KG cluster project
„Bewertung integrierter Elektromobilität“
Real world scenarios of a car sharing company

Insight
- The range problem persists
- Impact: velocity profile
- Impact: environmental conditions
Motivation
Address and mitigate Range Anxiety

- MIT study of drivers‘ behavior suggests that most personal vehicle travel could be covered by EV (90% of US personal vehicles days could be covered by EVs). [1]
- Range Anxiety is hindering electric vehicle acceptance

1) Feeling safe (w.r.t. reachable destination) when driving
2) Avoid empty batteries (rerouting to charging stations for worst case)

Motivation
Address and mitigate Range Anxiety

- BMBF project **GreenNavigation** addressed this issue: IPG, PTV Group, CarMediaLab, Daimler Fleetboard, Bosch, FZI

Range Estimation

- Vehicle Model
- Driver Model
- Map and Traffic information
- Weather forecast

Source: maps.google.com
Motivation
Typical wind velocities

Data Source: Lacunosa Weather Services
**Introduction**

**Our experimental vehicle**

- Front diesel engine is replaced with 47 kW electric motor and fixed transmission
- Inverter software is tuned such that the two inverters can provide a total of 94 kW peak power for front- and rear-axle electric motor
- Battery is replaced by four battery packs with a total of 36.8 kWh usable energy
- Vehicle control software on basis of a MicroAutobox II allows full control of vehicle systems
  - Powertrain: control of clutches, electric motors torque request, …
  - HVAC: PTC heater and A/C compressor power

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**Peugeot 3008 HYbrid4**

**Peugeot 3008 e4WD FEV**

Complete conversion to battery electric vehicle
Introduction
Our experimental vehicle

Ready for duty!
Introduction
Overview of the range prediction

Powertrain Measurement
Powertrain Modeling
Powertrain Simulation

Overview of the range prediction

Iterative Update
through test drives

MATLAB/Simulink
SystemC

Integration of the detailed vehicle model into the Co-Simulation environment

AVL Cruise

Energy Consumption Models

Static Consumers
Driving-operation-strategies

Abstraction

20.09.2016

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Introduction
Available Data

**Instrumentation**

- Sampling time 100ms and 1000ms
- All relevant telemetry data on CAN
  - Velocity
  - Torque and RPM
  - Temperature
  - Battery current and SOC
  - ...

**Weather Data**

Forecast at
- 00:00, 06:00, 12:00 and 18:00
- for up to +36h (hourly resolution)
- 0.01 Degree resolution for longitude and latitude

Source: Donn et al. - Optimized Utilization of E-Vehicle Range Using Route-Based Online Weather Forecast Data, 24th Aachen Colloquium Automobile and Engine Technology 2015
Data Source: Lacunosa Weather Services
Range Estimation
Algorithm: Detailed for Single Route

- Velocity Prediction
- Vehicle Chassis
- Vehicle Powertrain

Inputs:
- Weather Information
- Live Vehicle Data
- Start and Destination, Driver
- Map Data

Parameters:
- Elevation, Curvature, Temperature, Environmental Wind
- Velocity Profile
- Wheel Torque
- State of Charge
Range Estimation
Algorithm: Approximate for Routing

- Weather Information
- Mapping
  - Adaption
    - statistical approximation of traction and recuperation force
    - f(x)
    - temperature, (environmental wind)
- Segment information
- PTV xServer (Map Data)
  - segment information
- Vehicle Chassis
  - statistical information: velocity, acceleration
  - f(x)
- Vehicle Powertrain
  - Energy consumption for segment
- Driver Model
  - statistical information: velocity, acceleration
- Live Vehicle Data
Range Estimation
First Results

Source: maps.google.com
Range Estimation
Influence of wind velocity on power consumption
Analysis with Virtual Test Driving
Simulation Setup

- Weather log database
- Date and time
- Telemetry logs from test drives
- GPS logs (noisy)
- KML

Source: graphhopper.com; wiki.openstreetmap.org

KF smoother
Fuse SRTM elevation & multiple GPS measurements

Different operating points and resulting energy consumption
Analysis with Virtual Test Driving
Simulation with Wind Effects
Analysis with Virtual Test Driving
Addressing Wind Effects

- Measured Energy cons. from logs
- Modelled energy cons.

Segmentation → Nonlinear Regression → Smoothing

- street segment, wind direction, wind magnitude
  → weighting factor
Analysis with Virtual Test Driving
Preliminary Analysis of Learned Sensitivity

09.11.2015

Wind: 8.5017 m/s

09.11.2015

Wind: 9.4354 m/s

09.11.2015

Wind: 4.7508 m/s

17.11.2015

RMSE = 6.5373

RMSE = 6.9695

RMSE = 108.7343
Conclusion & Outlook

- Conclusion
  - Model-based and adaptive range prediction approach
  - Environmental wind is an important factor
  - Seamless approach to simulate in IPG CarMaker
  - Generally speaking simulation is working well. However, the environment needs to be considered
  - First approach to learn environmental effect was presented

- Outlook
  - Improve segmentation by taking into account map information about the road
  - Evaluate different regression approaches
  - Increase the number of test drives to get data for significant scenarios
  - Use large amounts of data e.g. from BiE project
Vielen Dank für Ihre Aufmerksamkeit!

Fragen?

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