Driving Cycle and Road Grade on-board prediction for the optimal energy management in EV-PHEVs

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Objective

Driving cycle and road grade on-line prediction over a time horizon.
• Research activities only focused on driving conditions (DCOs) real-time prediction.

  1. Obtaining some statistical parameters of the recent past vehicle speed that feed a classification technique (Fuzzy Logic, ANN, ...).

  2. Enhancing them with digital maps information and historical route data for building a Reference Driving Cycle (RCD).

• No approach **model the driver/vehicle behavior.**
  – Penalizing the prediction → extra up to 15% fuel consumption reduction can be achieved.
Proposal

• Use an ANN for modeling the driver/vehicle behavior.
  – Processing the deviation in the trip/distance domain between a RDC and the vehicle speed. It is only provoked by the driver behavior.
  – The RDC is dynamically and easily constructed using only road/route information:
    • Static → GIS (Geographical Information System, digital maps)
    • Dynamic → GIS + V2X
The idea in 3 steps

1. **Recording**
   - RDCs and driving cycles during usual journeys.
   - In the background.

2. **Neural Network Training**
   - Based on the speed deviation between the RDC and the vehicle speed **in the trip/distance domain** (not time domain).
   - Off-line task.
3. Prediction Execution (I)
3. Prediction Execution (II)

The idea in 3 steps

PRE-PROCESSING

Vehicle speed $V_{act} = f(t)$

Kalman filter

Trip domain transformation $V_x = f(d)$

Speed deviation calculation

RDC calculation $V^{RDC} = f(d)$

Dynamic adaptation of the Reference driving cycle

PREDICTION

NEURAL NETWORK NARX

POST-PROCESSING

Time domain Transformation

DCDD* = f(d)
DCTD* = f(t)
Neural Network

- NARX (Non-linear Autoregressive with exogenous inputs). Widely used in non-linear time series predictions.
  - Multilayer net with two delayed inputs, a sigmoid-based hidden layer (7-15 neurons) and pure linear-based output layer (1 neuron).
  - Training methods: Bayesian regularization, Levenberg-Marquardt.
  - Low computational efforts once trained → embedded into MCUs and DSPs.
• **Off-line work**
  – MATLAB-Based GUI for training and simulation.

• **On-line work**
  – Rapid prototyping in a MicroAutobox from dSPACE.
  – Tested in a real SEAT vehicle.
  – CANBus communication for receiving vehicle speed (road/route information **not available yet**, thinking in GIS + ADASYS Protocol).
1. Simulation results based on real speed data.
   - Predictions for 4 and 12 kilometric points with 2km prediction horizon
2. In-vehicle testing using a SEAT vehicle.
   - Trip: Martorell - Sant Joan Despí
   - Prediction horizon: 2km
   - Prediction Mean Error lower than 10 km/h
Conclusions

• Driving cycles in the surroundings of Barcelona have been on-line predicted using advanced computational techniques with an average error less than 10km/h.

• Good performances obtained using prediction horizons ranged from 1 to 5km.

• Driving cycles predictions could be used for optimizing different vehicle functions.
  – Among others, energy management in PHEVs, thermal management, transmission controls, eco-driving ADAS.
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