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A bi-level energy management strategy for HEVs under traffic conditions.

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ABSTRACT

In 2015, according to data from the European Environement Agency, road transportation contributed to 21% of total EU-28 greenhouse gas emissions [Eur]. Traffic congestion has a major impact on driving behaviors, and therefore plays a key role in the level of fuel consumption [VKK00]. Hybridization technologies allow for a better overall energy management between the two propulsion systems, and are able to recover energy during deceleration phases, making hybrid electric vehicle (HEV) less fuel demanding. Several approaches have been developed during the last decades [Mal14] to determine the optimal electric motor power P_m.

We propose here an energy management system taking advantage of the knowledge of the global traffic in order to reduce the consumption. A bi-level method is applied to optimize the consumption over a trip under traffic constraints. Based on [LBD18], the traffic constraint is represented as a joint probability distribution μ of speed and acceleration. The speed $\mathbf{V}$ and the acceleration $\mathbf{A}$ of the vehicle are then modeled as random variables following this distribution.

The first stage of the method ('micro') determines the electric torque T minimizing the mean consumption on a small road segment, given its traffic data and a final constraint on the state of charge (SoC_f). The method used to solve the problem is a stochastic dynamic programming (SDP).

$$\begin{aligned}
&\min_{T} && \mathbb{E}_\mu\left[\sum_{t=0}^{\mathcal{T}} C(T_t,\mathbf{V}_t,\mathbf{A}_t)\Delta t + (SoC_f - SoC(\mathcal{T}))^+\right] && (1)\\
&s.t\ \forall t, && T_t \in [T_{min}, T_{max}] && (2)\\
& && SoC_t \in [0,1] && (3)\\
& && SoC_{t+1} = SoC_t + \frac{1}{C_{max}} P_m(\mathbf{V}_t,\mathbf{A}_t,T_t)\Delta t && (4)\\
& && D_{t+1} = D_t + \mathbf{V}_t\Delta t && (5)\\
& && SoC(0) = SoC_{init},\ D(0) = 0 && (6)\\
& && \mathcal{T} = \inf\{t | D_t > L\} && (7)\\
& && && (8)
\end{aligned}$$

Below is a comparison of this SDP solution with the deterministic solution of the optimization with exact trafic information. The simulations use real data from the platform GECO air [Geco] and indicate a good relevance of the SDP micro approach.

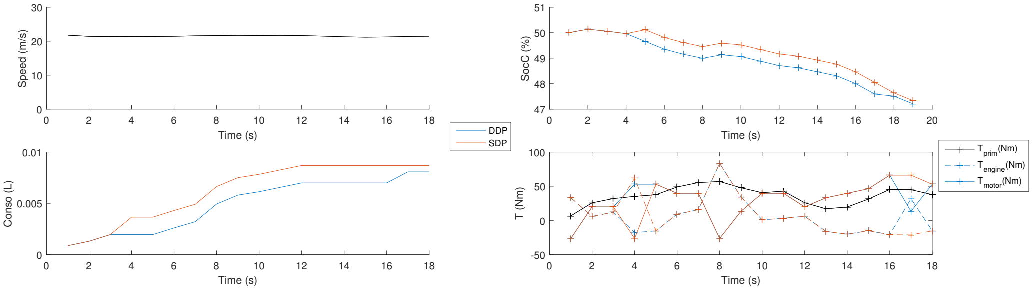

Figure 1: *Comparison between the deterministic and the stochastic solution.*

This 'micro' stage is solved for different values of SoC_f, which provides an estimate of the consumption function VF_s over the segment s depending on the traffic state, initial SoC and final SoC.

Then in the second stage ('macro'), we optimize the whole trip with the SoC increment over each segment as contol variable.

$$\min_{SoC_s} \quad \sum_{s=1}^{N} VF_s(SoC_{s-1}, SoC_s, \mu) \tag{9}$$

$$s.c \quad SoC_0 = SoC_{init} \tag{10}$$

$$SoC_N = SoC_{final} \tag{11}$$

This stage is solved by deterministic dynamic programming (DDP). Simulations based on real traffic data are currently in progress.

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[Geco] Geco air, URL: www.gecoair.fr.