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Design of an eco-gearshift control strategy under a logic system framework

Key words: Stochastic logic system; Gearshift strategy; Receding-horizon optimization; Traffic information; Eco-driving

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Motivation

- Development of information technology, e.g., ITS, V2X, and CAV, brings great opportunities and challenges to automotive powertrain control.
- Traffic and road condition is one of the most important factors influencing the fuel consumption of vehicles.
- The commuting vehicles such as public buses and logistics vehicles usually have fixed commuter routes, and the driving features such as driver power demand in specific route sections can be statistically analyzed (Fig. 1a).
- The gearshift and driver's gas pedal are the only two external control inputs for automotive powertrain systems. If the gas pedal information (e.g., probability distribution) in a future route section is predictable, an optimization strategy for gearshift can be developed to improve the fuel efficiency.

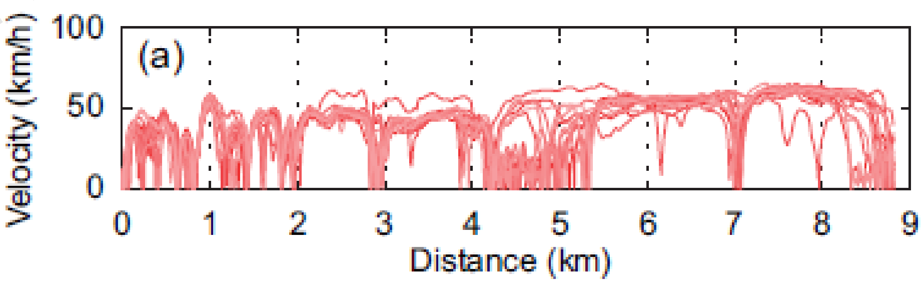


Fig. 1a Sample of commuting vehicle speed

Main idea

1. A receding-horizon optimal gearshift strategy is designed to minimize the fuel consumption over a fixed driving route in terms of driver-vehicle-traffic information.

2. Stochastic traffic information is applied to the control design, and with real-time update of the statistical probability, receding-horizon optimization for the gearshift control law can be solved online.

3. The simulation validation is implemented on professional vehicle-traffic software to guarantee requisite precision.

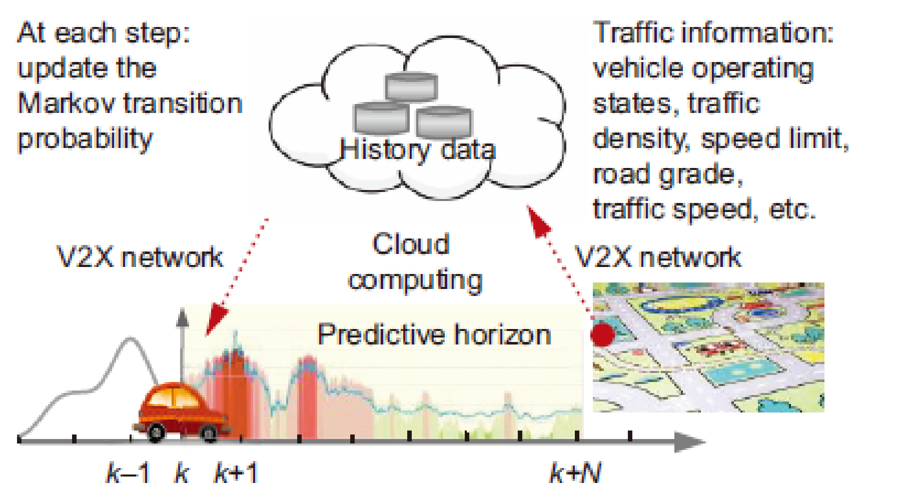


Fig. 2 Receding-horizon optimization for automotive powertrain control based on traffic data

Method

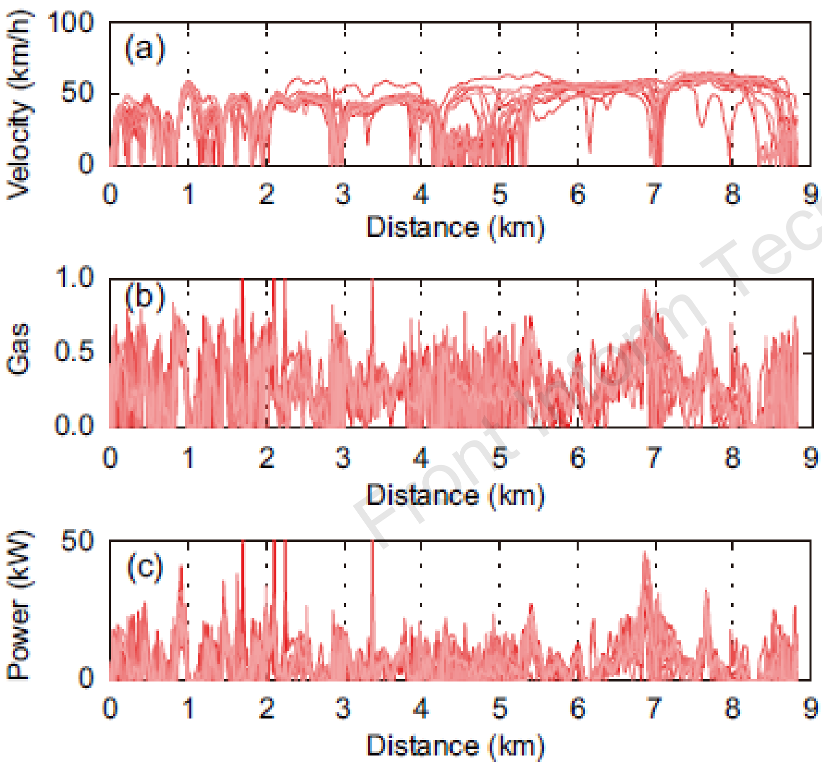
1. By analyzing the stochastic features of the driving behaviors and applying logic quantification technology, vehicle dynamics can be modeled as a Markov process model, which enables us to design the optimization problem under a logic system framework and then reduce the computational burden of the optimization process.

2. A trade-off optimization criterion between the fuel efficiency and drivability is chosen to avoid traction loss.

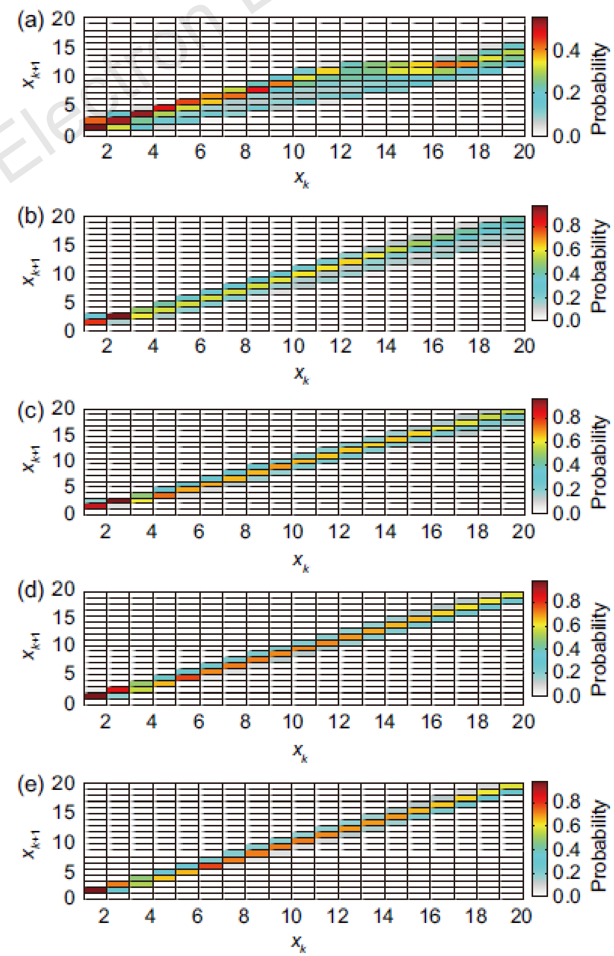
3. A dynamic programming algorithm with algebraic operations is applied to determine the optimal gearshift strategy online.

Major results

- Statistical characteristic of driving data



- An example of the state transition probability in one optimization horizon



Major results (Cont'd)

- The update example of the probability of the gas pedal position in one prediction horizon

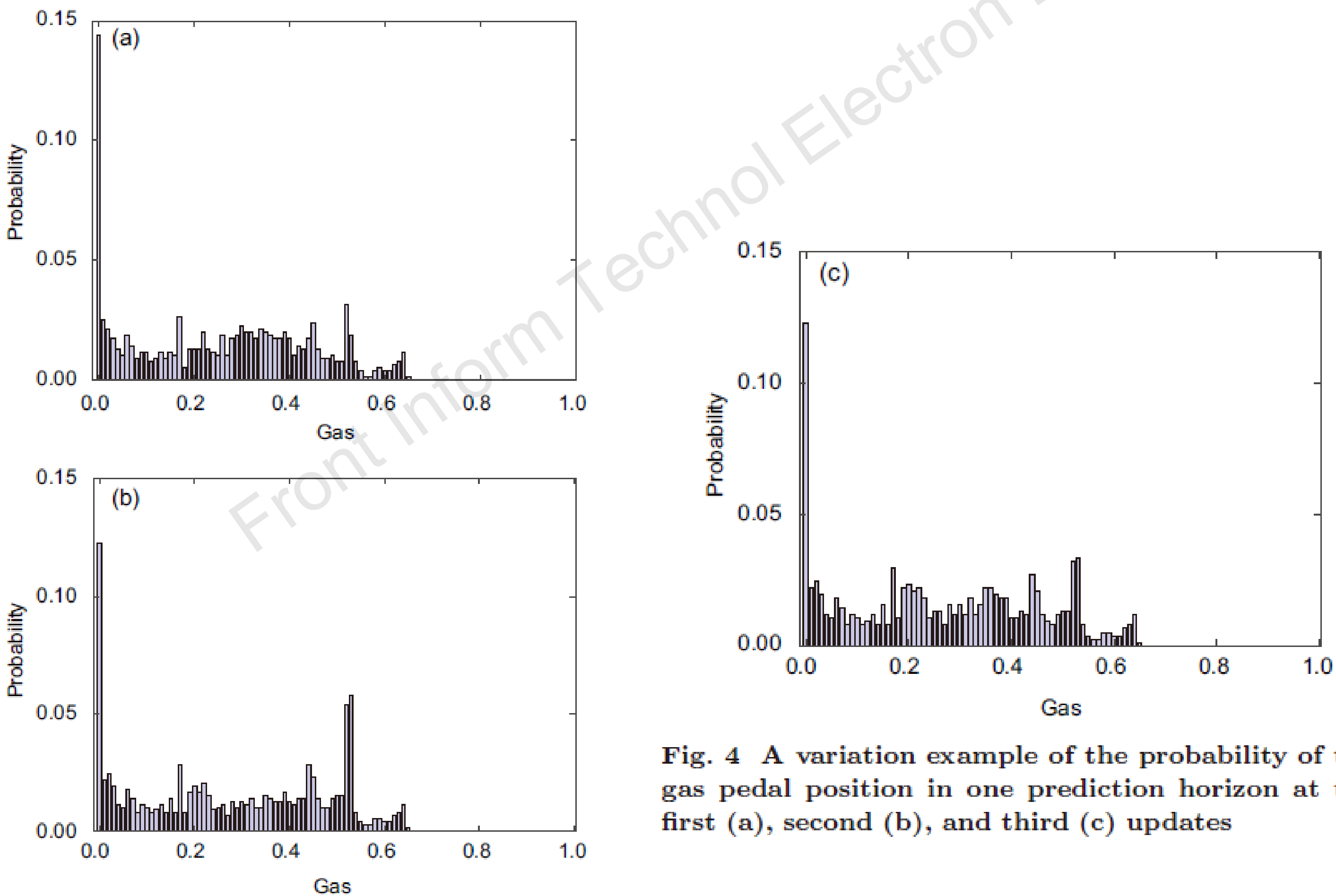
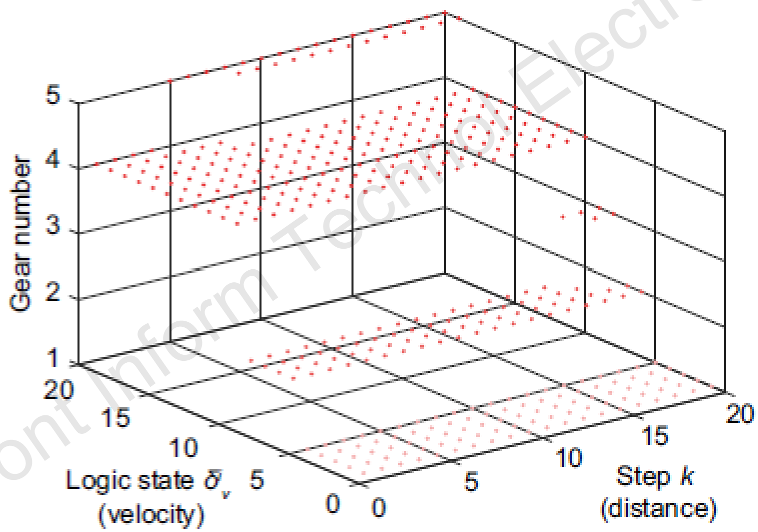


Fig. 4 A variation example of the probability of the gas pedal position in one prediction horizon at the first (a), second (b), and third (c) updates

Major results (Cont'd)

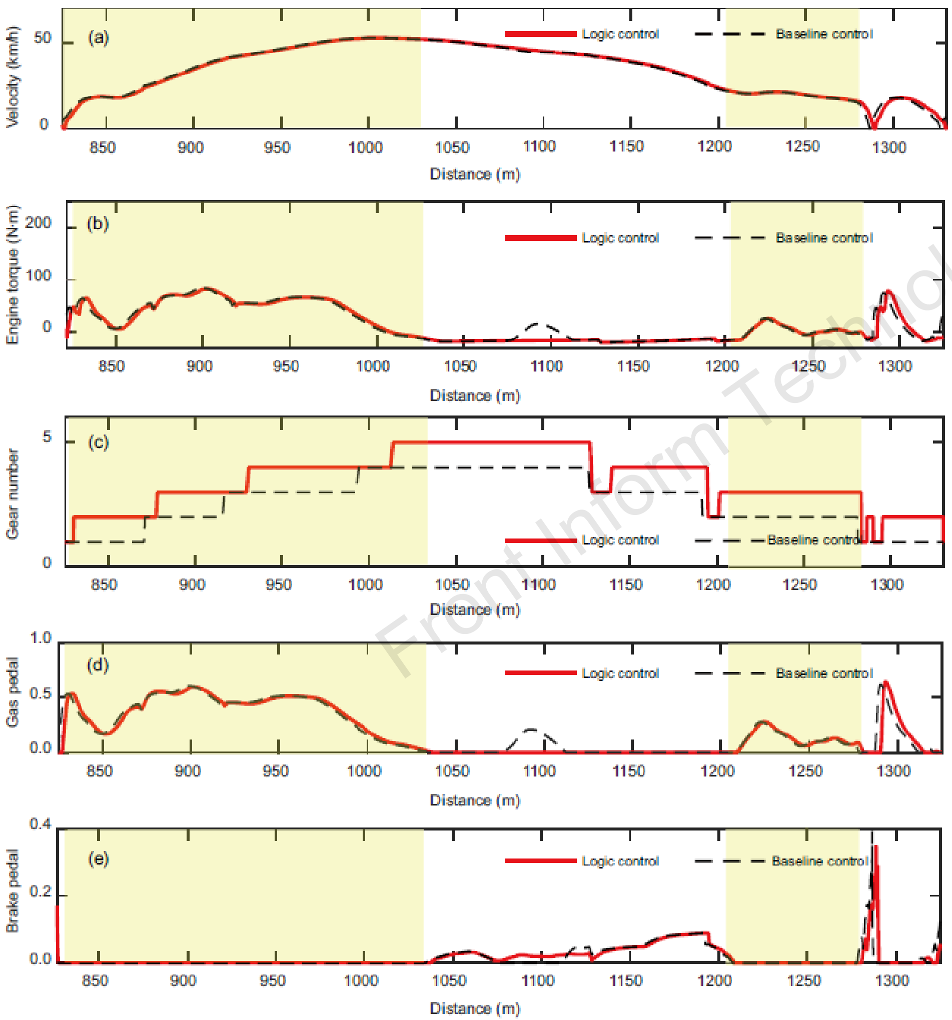
1. Optimal gearshift strategy calculated by the proposed logic controller



This figure indicates that in a certain road section, the optimal gear number can be found with respect to the vehicle speed (α=1, β=0.1).

Major results (Cont'd)

2. Simulation validation



- Given the prediction of future driving conditions, the logic control always exhibits early upshift behavior to lead the engine to the highly efficient work area.
- Logic control achieves better fuel efficiency than the baseline strategy.

The simulation performance comparison between logic control and baseline control (the colorful areas indicate the acceleration processes where the logic controller is activated)

Conclusions

1. The discrete nature of the gearshift causes the logic control design to have more merits, and a novel gearshift control approach under a stochastic logic system framework has been proposed.
2. Considering that the probability of the driver power demand at a specific position can be statistically analyzed based on traffic information, the receding-horizon optimization for the gearshift strategy is developed.
3. The optimization problem can be solved online by means of the algebraic operations of the dynamic programming (DP) algorithm with lower complexity.
4. Simulation results demonstrated the effectiveness of the proposed control design.