Velocity Optimization of Pure Electric Vehicles with Traffic Dynamics Consideration

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Outline

- Introduction
- System Design
- Performance Evaluation
- Conclusion
Introduction
Factors impeding wide electric vehicle application

- Short driving range

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Driving range (Mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tradtional vehicle</td>
<td>600</td>
</tr>
<tr>
<td>Pure EV</td>
<td>200</td>
</tr>
</tbody>
</table>

Driving range per battery charge or full fuel fill

60% difference in driving range between Traditional vehicle and Pure EV.
Introduction
Factors impeding wide electric vehicle application

- Short driving range
- Limited battery cycle life

![Graph showing driving range per battery charge or full fuel fill]

![Graph showing battery cycle life of lithium-ion battery]
Introduction
Solution: Velocity optimization

- Consider constraints such as vehicle acceleration, speed limit, stop sign and traffic light on the road.
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Solution: Velocity optimization

- Consider constraints such as vehicle acceleration, speed limit, stop sign and traffic light on the road
- Optimize the velocity profile to reduce total energy consumption

https://t3.ftcdn.net/jpg/01/51/49/66/500_F_151496666_8VitGP5svgi3vOOZz3NpeytN53jz3sh2.jpg
Introduction
Solution: Velocity optimization

- Consider constraints such as vehicle acceleration, speed limit, stop sign and traffic light on the road
- Optimize the velocity profile to reduce total energy consumption

Energy consumption reduced by 20%

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Introduction
Challenges of current velocity optimization methods

- How to estimate waiting vehicles in the traffic signal areas
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Challenges of current velocity optimization methods

- How to estimate waiting vehicles in the traffic signal areas
- How to apply waiting vehicle information into velocity optimization
Introduction
Our method: DP-based velocity optimization system

- Propose vehicle movement (VM) model
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Our method: DP-based velocity optimization system

- Propose vehicle movement (VM) model
- Build queue length model
Introduction
Our method: DP-based velocity optimization system

- Propose vehicle movement (VM) model
- Build queue length model
- Apply vehicle queue length into DP (Dynamic Programming) algorithm
System Design
Overview

Queue length model

Traffic volume → VM model → Leaving vehicle rate → Waiting vehicles in traffic signal areas

Arrival vehicle rate
System Design
Overview

Queue length model
- Traffic volume
- Arrival vehicle rate
- VM model
- Leaving vehicle rate

Constraints
- Speed limit
- Stop sign
- Acceleration

Waiting vehicles in traffic signal areas
DP-based velocity optimization
System Design
Overview

**Queue length model**
- Traffic volume
- Arrival vehicle rate
- VM model
- Leaving vehicle rate
- Waiting vehicles in traffic signal areas

**Constraints**
- Speed limit
- Stop sign
- Acceleration

**Optimized velocity profile**
- DP-based velocity optimization
System Design
Energy consumption model of pure EVs

Driving force:

\[ F_{\text{drive}} = m \frac{dv}{dt} + \frac{1}{2} \rho A_f C_d v^2 + mg \sin \theta + \mu mg \cos \theta \]
System Design
Energy consumption model of pure EVs

- Driving force:
  \[ F_{\text{drive}} = m \frac{dv}{dt} + \frac{1}{2} \rho A_f C_d v^2 + mg \sin \theta + \mu mg \cos \theta \]

- Energy generated by the battery pack:
  \[ E = UQ \eta_1 \eta_2 \]

- \( U \) - Battery pack voltage;
- \( Q \) - Charge consumption;
- \( \eta_1 \) - Battery transforming efficiency;
- \( \eta_2 \) - Powertrain working efficiency;
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Energy consumption model of pure EVs

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- Energy generated by the battery pack:
  \[ E = UQ\eta_1\eta_2 \]

- Energy consumption per time:
  \[ \xi = \frac{F_{\text{drive}}v}{U\eta_1\eta_2} \]

\[ \frac{1}{2} \rho A_f C_d v^2 \]

\[ mg \sin \theta \]

\[ \mu mg \cos \theta \]

\[ \theta \]

Driving force of pure EV

\( U \) - Battery pack voltage;
\( Q \) - Charge consumption;
\( \eta_1 \) - Battery transforming efficiency;
\( \eta_2 \) - Powertrain working efficiency;
Queue length model is built to estimate waiting vehicle numbers in traffic signal areas:

- Vehicle arrival rate $V_{in}$
- Vehicle leaving rate $V_{out}$
System Design
Traffic dynamics in traffic signal areas

- Arrival vehicle rate $V_{in}$: estimated based on real-time traffic volume

![Graph showing Arrival and leaving vehicle rates](image-url)
System Design
Traffic dynamics in traffic signal areas

- Arrival vehicle rate $V_{in}$: estimated based on real-time traffic volume
- Vehicle leaving rate $V_{out}$: estimated with vehicle movement model
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Waiting vehicle numbers in one traffic light period of US-25 highway
Experiment
Simulation settings

1. Vehicle parameters in energy consumption model

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<tr>
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<th>$\eta_1$</th>
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<td>Values</td>
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2. Experiment road segment on US-25 highway

- Total 4050 m long
- One stop sign
- Two traffic signals
- Speed limit - 65 mile/hour
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- Total 4050 m long
- One stop sign
- Two traffic signals
- speed limit - 65 mile/hour

3. Velocity optimization results are verified in SUMO environment
Experiment
Velocity optimization

**Metric:** Total energy consumption during the trip

**Observation:** Reduces by 8.4% energy compared with current method in the experiment

**Reason:** Enables EVs to immediately pass through traffic lights without meeting waiting vehicles
Conclusion

1. We proposed a velocity optimization system for EVs with considering queue length in traffic signal areas
2. We conducted velocity optimization simulation study with SUMO to verify our method
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2. We conducted velocity optimization simulation study with SUMO to verify our method.

Future work

1. Consider the effect of road gradient on the proposed system.
2. More practical experiments in different traffic conditions.
Thank you! Questions & Comments?

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