Connected Vehicle Based
Active Traffic and Demand Management

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Outline

Introduction
Challenges and Opportunities for Research
Connected Vehicle ATDM Case Study
Conclusion
What is Connected Vehicle?

- **Definition**
  - Connected Vehicle is a suite of technologies and applications that use **wireless communications** and **multiple sensors** to provide connectivity.

- **Objectives:**
  - To improve Safety, Mobility and Environment.

- **Communications:**
  - Vehicle to Vehicle (V2V)
  - Vehicle to Infrastructure (V2I)
  - Vehicle to Vehicle and Infrastructure (V2VI)
Connected Vehicle

Connected Vehicle is a multimodal initiative, and provides the feasibility to generate more comprehensive and accurate traffic state estimation.

Active Traffic and Demand Management

Active Traffic and Demand Management (ATDM) is the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing traffic conditions.
Connected Vehicles based ATDM will build the wireless connectivity

- **among vehicles** to enable crash prevention;
- **between vehicles and infrastructure** to enable safety, mobility and environmental benefits; and
- **among vehicles, infrastructure, and wireless devices** to provide continuous real-time connectivity to all system users.
Three Major Steps
Connected Vehicle Development

- Dynamic Sensing (Upward-V2I, V2V)
  - Establish Data Sensing Environment (V2I, V2V)
  - Increase Market Penetration
  - New Application Development

- Active Control (Downward-I2V, V2V)
  - Establish Reliable I2V Control Environment
  - Active and Proactive Applications

- Integrated Coordination (Complete connection)
  - Complete upward/downward communications
  - Considering Interaction/Feedback/System Optimal
  - Integrated and System Application Development
Data Environment
Opportunities VS Challenges

Opportunities

- Data
  - Rich data environment
  - High resolution
  - Large sample size
- Control and Guidance
  - Bi-directional
  - Microscopic
  - User-specific
- Models
  - Real-time models
  - High-resolution models
  - Feedback models
  - System-optimal models
  - Integrated models

Challenges

- Data
  - Data noises
  - Multi-data sources
- Control and Guidance
  - High interaction
  - High sensitivity
  - User-specific
- Models
  - Changed nature of transportation system
  - Increased computation efficiency requirement
  - Interdisciplinary efforts
Opportunities VS Challenges

- Practice — Theory
- Next Generation Traffic Models
  - Transportation research made major advances since Greenshields’ fundamental diagrams model in 1935.
  - For young transportation researchers, it is easy to understand the details of a model than to understand the general trend and big picture of research.
  - We are at the edge of a new wave of transportation models with technological and theoretical advances in transportation.

7/20/2012
Traffic Model Development

- The first wave (1950s – 1980s)
  - The completion of major freeway systems: US Interstate system, German Autobahn.
  - Models to describe and manage increased traffic flow.

- The second wave (1980s – 2000s)
  - The advances in information technologies.
  - Models taking the advantage of faster computers to collect, process, and use traffic data more efficiently.

- Distributed and Cloud Computing, Smart Vehicle Technologies
- Models to handle automated vehicles and user-specific control
- Dynamic/Microscopic Traffic Control for Autonomous and Automated Vehicles
## Evolution of Traffic Model

<table>
<thead>
<tr>
<th></th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Generation (1950s-1980s)</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; Generation (1980s-2000s)</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; Generation (2000s-?)</th>
<th>4&lt;sup&gt;th&lt;/sup&gt; Generation (?-Future)</th>
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<tbody>
<tr>
<td><strong>Background</strong></td>
<td>Understand Basic Characteristics</td>
<td>Estimating Dynamic characteristics</td>
<td>Real-time characteristics and control</td>
<td>Automated driving and control</td>
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<tr>
<td><strong>Key Characteristics</strong></td>
<td>Empirical Static</td>
<td>Descriptive Dynamic</td>
<td>Real-time Interaction</td>
<td>Automated Integrated</td>
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<td><strong>Data Environment</strong></td>
<td>Survey Experimental</td>
<td>24 hours/7 days Historical</td>
<td>24 hours/7 days High-resolution</td>
<td>24 hours/7 days Full information</td>
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<td><strong>Issues</strong></td>
<td>• Labor-intensive data collection.</td>
<td>• Limited spatial/temporal coverage</td>
<td>• Data reduction</td>
<td>• Integration with autonomous vehicles, System reliability and security</td>
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<td>• Not reliable for operations.</td>
<td>• Limited penetration rate</td>
<td>• Data fusion and integration</td>
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<td>• Strong interaction</td>
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Case Study: CV Based ATDM

- Macroscopic Traffic State Estimation
  - Density
  - Speed (space mean)
- Driver’s Response to Traffic Control
  - On Board Unit (I2V)
  - Message Broadcasting (V2V)
- Measurement of Effectiveness
  - Reduce travel time
  - Increase total traffic flow
  - Reduce collision
Case Study: CV Based ATDM

- Freeway Density Estimation
Case Study: CV Based ATDM

- Variable Speed Limit for Freeway Control

Whitemud Drive between 122 Street and 159 Street, Edmonton, Alberta
Model Prediction Control

**Speed Dynamics**
- 3 parameters

\[ v_{m,i}(k + 1) = v_{m,i}(k) + \frac{T}{\tau} \left( u_{m,i}(k) - v_{m,i}(k) \right) + \]

\[ \frac{T}{L_{m,i}} v_{m,i}(k) \left( v_{m,i-1}(k) - v_{m,i}(k) \right) \]

\[ \frac{\eta T}{\tau L_{m,i}} \frac{\rho_{m,i+1}(k) - \rho_{m,i}(k)}{\rho_{m,i}(k) + \kappa} , \]

**Density Dynamics**

\[ \rho_{m,i}(k + 1) = \rho_{m,i}(k) + \frac{T}{L_{m,i} \lambda_{m,i}} \left( \rho_{m,i-1}(k) v_{m,i-1}(k) - \rho_{m,i}(k) v_{m,i}(k) + r_m(k) - s_m(k) \right) \]

**Flow**

\[ q_{m,i}(k) = \rho_{m,i}(k) v_{m,i}(k) \lambda_m \]
Model Prediction Control

- **Past**: Current traffic conditions
- **Future**: Predicted future traffic conditions
- **Control Variables** (u)
- **Control Horizon**: [k, k+1, k+Nc-1]
- **Predicted Horizon**: [k, k+Np]

The diagram illustrates the relationship between past and future traffic conditions, along with the control variables and horizons in the context of model prediction control.
Variable Speed Limit

- DynaTAM: Dynamic Tool for Active Traffic Management – used in Traffic Management Centre in City of Edmonton
CV Test Bed - ACTIVE

- **ACTIVE**: Alberta Cooperative Transportation Infrastructure and Vehicles Environment
- **ACTIVE**: Traffic Data and Control
- **ACTIVE** Partners
  - City of Edmonton
  - Alberta Transportation
  - Transport Canada
  - University of Alberta
  - Other Industry Partners
CV Test Bed - Applications

- Connected Vehicle Based Data Applications
  - Cellular Probe Based Speed Monitoring
    - Antoney Henday Drive
    - Other 4 corridors
  - Cellular Probe Based OD Estimation
    - Multimodal
    - Edmonton and Calgary, Edmonton airport

- Connected Vehicle Based Control Applications
  - Freeway Variable Speed Limit Control
    - Whitemud Drive
  - Adaptive Signal Control Considering Capacity Dynamics
  - Transit Bus Priority Control
  - Driver Guidance via Variable Message Signs
  - Enhance Winter Roadway Maintenance Efficiency
CV Based Traffic Monitoring

- Cellular Network

- Traffic Modeling
  - Map Match Engine
  - Sample Filtering Engine
  - Data Fusion Engine
  - State Estimation Engine
  - State Prediction Engine
  - Parameter Calibration Engine

Real-time Traffic Data

GPS (Phone) Probe Data

Cellular Probe Data

Signaling Collection Card
Phase 1: Anthony Henday Drive from Manning Drive NW to the Yellowhead Trail and the Whitemud Drive from 156 Street to 122 Street (2012 July-2014 March)

Phase 2: Anthony Henday Drive from Manning Drive NW to Yellowhead Trail, to Gateway Blvd from Yellowhead Trail to 170 street, Whitemud Dr. and 75 Street (2014 April-2016 March)

Phase 3: Cover most of the major roads in Edmonton Metro area. (2016 April -2018 March)
Conclusion

- Connected Vehicle is approaching us, and it potentially will make transportation smarter!
- The involvement of public sectors, private sectors and academic institutes are required!
- More challenges and opportunities in the ITS field!
THANKS

QUESTION?