Integrated Variable Speed Limit and Ramp Metering Control for Managing Recurrent Freeway Congestion ----System Framework

Yang (Carl) Lu
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Outline

- Key Research Issues
- Proposed System Framework
- System Functions
Research Background

What can we do?

Key Issues

- Monitor the real-time network conditions to:
  - provide inputs to adjust parameters in traffic prediction models
  - help determine the control boundaries and activation time
  - provide inputs to change the control objectives
Key Issues

- Accurately model the driver responses to VSL signs
- Formulate the traffic evolution under mixed-flow conditions
Key Issues

- Develop algorithms to identify of the control boundaries
Key Issues

- Develop algorithms to identify of the control boundaries

Coordinated Corridor Control
Key Issues

- Develop algorithms to identify of the control boundaries

Integrated Off-ramp Control
Key Issues

- Construct the optimal traffic control model which can:
  - Determine of appropriate control objectives
  - Coordinate between VSLs and RMs
  - Coordinate between multiple RMs
  - Coordinate between freeways and local arterials
Proposed System Framework

System Input

Traffic Surveillance System

Traffic Demand Estimation

Traffic State Prediction/Parameter Update

Mixed Traffic Flow Formulation

Compliance Rate Modeling

Identification of the Control Boundaries/Activation Time

System Output

Integrated Optimal Control

Local Bottleneck Control

Coordinated Corridor Control

Integrated Off-ramp Control

MOEs

Control Strategies
- Activation Time
- Boundaries
- RM Rates
- Displayed Speeds

Dynamic Monitoring System

Adjust Control Objectives
System Functions

- Dynamic Monitoring System
  - There are five states defined in the monitoring system, which are [1]
    - I. Stable free-flow
    - II. Meta-stable free-flow
    - III. Unstable
    - IV. Meta-stable congestion
    - V. Stable congestion

System Functions

- Dynamic Monitoring System
  - The boundaries between these five states are estimated from the field data with the k-means [1] clustering method.

System Functions

- Dynamic Monitoring System
  - The classified state could be used to adjust the parameters in the prediction model.
  - The states could be helpful in determining control boundaries and activation time.
  - Based on the current state, the control objective will also be dynamically adjusted.
System Functions

- **Traffic State Prediction/Parameter Update**
  - **Mixed Traffic Flow Model**
    - The slow moving vehicles will affect the movement of vehicles of higher speed.
    - More vehicles complying to VSL and higher density value will both lead to more significant impacts on the effectiveness of VSL.
  - **Compliance Rate Modeling**
    - Affected by the speed difference between displayed and perceived speeds
    - Affected by the downstream conditions
  - **Parameter Update**
    - Adjusted through Kalman Filter
System Functions

- Identification of the control boundaries and activation time
  - Activation Time
    - If congestion is predicted in the network within the projected time horizon, the control system should be activated.
  - Determine the Starting Point of the VSL Control
    - The mainline control should start from the upstream of the bottleneck, not currently covered by the congestion.
System Functions

- **Identification of the control boundaries and activation time**
  - *Determine the number of VSLs to be activated in the local bottleneck control*
    - Based on the targeted flow rate reduction and VSL operational constraints, determine the maximum number of VSLs to be activated if only VSL control is applied.
    - Distribute part of the flow rate reduction to on-ramps and finalize the VSLs need to be used.
System Functions

- Identification of the control boundaries and activation time
  - **Determine the timing to activate the coordinated corridor control**
    - when the local bottleneck control is not sufficient (on-ramp queue spillback or unavoidable congestion in the VSL control area)
    - more on-ramps and VSLs upstream should be added into the control system
System Functions

- Identification of the control boundaries and activation time
  - **Determine the timing to activate the integrated off-ramp control**
    - when queues are detected at off-ramps and potential spillover to freeway segments are predicted
    - signal timings at local intersections should be optimized to discharge the off-ramp queued vehicles
System Functions

- **Local bottleneck control**
  - Based on the mixed-flow traffic prediction model
  - Select the control objective based on the current traffic state
  - Determine the first-stage control strategy based on traffic flow analysis
  - Determine the second-stage control strategy based on optimization and local search
System Functions

- **Coordinated corridor control**
  - Multiple coordinated on-ramp controls
  - Make sure each control zone to be operated in the capacity region
  - On-going work
Thank you.
yanglu@umd.edu