Traffic Flow and Ramp Meter Signal Prediction

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Problems and Motivations

• One challenging problem in transportation area:
  • Reducing delay and maintaining capacity flow on a freeway by regulating access of ramp traffic to the mainline
  • Solution: Ramp metering

• But current ramp metering algorithms have some weaknesses and they do not use historical traffic data

• Our goal: Predict traffic flow and control ramp signal using ML approaches while benefiting from historical traffic data
Ramp Metering

- Mainline Sensors
- Freeway Mainline
- Ramp Metering Signal
- Demand Sensor
- Stop Line
Freeway Breakdown

![Graph showing speed, flow, and queue discharge speed over time with breakdown and service capacity indicated.](image-url)
Weekly Traffic Patterns based on Volume
Our Approach

• Feature Selection
• Regression
• Clustering
• Final Ramp Meter Algorithm
Regression

• Training Data:
  • Over 1 week (only working days)
  • Time slots of 5 minutes
  • $X$: $\text{Time}(t), \text{Occupancy}(t), \text{Speed}(t), \text{Volume}(t)$
  • $Y$: $\text{Volume}(t+1)$

• Online Data:
  • Data of one day
  • $X$: $\text{Time}, \text{Occupancy}, \text{Speed}, \text{Volume}(t)$
  • Predict $\text{Volume}(t+1)$ using the fitted model

• Compare the results with recorded data
  • Observe the trend
Evaluation of Regression

Real Vol(t+1) vs. Predicted Vol(t+1)
Clustering

• Two K-means (K=5) clustering approaches:
  • Cluster data based on time and $\frac{\Delta Vol}{\Delta t}$
  • Cluster data based on just $\frac{\Delta Vol}{\Delta t}$
    • Cluster 1: --
    • Cluster 2: -
    • Cluster 3: Const.
    • Cluster 4: +
    • Cluster 5: ++
Clustering Results

Clustering based on $\Delta \text{Vol} / \Delta t$

Clustering based on $\Delta \text{Vol} / \Delta t$

Clustering based on $\Delta \text{Vol} / \Delta t$ and Time

Clustering based on $\Delta \text{Vol} / \Delta t$ and Time
Our Ramp Metering Algorithm

Start

- $PE(t) < -20\%$ or $PE(t) > 20\%$
  - $V(t+1) = V(t+1) \ast (1 - PE(t))$

- $20\% < PE(t) < 20\%$
  - $V(t+1) < 220$
    - Traffic phase: 2, 3, 4 (load)
      - Traffic phase: 1, 5 (off load)
        - Set UAF
        - $RS(t+1) = 0$
    - $V(t+1) > 220$
      - Traffic phase: 1, 5 (off load)
        - Traffic phase: 2, 3, 4 (load)
          - Set DAF

- $\Delta V(t) = 1$
  - $RS(t+1) = 1 + [2 \times \text{Cap}]$
- $\Delta V(t) = 2.4$
  - $RS(t+1) = 1 + [1.9 \times \text{Cap}]$
- $\Delta V(t) = 3.5$
  - $RS(t+1) = 1 + [2.1 \times \text{Cap}]$
ALINEA as a Baseline Algorithm for Evaluation

- **ALINEA**
  - A local traffic-responsive ramp metering strategy
  - Stabilizes traffic flow
  - Reduces the risk of flow breakdown
  - Making effective use of freeway capacity

\[ g(k) = g(k - 1) + K_R \frac{C}{r_{sat}} \left( \hat{\phi} - O_{out}(k) \right), g_{min} \leq g \leq g_{max} \]

- \( g(k) \): green-phase duration at time interval \( k \) (sec.)
- \( g(k - 1) \): green-phase duration at time interval \( k-1 \) (sec.)
- \( C \): the fixed signal cycle duration (red phase + green phase) (sec.)
- \( r_{sat} \): the ramp capacity flow (veh/hour)
- \( K_R \): regulator parameter (veh/hour)
- \( \hat{\phi} \): critical occupancy (%)
- \( O_{out}(k) \): occupancy downstream of the merge area at time interval \( k \) (%).
Evaluation and Comparing Results

- S0: Ramp signal is disable
- S1: Ramp signal is active with Low Delay
- S2: Ramp signal is active with Medium Delay
- S3: Ramp signal is active with High Delay
Flexibility based on Breakdown Point
Conclusion and Future Work

• Developing a new ramp metering algorithm using ML approaches
  • Regression: consistent predictions regarding traffic trend
  • Clustering
  • More flexible on entering on-ramp vehicles compared to ALINEA

• High quality incident data was not available
• Traffic accident validation
• Run Simulation
Thank You

• Question and Answer