Queue Length Estimation and Prediction on Freeway off-ramps using traffic volume count data and Kalman filter

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Background

➢ Congestion on Freeways

- Traffic queue on merge and divergent points

Queue on Off-ramps

Queue on On-ramps

(CBC Calgary) (CBC Calgary)
Background

➢ Causes of Queue Formation

  - Recurrent Congestion
  - Non-recurrent Congestion

➢ Role of Real-time Queue Length Information

  - Proactive Queue Management Strategies
Objectives and Contributions

- Real-time queue length estimation on off-ramps
- Predicting the queue length over a short time period
- Using traffic count data as the only data source
- Applying different methods of noise estimation
Methodology

1: Kalman gain calculation
2: Update measurements
3: Update error covariance
4: Project into the next time step

Initial estimates

Measurements from video-based count data

Predicted estimates

Corrected estimates
Methodology

- Initial queue measurement based on count data

  Step 1: Estimating the average travel times between cameras

  Step 2: Estimating the average speed between cameras

  Step 3: Estimating the density and queue length of each section based on traffic count

  Step 4: Using the estimated queue length as the initial measurement in Kalman filter for each time step
Methodology

- **Kalman Filter (KF)**
  - **Input data for KF**
    - Measured queue length from count data
    - Traffic count from upstream and downstream detectors
  - **Fundamental KF Equations**
    - **State Equation**
      \[
      x_{k+1} = \varphi x_k + \beta u_k + w_k
      \]
      \[
      \hat{x}_{k+1} = \hat{x}_k + (f_{in_k} - f_{out_k}) + w_k
      \]
    - **Measurement Equation**
      \[
      Z_k = Hx_k + v_k
      \]
      \[
      w_k \sim N(0,Q)
      \]
      \[
      v_k \sim N(0,R)
      \]
Methodology

Kalman Filter Process

Prediction

Initialize $\hat{x}_k$, $P_k$

**State equation:**

$\hat{x}_{k+1}^- = \phi \hat{x}_k + \beta u_k + w_k$

**Update covariance:**

$P_{k+1}^- = \phi P_k \phi^T + Q$

Correction

Kalman gain calculation:

$K_k = P_k^- H^T (H P_k^- H^T + R)^{-1}$

Update the estimate via measurement:

$\hat{x}_k = \hat{x}_k^- + K_k (Z_k - H \hat{x}_k^-)$

Update error covariance:

$P_k = (I - K_k H) P_k^-$
Case Study

- Study Area
  - Deerfoot Trail southbound off-ramp to 17th Ave SE
Results and Analysis

Flow-Density from RTMS data

| Jam Density | 100 Vh/Km |
Results and Analysis

Measured queue length based on count data

Corrected and predicted queue length with KF and Mayers adaptive Q and R estimation

Corrected and predicted queue length with KF and video processing errors
Conclusions and Keynotes

- Estimating the queue length on freeway off-ramps
- Predicting the queue length for the next time step
- Applying Kalman filter based on two different noise covariance calculation
Future Studies

- Advanced processing of video files to produce other types of data including occupancy and speed and estimate the queue length based on new data and comparing the results.

- Examining the model on long on-ramps or other network components.

- Integrating the model with a responsive and adaptive signal control strategy.
Thank you

Questions and Comments