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Optimizing Intersection Offsets Using High Resolution Traffic Data
Motivation

- Intersections are often poorly managed because of the lack of systematic data collection
- Recent advances in technology are making HR data collection economical
- Improving performance of the signalized network by
  - Optimizing the offsets to reduce
    - Number of the stops
    - Average delay
    - Total delay
Existing Methods

• Focus on major approach
• Do not consider traffic volume profile
• Minimize the delay

• Synchro:
  • For each offset combination Synchro evaluates the departure patterns at this and surrounding intersections and recalculates delays
  • Synchro estimates delay using HCM equation and Percentile Delay method.
  • Percentile Delay method calculates the delay for five percentile volume levels and then uses weighted average delay of all scenarios.
New Approach

• Introduced by S. Coogan, et. al. in “Offset optimization for a network of signalized intersections via semi-definite relaxation”[1]

• Considers all approaches
• Minimizes queue length
• Assumes sinusoidal arrival and departure process to obtain analytical formulas for queue lengths at all intersections as a function of the offsets

Offset Optimization Algorithm
Offset Algorithm Formulation

\[
\min_{\{\theta_s\}_{s \in S}} \sum_i Q_i
\]

\[Q_i \geq 0 \quad \forall i\]

\[Q_i = \text{Queue length in link } i\]

\[\theta_s = \text{Offset at node } s\]
Offset Algorithm Input and Output

• Inputs:
  • Vehicle counts
  • Cycle length
  • Green Split
  • Green time per phase
  • Travel time between consecutive intersections
  • Geometry of the network

• Output:
  • Optimum offset value for each signal
Using HR Data

- Continuous detector data as vehicles approach and leave intersection
- Simultaneous signal status
Case Study
Testing Site

- Montrose Rd. in Montgomery County (Maryland)
  - 7 intersections
  - 2 approaches merge in to 1
• Estimated 3 different measures for 5 traffic volume profiles in VisSim (Simulator) for following scenarios:

1. Synchro’s optimum offset
   • estimated by minimizing the delay

2. Algorithm optimum offset
   • estimated by minimizing the queue length in the whole network
Site Layout

- Major traffic input approaches:
  1. East bound
  2. Top west bound
  3. Bottom west bound
Traffic Profiles

Traffic profile for each Scenarios

Input (Vehicle/hour)

Case 1  Case 2  Case 3  Case 4  Case 5

Scenarios

EB input  Top WB input  Bottom WB input
Offset Values

Offset Values for Case 1

Offset Values for Case 2

Offset Values for Case 3

Offset Values for Case 4

Offset Values for Case 5
### Evaluation Process

<table>
<thead>
<tr>
<th>Route Direction</th>
<th>Route Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>←</td>
<td>1</td>
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<tr>
<td>→</td>
<td>2</td>
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<tr>
<td>←</td>
<td>3</td>
</tr>
<tr>
<td>←</td>
<td>4</td>
</tr>
</tbody>
</table>
Evaluation Process

• We will compare 4 parameters:
  
  • **Number of stops**
    • Average number of stops =\(\text{Sum over all routes}(\text{number of stop in each route} \times \text{number of vehicles in that route})/\text{total number of vehicles in all routes}\)

  • **Vehicle Delay**
    • Average vehicle delay =\(\text{Sum over all routes}(\text{average vehicle delay in each route} \times \text{number of vehicles in that route})/\text{total number of vehicles in all routes}\)

  • **Stop Delay**
    • Average stop delay =\(\text{Sum over all routes}(\text{average stop delay in each route} \times \text{number of vehicles in that route})/\text{total number of vehicles in all routes}\)

  • **Social Cost (Total vehicle delay)**
    • Social cost=\(\text{Sum over all links}(\text{average vehicle delay in each route} \times \text{number of vehicles in that route})\)
Number of Stops

- **Number of stops** = number of stops that vehicle makes during their trip
Vehicle Delay

- Vehicle delay = travel time in free flow – actual travel time
Stop Delay

- Stop delay = time that vehicle has zero speed

![Stop Delay Chart]

- Average Delay in Second

- Case Number

- Synchro
- Algo
Total Vehicle Delay

- Total delay that all vehicle experienced in 1 hour, in another word, social cost under each condition.
- Total delay = average vehicle delay \times number of vehicles

![Graph showing total delay in vehicle-hours for different scenarios.](image)
Conclusion

• We can reduce the number of the stops, vehicle delay, and stopped delay by using the optimum offset.

• Depending on the traffic profile, improvement can be between 5% and 30%.

• Offset optimization algorithm can be a better and more effective method for estimating the optimum offset for large networks.

• Offset optimization algorithm could be used real time and became a part of the online control system.
Thank You!

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