MIDAS: Proactive Traffic Control System for Diamond Interchanges

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What is MIDAS?

Managing Interacting Demand And Supply

Demand

Supply
A Note on Control Systems

• Classification of control systems
  – Open Loop
  – Closed Loop (defined by feedback path)

• Open Loop
  – In open loop control systems, output is not fed-back to the input. So, the control action is independent of the desired output.
  – Fixed time signal control.

• Closed Loop
  – In closed loop control systems, output is fed back to the input. So, the control action is dependent on the desired output.
  – Actuated signal control & adaptive traffic control systems.
Adaptive Control System

- Proactive
- Reactive
Open-loop vs Reactive vs Proactive

- Actual Trajectory
- Reactive
- Open Loop
- Proactive
General Proactive Control Architecture
Measurements

• Eulerian Measurements
  – Data collected at a fixed point in space, also called point detectors.
  – Inductive loop detectors, video detectors, etc.
  – They give traffic counts and approximate vehicle speeds.

• Lagrangian Measurements
  – Data collected from mobile detectors that move with flow of traffic.
  – Cell phones, GPS-based locator, etc.
  – They give travel times, vehicle trajectories, speeds, etc.

• MIDAS uses Lagrangian measurements.
MIDAS for Diamond Interchanges

- Signal control of two closely spaced intersections at diamond interchange faces following challenges
  - Complicated traffic movements
  - Phase overlaps
  - Limited inter storage capacity for queued vehicles
  - Fluctuating demand and heavy off-ramp traffic
MIDAS Prediction & Control; Arterial

- PREDICT
- TURNING RATIOS
- TRAVEL TIMES
- DISCHARGE RATES
- ESTIMATION MODELS
- DATA STREAMING (GPS)

Arrivals & Queues → Control Algorithms

State of traffic network
MIDAS Signal Control Algorithm

- MIDAS employs efficient Dynamic Programming (DP) approach to optimize traffic movements at the intersection, at a lane level resolution.
- Determines optimal phase sequence & duration of phases.
- Totally cycle free control strategy.
- Employs forward recursion DP approach to solve and backward recursion to retrieve optimal phase schedule.
- Flexible enough to optimize user defined performance measure, like stops, delays and queues, etc. over a finite time horizon that rolls forward.
MIDAS Signal Control Algorithm

- Decision variable: $x_j$ (Phase duration of stage j)
- Stage: Phase j
- State variable: $s_j$ (time horizon with stage j)
- Incremental value of objective function: $f(s_j, x_j)$
- Cumulative value of objective function: $V_{j-1}(s_{j-1})$
- $V_j(s_j) = \min \{ f(s_j, x_j) + V_{j-1}(s_{j-1}), \forall x_j \in X_j \}$
Diamond Interchange DP Solution Example

Possible Phase Combination

phase duration
VISSIM Network Simulation

- I-17 & 19th Ave., Phoenix, AZ
Evaluation

• RHODES
  – A predecessor to MIDAS
• Optimal Fixed Time Control (OFTC)
  – VISSIM stage based optimization algorithm
  – Sequence of simulation runs performed to determine best signal program.
  – Signal program is constructed by modifying green times of best & worst stage.
  – The stage with the lowest maximum average delay is selected as the best stage.
  – The stage with the highest maximum average delay is selected as the worst stage.
Performance Metrics

• Delay Average
  – Average of all vehicle delays due to presence of signal controller in their path when compared to free flow, without any signal control.

• Total Delay
  – Sum of all vehicle delays in network, in seconds.

• Stops Average
  – Average number of stops made by a vehicle.

• Average Queue Length
  – Average queue length at any given movement at the stop line of the interchange.

• Total Travel Times
  – Sum of travel times of all vehicles in the network, in seconds.
Results

**Network Level Performance**

<table>
<thead>
<tr>
<th>SC</th>
<th>SimTime(s)</th>
<th>TrafficLoad</th>
<th>DelayAvg(s)</th>
<th>TotalDelay(s)</th>
<th>TotalTravelTime(s)</th>
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</thead>
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<tr>
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<td>4900</td>
<td>13.25</td>
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<td>OFTC</td>
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</table>

**Intersection Level Performance**

<table>
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<th>SC</th>
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<th>TrafficLoad</th>
<th>DelayAvg(s)</th>
<th>StopsAvg(s)</th>
<th>TotalStops(s)</th>
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<td>25.74</td>
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<td>18.23</td>
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</tbody>
</table>
Average Delay vs Traffic Load

Average Delay (Secs) vs Traffic Load (Veh/Hr)

- **Midas**: 14.63, 30, 20.3, 31.51, 24.68, 38, 65.69
- **Rhodes**: 15.8, 16.93, 1472, 30, 31.51, 38, 70.4
- **OFC**: 4500, 4800, 5100, 5400, 5700, 6000, 6300, 6600, 6900, 7200

**Data Points**:
- Rhodes: 15.8, 16.93, 1472, 30, 31.51, 38, 70.4
- OFC: 4500, 4800, 5100, 5400, 5700, 6000, 6300, 6600, 6900, 7200

**Graph Elements**:
- **X-axis**: Traffic Load (Veh/Hr)
- **Y-axis**: Average Delay (Secs)
- **Lines**:
  - Midas: Blue
  - Rhodes: Red
  - OFC: Green
Average Stops vs Traffic Load
Average Queue Length vs Traffic Load

Traffic Load (Veh/Hr)

Avg. Queue Length

midas
rhodes
oftc
References

- Brent A. Cain, ADOT. I-17 & 19th AVE. Proactive traffic control of diamond interchange project.
Thank You