Integration of the global positioning system and geographical information systems for traffic congestion studies

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Background

Congestion

Experiments

Relation to Our Project

Strong and Weak Points
GPS/GIS Integration

- Idea: Combine GPS-data with other data sources
- Why: Traffic studies (ex. travel times, congestion), environmental studies and planning
- How: Integrated GPS/GIS (Geographical Information Systems)
GPS/GIS Integration

- GPS-data (longitude, latitude)
- Environmental data (emissions, engine revolutions, gear, fuel consumption)
- Geographical data (topography, land-data)
GPS/GIS Integration

- Impact Analysis
- Travel Demand Modelling
- Forecasting
- Land use

INTEGRATED SPATIAL/TEXTUAL DATABASE

INDIVIDUAL DATABASES
- Traffic and Environmental Impacts
- Traffic Flows
- Socio economic and Demographic data
- Transport Networks
- Land/property Data
- Topography
Probe Vehicle

- GPS equipped car
- Additional equipment for recording ex. fuel consumption, engine revolutions and gear
- Expensive, not stock equipment

Table 1
Vehicle parameters logged in real time by the TSC probe vehicle

<table>
<thead>
<tr>
<th>Variable</th>
<th>Measurement units</th>
<th>Variable</th>
<th>Measurement units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>s</td>
<td>Air conditioning</td>
<td>on/off</td>
</tr>
<tr>
<td>Distance</td>
<td>m</td>
<td>Power/economy mode</td>
<td>on/off</td>
</tr>
<tr>
<td>Speed</td>
<td>km/h</td>
<td>Engine gear</td>
<td>gear (1–4)</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>l</td>
<td>Hydrocarbons (HC)</td>
<td>ppm</td>
</tr>
<tr>
<td>Engine revolutions</td>
<td>rpm</td>
<td>Nitrogen oxides (NOₓ)</td>
<td>ppm</td>
</tr>
<tr>
<td>Manifold pressure</td>
<td>Pa</td>
<td>Carbon monoxide (CO)</td>
<td>ppm</td>
</tr>
<tr>
<td>Throttle position</td>
<td>ratio</td>
<td>Carbon dioxide (CO₂)</td>
<td>ppm</td>
</tr>
<tr>
<td>Engine temperature</td>
<td>°C</td>
<td>Oxygen (O₂)</td>
<td>ppm</td>
</tr>
<tr>
<td>GPS position</td>
<td>Latitude + Longitude</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Moving Observer

- Appropriately equipped vehicle
- Records ex. travel times and queue lengths
- Represents the average driver
- Should traverse each route several times
Floating Car

- Is a moving observer
- Floats naturally through traffic
- Aims at being the "average" driver
- Should overtake the same number of cars as overtaken by
- Limits moving observer bias
Floating Car

▶ Mean travel time

\[ t_{ab}^- = t_{ab} + \frac{O}{q} \]

, where \( t_{ab}^- \) is the travel time, \( t_{ab} \) is the recorded travel time, \( O \) is the number of cars overtaken minus the number of cars who overtake and \( q \) is the mean flow rate.

▶ Mean flow rate is calculated by having a second vehicle traveling in the opposite direction

\[ q = \frac{m - O}{t_{ab} + t_{ba}} \]

, where \( m \) is the number of cars met and \( t_{ba} \) is the travel time for the opposite direction.
Congestion

- Congestion is traffic jams
- Congestion is a major issue in traffic both for drivers and planners
- When is a road congested?
- And how much?
Definition of Congestion

- Increased disruption of traffic movement
- Results in delays and queues
- "Is generated by the interactions amongst the flow units in a traffic stream or in intersecting traffic streams"
- Visible when the capacity of a road is exceeded
Congestion Measures

- Delay is when the recorded travel time is greater than the free-flow travel time

\[ d = T - T_0 \]

, where \( T \) is the recorded travel time and \( T_0 \) is the free-flow travel time.

- Congestion can be measured using different methods:
  - Congestion Index
  - Proportion Stopped Time
  - Acceleration Noise
Congestion Index (CI)

- Delay on a piece of road will depend on the length of the road, road type and other characteristics
- CI enables comparison between roads with different characteristics
- Congestion Index is derived from Delay

\[ CI = \frac{d}{T_0} \]

- A road or route will naturally have a CI of 0 in a state of free-flow
- The higher the CI gets, the more congested the road or route is
Proportion Stopped Time (PST)

- Travel time can be divided into running time $T_r$ and stopped time $T_s$
- PST is the ratio of stopped time to the total journey time

$$PST = \frac{T_s}{T}$$

, where $T$ is $T_s + T_r$

- Unlike CI, PST is usually not 0 as intersections will often induce stopped time
Acceleration Noise (AN)

- Acceleration Noise is calculated from a speed profile
- Idea: Congestion will induce more fluctuation in speed
Acceleration Noise (AN)

\[ AN = \sqrt{\frac{1}{T_r} \sum_{i=1}^{n} \frac{\Delta v_i^2}{\Delta t_i}} \]

, where \( \Delta t_i \) is the time interval taken for a speed change \( \Delta v_i \)

- AN is different from CI and PST in that it provides a measure of the quality of the traffic flow
- AN is data-hungry as it requires prior knowledge about speed profiles on a specific road or route
Experiment setup
Experiments

- Construction of the new road does not consequently lower the travel times
- Travel times on the new road are lower, but the problems on the old road are not gone
### Table 4
Congestion indices for the Southern Expressway

<table>
<thead>
<tr>
<th>Run code</th>
<th>Total distance (m)</th>
<th>Travel time (s)</th>
<th>Stopped time (s)</th>
<th>Mean journey speed (km/h)</th>
<th>Proportion stopped time</th>
<th>Acceleration noise</th>
<th>Mean velocity gradient</th>
<th>Congestion index</th>
</tr>
</thead>
<tbody>
<tr>
<td>301198amn1</td>
<td>8154.7</td>
<td>424.0</td>
<td>22.0</td>
<td>69.2</td>
<td>0.052</td>
<td>0.459</td>
<td>0.024</td>
<td>0.301</td>
</tr>
<tr>
<td>3011981mn3</td>
<td>8149.1</td>
<td>374.0</td>
<td>0.0</td>
<td>78.4</td>
<td>0.000</td>
<td>0.420</td>
<td>0.019</td>
<td>0.147</td>
</tr>
<tr>
<td>011298amn2</td>
<td>8141.8</td>
<td>469.0</td>
<td>61.0</td>
<td>62.5</td>
<td>0.130</td>
<td>0.548</td>
<td>0.032</td>
<td>0.439</td>
</tr>
<tr>
<td>011298amn4</td>
<td>8166.4</td>
<td>396.0</td>
<td>11.0</td>
<td>74.2</td>
<td>0.028</td>
<td>0.574</td>
<td>0.028</td>
<td>0.215</td>
</tr>
<tr>
<td>021298amn1</td>
<td>8142.8</td>
<td>365.0</td>
<td>0.0</td>
<td>80.3</td>
<td>0.000</td>
<td>0.481</td>
<td>0.022</td>
<td>0.120</td>
</tr>
<tr>
<td>021298amn3</td>
<td>8164.9</td>
<td>416.0</td>
<td>29.0</td>
<td>70.7</td>
<td>0.070</td>
<td>0.515</td>
<td>0.026</td>
<td>0.276</td>
</tr>
<tr>
<td>021298amn5</td>
<td>8167.6</td>
<td>376.0</td>
<td>18.0</td>
<td>78.2</td>
<td>0.048</td>
<td>0.440</td>
<td>0.020</td>
<td>0.153</td>
</tr>
<tr>
<td>031298amn1</td>
<td>8165.3</td>
<td>350.0</td>
<td>0.0</td>
<td>84.0</td>
<td>0.000</td>
<td>0.494</td>
<td>0.021</td>
<td>0.074</td>
</tr>
<tr>
<td>031298amn3</td>
<td>8153.3</td>
<td>378.0</td>
<td>0.0</td>
<td>77.7</td>
<td>0.000</td>
<td>0.400</td>
<td>0.019</td>
<td>0.160</td>
</tr>
<tr>
<td>031298amn5</td>
<td>8150.7</td>
<td>454.0</td>
<td>70.0</td>
<td>64.6</td>
<td>0.154</td>
<td>0.581</td>
<td>0.032</td>
<td>0.393</td>
</tr>
<tr>
<td>041298amn2</td>
<td>8144.2</td>
<td>379.0</td>
<td>5.0</td>
<td>66.4</td>
<td>0.013</td>
<td>0.473</td>
<td>0.022</td>
<td>0.163</td>
</tr>
<tr>
<td>041298amn4</td>
<td>8155.8</td>
<td>421.0</td>
<td>57.0</td>
<td>69.7</td>
<td>0.135</td>
<td>0.562</td>
<td>0.029</td>
<td>0.291</td>
</tr>
<tr>
<td>041298amn5</td>
<td>8158.9</td>
<td>382.0</td>
<td>24.0</td>
<td>76.9</td>
<td>0.063</td>
<td>0.503</td>
<td>0.024</td>
<td>0.172</td>
</tr>
</tbody>
</table>

*Morning peak direction, Southern Expressway, free travel time = 326.0 s, all data collected in period 07:00–09:00*
Our project

- Estimate travel times based on GPS-data collected by ex. cars and taxis
- Calculate fastest path from A to B for a number of A’s and B’s
- Identify/handle troublesome events such as rush hour
Relation to Our Project

- Our project is only concerned with traffic, not environment and other aspects
- We use multiple data collection vehicles which do not "float" but are moving observers
- We base our solution on travel time estimated from GPS-data, but not in the same way
- We might be able to use some of the congestion measures
  - Delay, CI and PST can be calculated using the data we receive, but might not be usable. We might need to do something like PST.
  - Given enough data we can use AN or speed profiles. We might store travel times in a manner that resembles speed profiles.
Strong and Weak Points

Strong points:
- Clear definitions of congestion measures
- Nice overview of GPS/GIS integration
- Practically usable experiments

Weak points:
- No clear contributions
- Data collection is based on a single probe vehicle
- Experiments could have been compared to the models used when designing the new road
Questions?