Using Smartphone for Travel Mode Detection in New York City

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Content Outline

- Background for Mode Detection
- Implementation Challenges for NYC
- Prior Work & Current Progress
- Questions
Benefits of Mode Detection
What are the benefits of TMD?

- It collects the same data as traditional Travel Surveys via smartphones.
- Increasingly done through smartphones which commuters carry most of the time (i.e. a convenience factor added).
- Improve the understanding of peoples' travel behavior.
Traditional Travel Survey:

1. How did you travel to work today?
   PLEASE TICK ALL MODES OF TRAVEL USED, NOT JUST THE MAIN ONE
   
   Bicycle  □  
   Bus  □  
   Car – driver  □  
   Car – passenger  □  
   Foot  □  
   Motorbike  □  
   Train  □  
   Working from home  □  → Go to Q10
   Other  □  → Go to Q2

   IF OTHER, PLEASE SPECIFY  → Go to Q2

   ALL WHO TRAVELLED TO WORK TODAY

2. From the options selected in Q1, which was your main mode of transport (i.e. most time spent)? PLEASE TICK ONE
   \[
   \begin{align*}
   &\text{Bicycle} \quad □ \quad \rightarrow \text{Go to Q6} \\
   &\text{Bus} \quad □ \quad \rightarrow \text{Go to Q6} \\
   &\text{Car – driver} \quad □ \quad \rightarrow \text{Go to Q3} \\
   &\text{Car – passenger} \quad □ \quad \rightarrow \text{Go to Q3} \\
   &\text{Foot} \quad □ \\
   &\text{Motorbike} \quad □ \\
   &\text{Train} \quad □ \\
   &\text{Other as previously specified} \quad □ \quad \rightarrow \text{Go to Q6}
   \end{align*}
   \]

   ALL WHO USED CAR AS MAIN MODE OF TRANSPORT

3. Including yourself, how many people were travelling in the car?

   ENTER THE NUMBER OF INDIVIDUALS IN THIS BOX
Smartphone Travel Survey

GPS
Assisted GPS
Location-based Service

Internet
Mobile

Web GIS
Mobile GIS

GIS
Technologies involved in TMD?
Table 2. Summary of different approaches for mode detection

<table>
<thead>
<tr>
<th>Author/s</th>
<th>Method</th>
<th>Attributes</th>
<th>Accuracy</th>
<th>Ground truth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopher et al. (2008)</td>
<td>Rule-based algorithm</td>
<td>Speed, GIS, car/bike ownership</td>
<td>95%</td>
<td>PR survey</td>
</tr>
<tr>
<td>Schüssler and Axhausen (2009)</td>
<td>Fuzzy-logic system</td>
<td>Speed, acceleration</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Biljecki (2010)</td>
<td>Fuzzy expert system</td>
<td>Speed, proximity to the nearest networks</td>
<td>91.6%</td>
<td>PR survey</td>
</tr>
<tr>
<td>Gonzalez et al. (2010)</td>
<td>NNs</td>
<td>Speed, acceleration, data quality, travel distance, average dwell time</td>
<td>90%</td>
<td>User input in mobile phones</td>
</tr>
<tr>
<td>Tsui (2005)</td>
<td>Fuzzy system plus existing NNs</td>
<td>Speed, acceleration, data quality</td>
<td>94%</td>
<td>Travel diaries</td>
</tr>
<tr>
<td>Feng and Timmermans (2012)</td>
<td>BBNs</td>
<td>Speed, GIS, car/bike ownership, data quality</td>
<td>96%</td>
<td>Travel diaries</td>
</tr>
<tr>
<td>Troped et al. (2008)</td>
<td>DFA</td>
<td>Speed, accelerometer counts and steps</td>
<td>90%</td>
<td>n/a</td>
</tr>
<tr>
<td>Reddy et al. (2010)</td>
<td>Decision tree and discrete hidden Markov model</td>
<td>Speed, acceleration</td>
<td>93.6%</td>
<td>Experiment (i.e. mode known)</td>
</tr>
</tbody>
</table>

(obtained from Shen & Stopher 2013)
Implementation Challenges for NYC
Multiple Modes in NYC (e.g., walk, bus, subway, etc)
Urban Canyon Effect
Cold Start / Warm Start

(see Gong et al. 2012)
Prior Work & Current Progress
Overview of Mode Detection
Advantages of using GIS:

Connectivity to identify mode transfers

Combining network analysis + proximity analysis

Identifying activity nodes

Spatial editing in Web GIS
## Building a Multi-Modal Network

<table>
<thead>
<tr>
<th>Line Feature Class</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commuter Rail</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commuter Rail to Street Links</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commuter Rail to Subway Links</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Streets</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subway Entrances to Station Links</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Subway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Subway Transfer Links</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overview of Mode Detection

Figure 1. Methodology flow chart
## Mode Detection Success Rate

<table>
<thead>
<tr>
<th>Identified by GIS algorithm as:</th>
<th>Walk</th>
<th>Subway</th>
<th>Rail</th>
<th>Car</th>
<th>Bus</th>
<th>Unknown</th>
<th>Success rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>182</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>4</td>
<td>0</td>
<td>92%</td>
</tr>
<tr>
<td>Subway</td>
<td>0</td>
<td>40</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>15</td>
<td>66%</td>
</tr>
<tr>
<td>Rail</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>36%</td>
</tr>
<tr>
<td>Car</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>37</td>
<td>5</td>
<td>0</td>
<td>84%</td>
</tr>
<tr>
<td>Bus</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>15</td>
<td>0</td>
<td>63%</td>
</tr>
<tr>
<td>Total</td>
<td>186</td>
<td>41</td>
<td>5</td>
<td>66</td>
<td>27</td>
<td>15</td>
<td>83%</td>
</tr>
</tbody>
</table>
Prior Model Used:

Speed
+
Network Analysis (GIS)
Current Model Uses:

Speed
+
Accelerometer Reading
+
Network Analysis (GIS)
Compute Magnitude of Acceleration (MOA):

\[ A_{\text{mag}} = \sqrt{(A_x)^2 + (A_y)^2 + (A_z)^2} \]

(XYZ accelerometer data)
Using Personal Travel Data:
MOA by Mode:

- Car & Bus (0 to 4)
- Subway & Train (0 to 1)
- Bicycle (2 to 9)
- Walk (5 and above)
Supported by Research

Figure 1. Smartphone data: velocity (top row), magnitude of accelerometer readings (middle row) and frequency spectrum of the accelerometer signal (bottom row).

(obtained from Widhalm et al. 2012)
Supported by Research

(obtained from Reddy et al. 2010)
Conclusion

- Using accelerometer data
- Provide travel data for commuters, especially their underground commute
- After successfully implemented can be extend to wider transit region
- Facilitate Intelligent Transportation System (ITS) goals
Questions
Thank You!

University Transportation Research Center