Sensitivity of estimates of travel distance and travel time to street network data quality

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Outline

• Street network quality
• Approaches to validation
• Study design
• Results
• Conclusions
• Future work
Street Network Quality

- Positional accuracy
- Completeness
- Connectivity
- Restrictions (one-way, turns)
- Speed limit
- Traffic conditions
- Traffic signals
- Lane representations

\{ Individual intersections \}
Intersections

Source: Turner-Fairbank Highway Research Center

Source: TTM Traffic Engineering Group
Typical Network Data (in US)

- Commercial providers
- TIGER from the US Census Bureau
- Local agencies (counties, cities)
Validation of Street Network Data Quality

1. Test individual network components
   • E.g. measure positional accuracy, reliability of attributes, etc.

2. Test network analysis output
   • E.g. compare network travel times to tracking data of vehicles

3. Compare network analysis output to “gold standard”
   • E.g. use higher quality data
Microsoft Multiperson Location Survey (MSMLSS)

- 55 GPS receivers / 226 subjects
- 12,418 trips / 95,000 miles
- Basis for Microsoft’s Clearflow technology in maps.live.com
Study Objective

Determine the agreement in street network routing solutions between two network datasets of different quality.
Street Network Datasets

- Two street networks of different quality for Travis County, Texas:
  1. StreetMap USA 2005, a widely employed dataset that is provided with popular GIS software
  2. Network derived from local street centerlines created by local authorities.

- For the purpose of this analysis the network derived from local street centerlines is considered the “gold standard”.
Analysis Methods

- **Origins:**
  - 3,000 residential address locations (building centroids)

- **Destinations:**
  - Hospitals (9)
  - Emergency Medical Services (32)
  - Elementary Schools (169)

- **Network solutions:**
  - Shortest travel distance
  - Shortest travel time

- **Comparisons:**
  - Agreement in distance and time estimates
  - Agreement in nearest facility
  - Agreement in spatial accessibility measures
Spatial Distribution

Legend
- Residential Addresses
- Hospitals
- Emergency Medical Services
- Elementary Schools
- Travis County
# Descriptive Statistics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Elementary Schools</th>
<th>EMS</th>
<th>Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance (miles)</strong></td>
<td>Gold Standard</td>
<td>StreetMap USA 2005</td>
<td>Gold Standard</td>
</tr>
<tr>
<td>Min</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Max</td>
<td>14.79</td>
<td>14.83</td>
<td>16.89</td>
</tr>
<tr>
<td>Average</td>
<td>1.37</td>
<td>1.38</td>
<td>2.64</td>
</tr>
<tr>
<td>Median</td>
<td>0.86</td>
<td>0.85</td>
<td>2.02</td>
</tr>
<tr>
<td><strong>Time (minutes)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0.06</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Max</td>
<td>23.29</td>
<td>29.55</td>
<td>25.73</td>
</tr>
<tr>
<td>Average</td>
<td>2.43</td>
<td>2.92</td>
<td>4.49</td>
</tr>
<tr>
<td>Median</td>
<td>1.63</td>
<td>1.90</td>
<td>3.54</td>
</tr>
</tbody>
</table>
Correlation Example

\[ y = 1.1374x \]

\[ R^2 = 0.9488 \]
## Regression Results

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Distance</th>
<th></th>
<th></th>
<th>Time</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R-square</td>
<td>Slope</td>
<td></td>
<td>R-square</td>
<td>Slope</td>
</tr>
<tr>
<td>Elementary Schools</td>
<td>0.966</td>
<td>1.014</td>
<td></td>
<td>0.949</td>
<td>1.254</td>
</tr>
<tr>
<td>EMS</td>
<td>0.967</td>
<td>0.974</td>
<td></td>
<td>0.949</td>
<td>1.137</td>
</tr>
<tr>
<td>Hospitals</td>
<td>0.994</td>
<td>0.986</td>
<td></td>
<td>0.964</td>
<td>1.035</td>
</tr>
</tbody>
</table>

- Overestimate of travel time
- Agreement stronger for distance
- Agreement is stronger for greater distances/times
Addresses Routed to Incorrect Facility

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Distance</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary Schools</td>
<td>8.2 %</td>
<td>10.4 %</td>
</tr>
<tr>
<td>EMS</td>
<td>8.7 %</td>
<td>14.0 %</td>
</tr>
<tr>
<td>Hospitals</td>
<td>11.0 %</td>
<td>10.9 %</td>
</tr>
</tbody>
</table>

- Error larger for shortest travel time
- Error similar across different distance/time scales
## Addresses Assigned Incorrectly to Travel Thresholds

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Gold Standard</th>
<th>StreetMap USA 2005</th>
<th>% Correct Positives</th>
<th>% False Positives</th>
<th>% False Negatives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elementary Schools - Minutes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>650</td>
<td>481</td>
<td>69.08</td>
<td>4.92</td>
<td>30.92</td>
</tr>
<tr>
<td>3</td>
<td>2392</td>
<td>2209</td>
<td>91.89</td>
<td>0.46</td>
<td>8.11</td>
</tr>
<tr>
<td>5</td>
<td>2697</td>
<td>2598</td>
<td>96.18</td>
<td>0.15</td>
<td>3.82</td>
</tr>
<tr>
<td><strong>EMS - Minutes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>118</td>
<td>97</td>
<td>71.19</td>
<td>11.02</td>
<td>28.81</td>
</tr>
<tr>
<td>3</td>
<td>1170</td>
<td>1019</td>
<td>80.34</td>
<td>6.75</td>
<td>19.66</td>
</tr>
<tr>
<td>5</td>
<td>2087</td>
<td>1955</td>
<td>91.66</td>
<td>2.01</td>
<td>8.34</td>
</tr>
<tr>
<td><strong>Hospital - Minutes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>17</td>
<td>14</td>
<td>35.29</td>
<td>47.06</td>
<td>64.71</td>
</tr>
<tr>
<td>3</td>
<td>354</td>
<td>365</td>
<td>89.27</td>
<td>13.84</td>
<td>10.73</td>
</tr>
<tr>
<td>5</td>
<td>912</td>
<td>948</td>
<td>88.93</td>
<td>15.02</td>
<td>11.07</td>
</tr>
</tbody>
</table>
Conclusions

• Strong correlations for estimated travel distances/times between high and low quality network
• Substantial number of incorrectly routed addresses (~10%)
• Greater discrepancy in travel time estimates vs. distance estimates
• Resolution of low quality network ~ 1 to 2 minutes
Ongoing Work - Online Networks
Ongoing Work - Online Networks

• **Functionality has increased dramatically**
  - Basic (from A to B) expanded to include multiple stops
  - Routing options (time or distance, avoid highways)
  - General data quality improvements
  - Multi-modal networks (selective)

• **Still limited in other aspects**
  - No complex routing solutions
  - Limited origin-destination combinations
  - No quality information published
Example Result

![Graph showing the relationship between Online Network (min) and Austin Network (min). The graph illustrates a positive correlation with a trend line indicating that as the Austin Network increases, the Online Network also increases.]
Ongoing Work - Car Navigation Systems
ACCIDENTS

Bus Driver Scalps Bus Thanks to GPS Guidance

We may be inching towards the future of autonomous vehicles, but we're not quite there yet and a bus driver in Seattle has yet to figure that out. This is just another instance of individuals putting too much faith into GPS navigation devices. Following the directions from a Garmin GPS navigation unit, the Seattle bus driver attempted to go under a low footbridge that was a bit too low as it managed to scale the bus and injure five. The driver was carrying home the Garfield High School girl's softball team. This unfortunate accident does bring up an interesting conundrum. The driver had put the Garmin device on the "bus" setting and failed to notice the signs prior to the bridge. Obviously, the driver is to blame, but how much consideration should Garmin and other GPS manufacturers take when including a "bus" setting?

Driver follows GPS onto pedestrian walkway, into cherry tree

by Joshua Topolsky, posted Jul 21st 2007 at 5:15PM

In another example of the evils of computer navigation, a 37-year-old trucker followed his GPS directions to their totally illegal conclusion when he drove his truck down a pedestrian walkway and wedged the delivery vehicle into a cherry tree. The driver, who was looking for a factory to drop off his cargo, blindly followed the female voice of his navigation system, apparently ignoring several no-entry signs and turning onto the walkway in broad daylight. The motorist then attempted to reverse out, damaging two lamp posts, a hedge, and of course the cherry tree, which Swiss workers later had to take a chainsaw to. The trucker was fined 850 Swiss francs (about $540), and his GPS was given a firmware update and a copy of Google Maps.