Systems approach to sizing of C-HALO

Venkatesan Ekambaram, Christian Manasseh, Adam Goodliss, Raja Sengupta, Kannan Ramchandran
University of California Berkeley

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Outline

• Motivation

• Model for GPS satellite coverage estimation

• Experiments and Results
Motivation

- HALO needed for ITS applications.
- Benefits are huge ($160B - $320B).
- Questions:
  - What fraction of the US has good GPS coverage?
  - Where are the “dark” areas?
  - Can we estimate these with available data?
- Goal:
  - Estimate of GPS coverage and accuracy in different US cities.
Modeling Ground-based Satellite Visibility in San Francisco
Results

- 0.3 %– 4% of San Francisco has a GPS visibility of less than 6 satellites.

- Model prediction accuracy is 87%
  - validated on experimental data collected.
Model for satellite coverage

- GIS Database
- Experimental Satellite Visibility data
- Model for satellite coverage
Basic idea

- Calculate mask angle from building heights.

- Estimate number of satellites visible in the cone defined by the mask angle.
Data from GIS Systems

- About 200,000 parcels from city of San Francisco
- Building heights
- Street widths
  - Google
  - SFPParcel
- Mapped data into USNG reference grids
Real data collected using Smartphone GPS

6 Satellites – Green, 4 to 6 Satellites – Yellow, < 4 Satellites - Red
Model I accuracy

<table>
<thead>
<tr>
<th>Satellites</th>
<th>True &lt; 4</th>
<th>True 4 to 6</th>
<th>True &gt;6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted &lt; 4</td>
<td>0.74</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>Predicted 4 to 6</td>
<td>0.24</td>
<td>0.25</td>
<td>0.07</td>
</tr>
<tr>
<td>Predicted &gt; 6</td>
<td>0.02</td>
<td>0.59</td>
<td>0.91</td>
</tr>
</tbody>
</table>

- 1657 data points
- Overall prediction accuracy 69%.
A better metric (HDOP)
Model II – Using HMM

- Satellite counts in adjacent grids are correlated
- Model parameters are empirically estimated
HMM Model accuracy

<table>
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<tr>
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<th>True 4 to 6</th>
<th>True &gt;6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted &lt; 4</td>
<td>0.70</td>
<td>0.01</td>
<td>0</td>
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<tr>
<td>Predicted 4 to 6</td>
<td>0.08</td>
<td>0.41</td>
<td>0.11</td>
</tr>
<tr>
<td>Predicted &gt; 6</td>
<td>0.22</td>
<td>0.58</td>
<td>0.89</td>
</tr>
</tbody>
</table>

- 87% prediction accuracy.
Zoomed-in View of DT SF

6 Satellites – Green, 4 to 6 Satellites – Yellow, < 4 Satellites - Red
Use of the model

- Can predict satellite visibility in all cities
  - Building heights from assessor’s office.

- Help in phased deployment of CHALO

- Benefits can be better understood by overlaying other data like accident data.
Locate areas of Highest Benefit from deploying C-HALO
Comparison to existing models

- Taylor et al – LiDAR, Digital Surface Map – 54% accuracy

- Higher accuracy LiDAR data gives better results.

- LiDAR, DSM expensive to obtain.

- Our method – rough estimate but cheaper.
Conclusions

- Simple but effective model to estimate satellite visibility.
  - Estimated that 0.3% to 4% of San Francisco has a coverage less than 6 satellites.
  - 87% accuracy on real data.

- Required data sources to extend to other cities
  - GIS database – heights of buildings and street widths.
  - Training data would help get better estimates.

- Time and satellite almanac to be included.