Big Data for Smart Mobility

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What is Smart Mobility?

A tool to achieve sustainable cities (Hesssel 2015)
What is big “mobility” data?
Currently, each vehicle has an average of 60-100 sensors on board. The number of sensors is projected to reach as many as 200 sensors per car. These numbers translate to approximately 22 billion sensors used per year by 2020. One vehicle will produce 4 terabytes per hour…
V2V

Vehicles are getting connected and the main use is for safety and improvement of a driver experience.

Nearly 3,287 people die in road crashes every day...

Annual Global Crash Statistics 2017
V2I

- Intersection Collision Warning
- Real-time Traffic Flow Regulation
- Increased Accessibility for all Pedestrians
- Warnings based on Driver Profiles

V2I has not been fully adopted yet because cities can not afford it.
Big “Mobility” Data

V2X = V2V + V2I will be the main data sources in the future

Potentials:

• V2X will happen before autonomous cars
• 5G will play an important role in providing low latency
• Transportation as an utility that will come when you buy a house

Siemens (2015)
Big “Mobility” Data

V2X = V2V + V2I will be the main data sources in the future

Barriers:

• Continuous network coverage
• Security
• Legacy systems in transportation

Stop adding so many sensors to a vehicle and infrastructure and start understanding about human mobility behaviour.
Human Mobility Behavior
Proximity

Generating Mobility Neighbourhoods

• It is a pre-defined radius around any mobile thing at any given point in time.

• Any other thing within the predefined radius around a mobile thing is a neighbor to this mobile thing.
Mobility Neighborhoods
Bi-Partite Graph

Recognizing proximity as a graph problem

- Two disjoint sets of nodes
- Edges represent the proximity among mobility nodes at a timestamp $t$
We use Louvain clustering, as it uses modularity to determine its clusters.

Value between -1 and 1 which measures the density of links inside a community compared to links between communities.

\[ Q = \frac{1}{2m} \sum_{i,j} \left[ A_{ij} - \frac{k_i k_j}{2m} \right] \delta(c_i, c_j) \]
Vehicle Dataset

- Vehicle trajectory data
- 600 meter strip of Highway 101, United States
- Data collected on every vehicle every decisecond
- Approximately 15 minutes of data
- X position, Y position, velocity, lane, vehicle type, etc.
Bi-partite Graph of Mobility Data Neighbourhoods

Kaine and Wachowicz (2017)
Clusters Over Time and Space

Kaine and Wachowicz (2017)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total # of Clusters</td>
<td>5108</td>
</tr>
<tr>
<td>Mean # of Clusters</td>
<td>7.016</td>
</tr>
<tr>
<td>Max # of Clusters</td>
<td>9</td>
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<tr>
<td>Min # of Clusters</td>
<td>2</td>
</tr>
<tr>
<td>SD of # of Clusters</td>
<td>1.129</td>
</tr>
<tr>
<td>Mean # of Cars per Cluster</td>
<td>17.95</td>
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<tr>
<td>SD of Cars per Cluster</td>
<td>6.97</td>
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<tr>
<td>Minimum # of Cars in a Cluster</td>
<td>1</td>
</tr>
<tr>
<td>Maximum # of Cars in a Cluster</td>
<td>52</td>
</tr>
<tr>
<td>Mean Modularity</td>
<td>0.728</td>
</tr>
</tbody>
</table>
How can mobility neighbourhoods be useful?

- Manage V2X communication and interaction among vehicles without human intervention
- Real-time mobility analytics at both local scale and global scale
Connectivity
Recognizing smart mobility as a graph problem

**TYPES OF GRAPHS**
- Undirected / Directed Graphs
- Vertex / Edge labeled Graphs
- Cyclic Graphs
- Weighted Graphs
- Disconnected Graphs
- Bi-Partite Graphs

**METRICS**
- Centrality
- Shortest path
- Eigenvalues
- Betweenness
- Degree
- Cluster Coefficient
Recognizing that everything is a node
Transit Network
Trip Connectivity
People In Motion Lab

Biological Network
Protein Connectivity
CoNe Lab
Transit Network
Trip Connectivity
People In Motion Lab

Biological Network
Protein Connectivity
CoNe Lab
How can graphs be useful?

- Provide an ubiquitous analytical framework
- Explain mobility using complex networks

Contreras-Castillo, Zeadally, Ibáñez (2017)
Conclusions

(Adapted from Caragliu et al. 2009)

**Smart City Pillars**

- **Smart Living**
  - e.g. Emission free transport, advanced parking, accessibility

- **Smart Economy**
  - e.g. High-tech industry, ease of doing business, innovation culture

- **Smart Government**
  - e.g. Sustainable buildings, water management

- **Smart Environment**
  - e.g. e-Health, public safety, intermodal transport

- **Smart Society**
  - e.g. agile civil society, social inclusion, e-learning

- **Smart Mobility**
  - e.g. e-government services, open data, transparency, resilience