A comparison of distributed vs. centralized design

Preliminary results from the study of subway networks and encyclopedias

Joao Castro  Nirav Shah  Robb Wirthlin

Advisor: Prof. Magee
Defining the problem

• **Hypothesis:** Systems that are structured or centrally designed are **different** than those that are unstructured or emerge in an evolutionary fashion

• **Approach:** Observe transportation networks and knowledge networks with network analysis tools for comparison between types of systems
Bottom-line

Structured vs. Unstructured
Planned vs. Evolved

• Information Networks are different:
  – Different path lengths
  – Different depth of information

• Transportation Networks:
  – No common structure among each class
EB Circle of Knowledge

• Terms:
  - Adenomyosis
  - Algebra
  - Aluminium
  - Baseball
  - Basketball
  - Beekeeping
  - Brigadier
  - Cellular_automaton
  - Christmas
  - Colonization_of_Africa
  - Color_photography
  - Criminology
  - Design
  - DNA
  - Elisabeth_of_Bavaria
  - Entrepreneur
  - Francisco_Franco
  - Golf
  - Hans_Christian_Andersen
  - History_of_Manchester
  - Ice_cream
  - India
  - Industrial_Revolution
  - James_Chaney
  - Locomotive
  - Massari
  - Meditation
  - Moscow
  - Nobel_Peace_Prize
  - Paris
  - Politics
  - Population
  - Radio
  - Stradivarius
  - World_war_II
Path length comparison between wikipedia and EB

- Terms:
  - Adenomyosis
  - Algebra
  - Aluminium
  - Baseball
  - Basketball
  - Beekeeping
  - Brigadier
  - Cellular_automaton
  - Christmas
  - Colonization_of_Africa
  - Color_photography
  - Criminology
  - Design
  - DNA
  - Elisabeth_of_Bavaria
  - Entrepreneur
  - Francisco_Franco
  - Golf
  - Hans_Christian_Andersen
  - History_of_Manchester
  - Ice_cream
  - India
  - Industrial_Revolution
  - James Chaney
  - Locomotive
  - Massari
  - Meditation
  - Moscow
  - Nobel_Peace_Prize
  - Paris
  - Politics
  - Population
  - Radio
  - Stradivarius
  - World_war_II

Distance between two terms in wikipedia is shorter than in EB (lies below the diagonal)
Visualizing growth in wikipedia
Transportation Systems
Four Transportation Systems

Evolved

London

Planned

Beijing (Planned)

Boston

Moscow (Metro+Regional light rail)
Network Representation

- **Nodes**: Station that allow transfers between lines
- **Arcs**: Lines that connect those stations
  - If a line connects two stations, there is an arc
- Allows reuse of Whitney’s datasets
- Attempting to do a few systems at full scale -- every station
## Basic metrics

<table>
<thead>
<tr>
<th>City</th>
<th>n</th>
<th>m</th>
<th>&lt;k&gt;</th>
<th>C1</th>
<th>C2</th>
<th>l</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>London</td>
<td>92</td>
<td>139</td>
<td>3.02</td>
<td>0.222</td>
<td>0.1595</td>
<td>5.394</td>
<td>0.0997</td>
</tr>
<tr>
<td>Beijing</td>
<td>29</td>
<td>82</td>
<td>2.83</td>
<td>0.237</td>
<td>0.0667</td>
<td>3.409</td>
<td>-0.1053</td>
</tr>
<tr>
<td>Boston</td>
<td>21</td>
<td>44</td>
<td>2.09</td>
<td>0.074</td>
<td>0.0317</td>
<td>3.562</td>
<td>-0.3011</td>
</tr>
<tr>
<td>Moscow</td>
<td>136</td>
<td>408</td>
<td>3.00</td>
<td>0.080</td>
<td>0.0591</td>
<td>6.037</td>
<td>0.2601</td>
</tr>
</tbody>
</table>

**Small-worlds??**

**Negative degree correlation**
For technical systems???
# Centrality

<table>
<thead>
<tr>
<th>City</th>
<th>Degree</th>
<th>Closeness</th>
<th>Betweenness</th>
<th>Eigenvector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>10.099</td>
<td>30.234</td>
<td>8.922</td>
<td>22.053</td>
</tr>
<tr>
<td>Boston</td>
<td>10.476</td>
<td>29.293</td>
<td>13.484</td>
<td>23.693</td>
</tr>
<tr>
<td>Moscow</td>
<td>2.222</td>
<td>16.923</td>
<td>3.759</td>
<td>6.231</td>
</tr>
</tbody>
</table>

One planned, one evolved both have high centrality???
Next Steps

• Add more systems to the subway analysis
  – A few more big ones and some small ones

• Bring in the qualitative data – histories of the systems
  – Are there particular historic patterns that correspond to the numbers presented?

• Complete data analysis
Backups
Implications

• No clear differences between planned and unplanned systems
• Beijing and Boston have negative degree correlation reflecting central hub with spokes topology
• Moscow (when you include light rail) has a radial grid pattern which accounts for the high degree correlation and path length
• Beijing and Boston stand out as much more centralized – i.e. having many path go through a smallish central core than London and Moscow
• High centrality nodes are key transfer point – e.g. King’s Cross and North Station
Boston

Image removed for copyright reasons.
Map of the Boston subway system.
See:  http://urbanrail.net/am/bost/boston.htm
London

Image removed for copyright reasons.
Map of the London subway system.
See:  http://de.geocities.com/u_london/london.htm
Beijing

Courtesy of the Wikimedia Commons.
Moscow

Image removed for copyright reasons.
Map of the Moscow Metro.
See: http://urbanrail.net/eu/mos/moskva.htm