Unwinding spatial and transpatial networks

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University of Oulu

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Workshop on Computational Models of Physical/Virtual Space Interaction.
<table>
<thead>
<tr>
<th>Who</th>
<th>What</th>
<th>How</th>
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</thead>
</table>
| Vassilis Kostakos  
Prof. Computer Engineering in Ubiquitous Computing  
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www.ee.oulu.fi/~vassilis | Social and complex networks  
Sensing urban mobility  
Public interactive displays  
Security and privacy | Instrumenting mobile platforms  
Real-time city-sensing  
Human subjects studies  
Large scale deployments |
University of Oulu

- Founded in 1958
- 6 faculties
- 16,000 students
- 2,900 employees
- Total funding EUR 226 million
- Four research focus areas:
  - Information Technology
  - Biosciences and Health
  - Cultural Identity and Interaction
  - Environment, Natural Resources and Materials
Overview

• MediaTeam Research Group (Urban Interactions)
  – 4 professors, 50 researchers & staff

• Multidisciplinary
  – Computer Science (HCI, ubiquitous computing)
  – Anthropology
  – Sociology
  – Architecture (urban)
  – Design
Ongoing work

- **Human Computer Interaction, Trust, Privacy, Phishing**
- **Spatial & Transpatial Social Networks**
  - Urban Mobility & Encounter
  - Epidemiology & Diffusion
  - Space Syntax
- **Augmented Spaces**
  - Situated Services
  - Delay Tolerant Networks
- **Technology**

**UbiOulu**

**Slide 5**
• Real vs. Virtual “Space”
• Think of online space as a version of the “real” world
• Think of the urban space (“real” world) as a version of online space: data & numbers
• People: the link
Outline

• How do online and face-to-face networks relate to each other?
• How do networks effect trust in location-sharing?
• Ongoing work: the real-time city
Study 1

People with Bluetooth devices bumping into each other (school, shopping, work)

Cityware nodes record & upload data

Cityware servers analyze data

Facebook application presents data

Users' social network grows
Data

• 2602 participants

• Co-presence data [‘A’ was co-located with ‘B’]
  – Subset of actual physical encounters, March 2007

• Facebook friendship network [‘A’ is friends with ‘B’]
  – recorded after bluetooth data collection
Data coding

• **Encounter network (Spatial network)**
  – Users linked if they were co-located during the study

• **Facebook network (Transpatial network)**
  – Users linked if they were friends on Facebook

• **Fused network**
  – Encounter and Facebook networks fused
  – 3 types of ties: Encounter, Facebook & ‘Fused’
Facebook

Encounter

Fused
Results
**Structural Characteristics**

- Multiple connected components

![Graph showing cluster size vs. probability](chart.png)
Structural Characteristics

- Correlation of Structural Features of nodes
  - Degree - 0.68
  - Closeness - 0.46
  - Betweenness - 0.24
  - Clustering Coeff. - 0.46
Resilience

• Average size of clusters as edges are removed
Links

• Significant effect of link type on link betweenness \( (p<0.0001) \)
  – In the fused network
  – Types of links in order of importance: Encounter, Facebook, Fused
## Triads

- **Triad**: A set of nodes that are mutually connected
- **Observed**: Frequency of each type in our network
- **Expected**: Frequency in a random assignment of edge types

<table>
<thead>
<tr>
<th>Triad</th>
<th>Observed</th>
<th>Expected</th>
<th>Popularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>220</td>
<td>45</td>
<td>4.9</td>
</tr>
<tr>
<td>B</td>
<td>587</td>
<td>171</td>
<td>3.4</td>
</tr>
<tr>
<td>C</td>
<td>650</td>
<td>329</td>
<td>2.0</td>
</tr>
<tr>
<td>D</td>
<td>270</td>
<td>211</td>
<td>1.3</td>
</tr>
<tr>
<td>E</td>
<td>103</td>
<td>152</td>
<td>0.7</td>
</tr>
<tr>
<td>F</td>
<td>34</td>
<td>54</td>
<td>0.6</td>
</tr>
<tr>
<td>G</td>
<td>85</td>
<td>143</td>
<td>0.6</td>
</tr>
<tr>
<td>H</td>
<td>81</td>
<td>349</td>
<td>0.2</td>
</tr>
<tr>
<td>I</td>
<td>43</td>
<td>237</td>
<td>0.2</td>
</tr>
<tr>
<td>J</td>
<td>64</td>
<td>447</td>
<td>0.1</td>
</tr>
</tbody>
</table>
A generative model

1. Assume a fixed number of locations and people
2. At each location people encounter each other randomly
3. If two people encounter each other, there is a probably that they become friends on Facebook
4. People may become friends on Facebook even if they have not met face to face
5. Some Facebook friends may visit each other
6. People may travel to locations even if they know no-one there
Take-away points

• Bluetooth and Facebook networks exhibit similar structural characteristics
• Suggests that as users’ proxies to actual social networks, they reflect similar aspects
• Fused ties least important
  – Further reflects Granovetter’s ties strength hypothesis: Fused ties are more likely with close relatives or colleagues
• Spatial ties more ‘important’ than transpatial - might sound counterintuitive
  – Bluetooth has the potential to record “familiar strangers” relationships

Study 2
Question 1

- Given a group of users and the social ties amongst them
- is it possible to predict which of these users is likely to
- reveal the most about their whereabouts?
Question 2

• Given a “target user”, is it possible to predict which of his friends knows most about his whereabouts?
Collected data

• Study running for 1 year +
• For each user:
  – Friends (via Facebook)
  – Privacy preferences (policies)
• 340 users
• 889 friendship pairs
• 1778 policies (=889*2)
Policy definition

- Probability that user A will share his location with user B
- Values: 0 ~ 1
Trust vs. Trustworthiness

- User A’s average trust towards others
  - \((0.8 + 0.3 + 0.5)/3 = 0.53\)
- User A’s average trustworthiness
  - \((0.1 + 0.2 + 0.5)/3 = 0.27\)
Distribution of trust

Number of Users

Trust

0.0 0.2 0.4 0.6 0.8 1.0
Distribution of trustworthiness
Take-away points

• Q1: Given a group of users, which one is most likely to reveal their location?
  – The most central user
  – People that trust others more are more central in the network
  – People that are trusted more are less central in the network

• Q2: Given a “target user”, which of their friends is most likely to know the location of the “target”?
  – The person with most friends
  – The person with most common friends with the target

Ongoing work: the Real-time city
Public interactive displays

- Indoor hotspot
- Outdoor hotspot
- Oulu Swimming Hall
- UbiOulu
- Oulu10
- Valve
- Toripollisi
- Rotuaari N
- Rotuaari C
- Rotuaari E
- Rotuaari S
- Rotuaari W
- Oulu
- UbiOulu WLAN AP
- panOULU WLAN AP
- panOULU WSN AP
- panOULU BT AP
- Camera
- Control PC
- Loudspeaker
- NFC/RFID reader
- 57" Full HD LCD panel
- 500 GB RAID 1 disk
- 6 mm safety glass with capacitive touch screen foil

UBI Hotspot services
- Cityguide
- Restaurants
- Event Calendar
- Rotuaari Renovation
- Oulu檀Hall
- Service Directory
- City of Oulu

Check our partners services:
- BetaGarden
- Erkäepäinen
- EuroMia
- Fortum
- Mankala
- Oulu Richie
- Savonlinnan Nuoresta
- Savonlinnan Nuoren
- Service Directory
- City of Oulu
panOulu WiFi
Bluetooth network
3D Oulu
Reconstructing movement
Where is it busy now?
Catchment areas
Explore historic traffic patterns
Find visitors & visitor locations
Finding “shoals”
Twitter realtime analysis

![Crisis Tracker](image)

## Crisis Tracker

### What
- Demonstration
- Violence
- Detained/Missing
- Torture/Rape
- Killed
- Heavy weapons/Bombing
- Affected infrastructure

### Where
- Only show stories within map bounds

### Search Criteria
- **What**: Demonstration, Political movement, Political<Int'l> event, Risk/Hazard/Threat, Summary report, Eyewitness report, Rumor/False, High impact event
- **Who**: Enter name
- **When**: From [ ] to [ ]

### Table

<table>
<thead>
<tr>
<th>Size</th>
<th>Date/Time</th>
<th>Title</th>
<th>Tags</th>
</tr>
</thead>
<tbody>
<tr>
<td>139</td>
<td>9 Sep 17:10</td>
<td>#Syria <a href="http://t.co/Y70DE1Sj">http://t.co/Y70DE1Sj</a></td>
<td></td>
</tr>
<tr>
<td>229</td>
<td>9 Sep 15:19</td>
<td>Syria Criticizes France's Support of Rebels - <a href="http://t.co/CjsPYTiU">http://t.co/CjsPYTiU</a> - #world</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>9 Sep 10:38</td>
<td>New York police is joining the prayer for #Syria - <a href="http://t.co/no2By9ka">http://t.co/no2By9ka</a></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>9 Aug 13:25</td>
<td>More than a hundred of their women and children killed in a massacre by #Assad forces, #Houla protests today!! <a href="http://t.co/WF0TXLLL">http://t.co/WF0TXLLL</a> #Syria</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>8 Sep 17:28</td>
<td>Syria #news #RealSyria #MangoLmn <a href="http://t.co/nrXBHlHu">http://t.co/nrXBHlHu</a></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>8 Sep 11:04</td>
<td>#Syria #news #RealSyria #MangoLmn</td>
<td></td>
</tr>
</tbody>
</table>
Information Propagation on Twitter
Spread of news regarding earthquake outside Japan on July 10, 2011
(internal structure of a 3766 node story from CrisisTrackerPrototype)
Instrumenting mobile platforms

Capture data on phone (Instrumentation)

Capture behavior vector (Questionnaire/Automated)

Calculate metrics

Calculate metrics

Establish correlations

Describe behavior
Instrumenting social networks

Capture social network (Instrumentation)

Capture behavior vector (Questionnaire)

Calculate metrics

Calculate metrics

Establish correlations
Closing thoughts

• We do a lot of instrumentation
  – Social
  – Mobility
  – Smartphone

• A lot of data describing individual & community-level behavior

• Great potential for combining with other metrics (health, economy, education, etc)
More information

UBI program
http://www.ubioulu.fi

Try one of our hotspots!
http://vm.node0005.ubioulu.fi:8080/LayoutManager/

Try the 3D Oulu!
http://world.oulu3dlive.net

Real-time city statistics
http://stats.ubioulu.fi

Crisis Tracker
http://ufn.virtues.fi/crisistacker/

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