Marta C. González
CEE Assistant Professor
Joint ESD and ORC member
E-mail: martag@mit.edu
Office & phone: 1-153, +1 (617) 253-1715
Lab URL: http://web.mit.edu/humnet/index.shtml

Unraveling Human Mobility Motifs

Human Mobility and Networks Lab (HuMNet) at MIT!
CITIES ARE NOW HOME TO HALF OF THE WORLD’S 7 BILLION HUMANS. BY 2030, nearly 5 billion people will live in cities. 137,000 people move into Asia’s cities every day.

Source: google image
6 BILLION phones.

* CIA World Fact Book
Paths through cities

Paths through Los Angeles
Routing 30,000 randomly-chosen trips through the paths suggested by 10,000 randomly-chosen geotags.

Paths through Seattle
Routing 30,000 randomly-chosen trips through the paths suggested by 10,000 randomly-chosen geotags.

Paths through Moscow
Routing 30,000 randomly-chosen trips through the paths suggested by 10,000 randomly-chosen geotags.

Trajectories from 10,000 Twitter Users (POI -> Google Map Resolution)
Disruptions: Data Without Context Tells a Misleading Story

By NICK BILTON

The New York Times Technology | Personal Tech | Business Day
• Quantify?
• Validate?
• Applications?
Preferential Return

Understanding Individual Mobility Patterns
Gonzalez, Hidalgo and Barabasi et al.

Limits of Predictability in Human Mobility
*Science* (2010)
Song, Barabasi et al.

Modeling the Scaling Properties of Human Mobility
Song, Barabasi et al.

Unraveling Human Daily Mobility Motifs
Schneider, Gonzalez et al.

Exploration

* A universal model for mobility and Migration Patterns Mobility Patterns
Simini, Gonzalez, Maritan and Barabasi.

* A Multi-scale Multi-Cultural Study of Commuting from Digital Traces
To be Submitted (2010)
Understanding Road Usage Patterns in Urban Areas
*Scientific Report* (2013)
Wang, Gonzalez et al.
Regularity and Scaling


• Daily Travel Surveys (Chicago and Paris ~23,000 individuals)

• 154 days of 500,000 mobile phone users. We extract 43,000 with active 3.5 hours across the day.
Populated US City:

- City: 2,695,598
- Rank: 3rd US
- Density: 4,447.4/km²

23,400 weekdays of a representative sample
Individual Patterns in Urban Areas
Locations and Tours

\[ f(x) = e^{-\frac{(x-\mu)^2}{2\sigma^2}} / (x\sigma(2\pi)^{1/2}) \]

- \( \mu = 1, \sigma = 0.5 \)

\[ f(x) = e^{-\frac{(x-\mu)^2}{2\sigma^2}} / (\ln(x+1)\sigma(2\pi)^{1/2}) \]

- \( \mu = 0.75, \sigma = 0.36 \)
Motifs: represent the building blocks of families of networks.
Seminal work by Uri Alon et. al. They are sub graph that appear in real system much more than in their randomized network with the same global topological structure.
The observations can be modeled

This describes 90% of the daily networks in the three datasets
1) All motifs, except motif ID 5 and 9, have only one ‘central’ location, a node with more than two directed links, as the origin for a tour $T(x)$ visiting $x$ locations, if $x < N$.

2) The motifs can also be classified by four rules:
   I) $T(1)$ and $T(N - 2)$  
   II) $T(N)$  
   III) $T(1), T(1)$, and $T(N - 3)$  
   IV) $T(2)$ and $T(N - 3)$  
   Cycle + $T(1)$  
   Cycle  
   Cycle + 2$xT(1)$  
   Cycle + $T(2)$
Model

other

home

t
1-p(t)
t+1

\( \alpha p(t) \)

\( \alpha p(t) \)

\( p(t) \)

\( \alpha = 10 \)

\( P_{NW}(t) \)

\( p_1 \)

\( p_2 \)
Analytical Solution

\[ P(N = x) = \xi_0 \left( \prod_{t=1}^{K} \Lambda_t \right) U^T(C_x), \ C_x \in \Omega \]  
\[ \Omega = \{(x, i); \ x = 0, ..., K - 1; \ i = 0, 1\} \]  

Models of trips must introduce burtsy behavior

\[ f(N) = e^{-(\ln N - \mu)^2/(2\sigma^2)} / (N\sigma(2\pi)^{1/2}) \]
\[ \mu = 1, \sigma = 0.5 \]

\[ f(N) = p^{N-1}(1-p)^{K-N+1}K!/(K-N+1)! \]
\[ K = 32, p = 1.4/32 \]
Summary

The presence of motifs uncovers a basic principle that can be used in predictive models for trip chains on a relatively simple mathematical formula reducing complexity of algorithms that simulate human behavior.

Next steps in the analysis will have to incorporate the POIs (geolocated point of interests at the destination) to infer purposes of the activity.