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Social and Technological Network Analysis: Spatial Networks, Mobility and Applications

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Today's Outline

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1. Introduction to spatial networks
2. Geo-social networks
3. Location-based social networks
4. Special: Spatial economics & the sharing economy

www.pnas.org

What is a spatial network

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A spatial network is a graph whose nodes are embedded in a **metric space**.

Hence, in spatial networks, one can apply a **distance function** between two nodes in the network.

The distance metric used to analyse spatial networks is often **geographic distance**.

Can you think of any spatial networks emerging in the real world?

Spatial Networks

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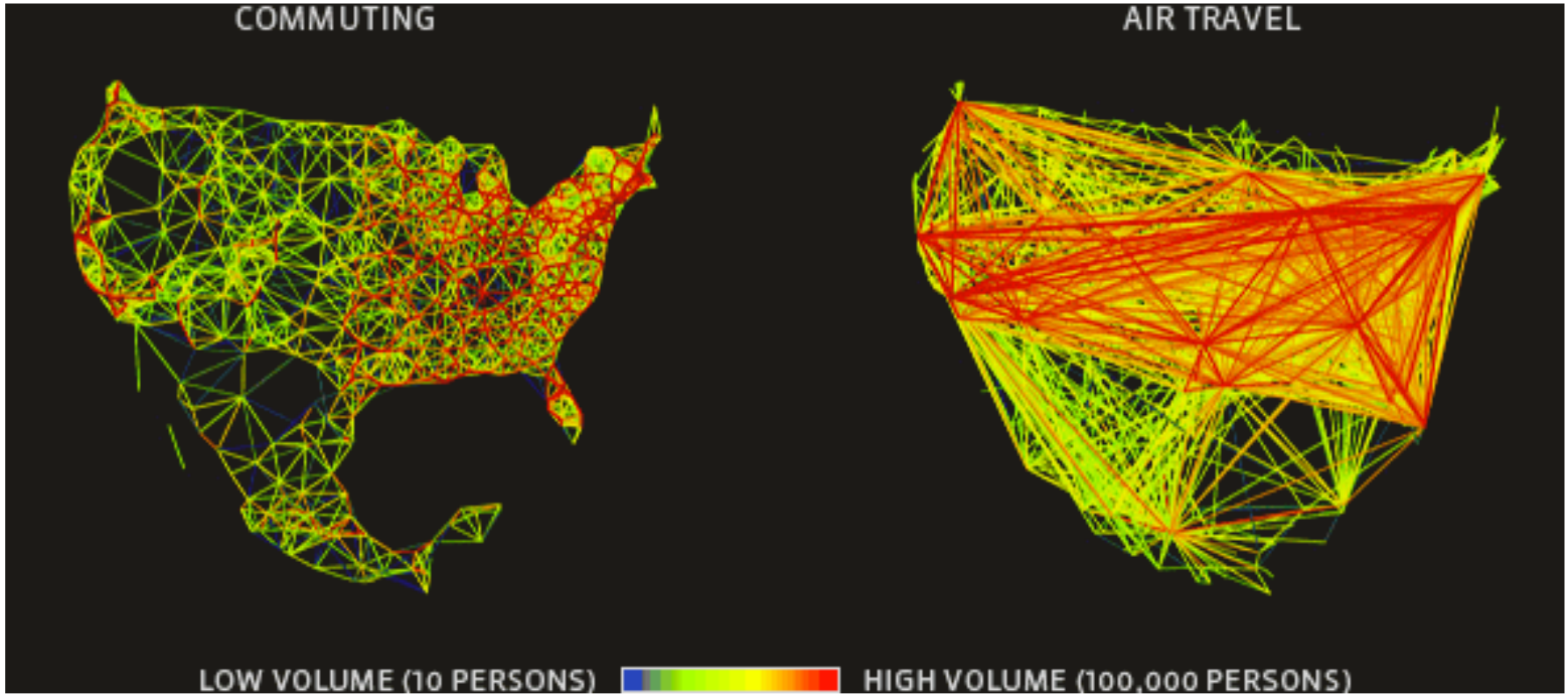

http://www.gleamviz.org/model/

Spatial Networks

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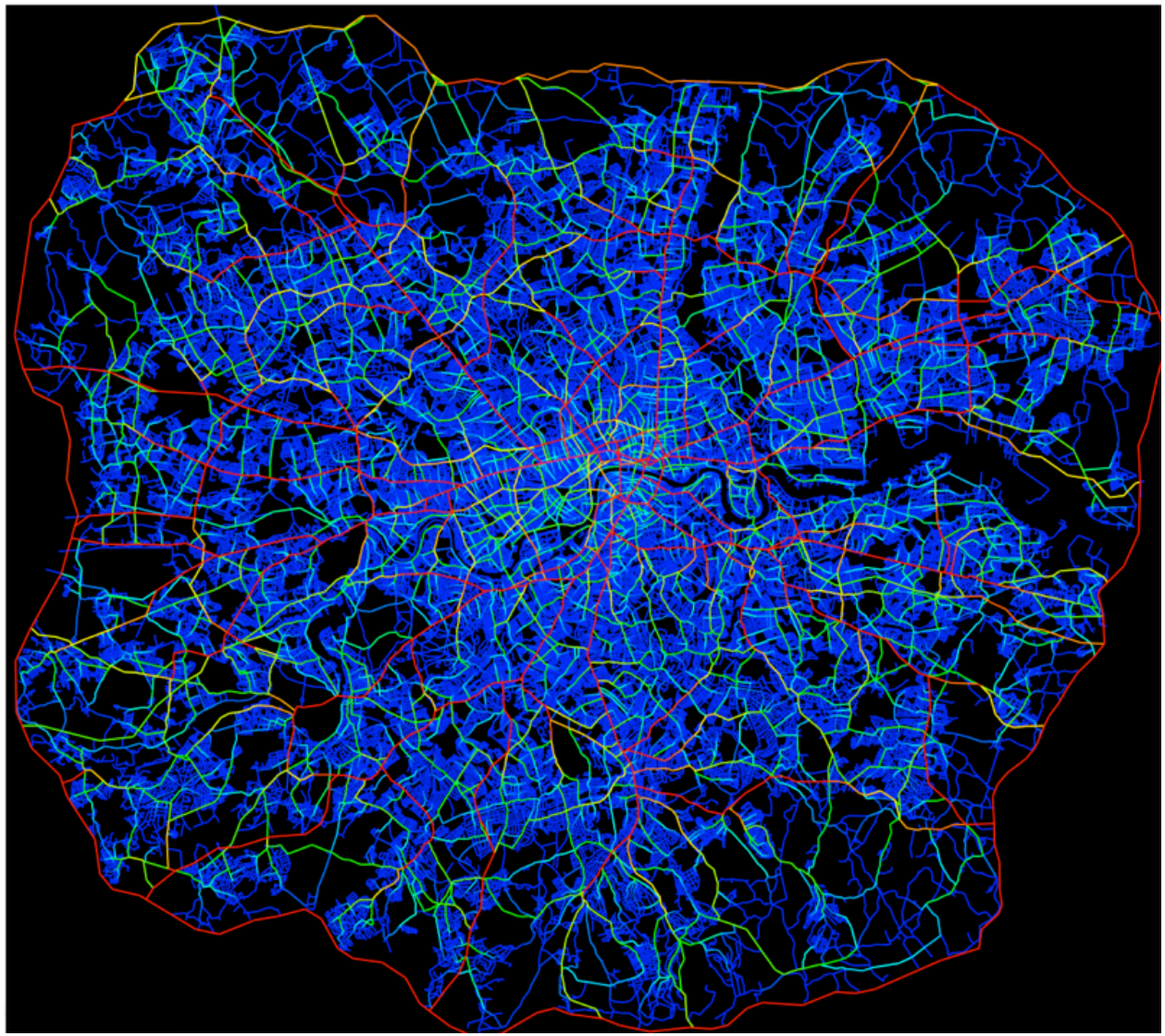

https://timstonor.wordpress.com/2014/01/03/skycycle-elevated-but-not-remote/

Spatial Networks

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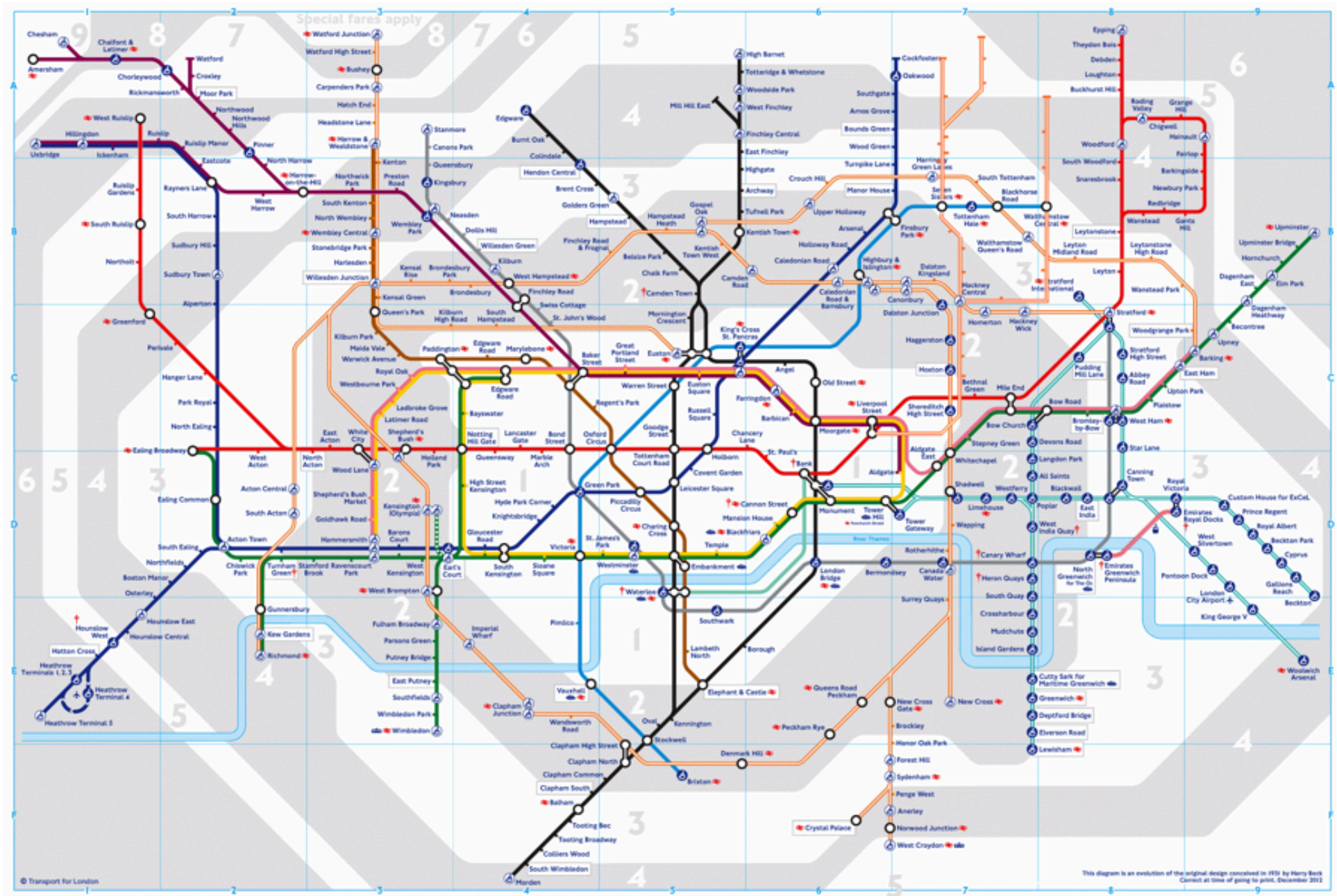

Spatial networks

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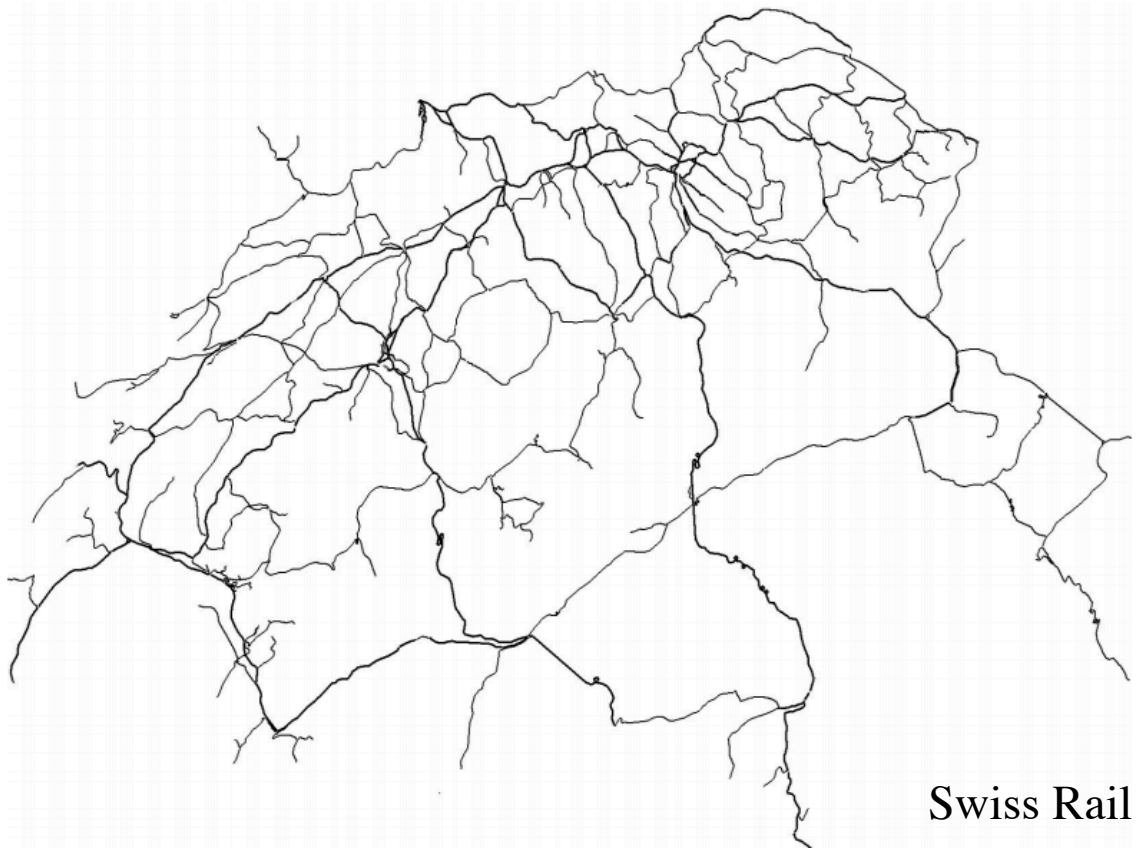
Planar networks: networks that can be drawn in a manner so that edges do not intersect (e.g. transport: rail networks, road networks etc.)

Non-planar: airline networks, networks of social relationships.

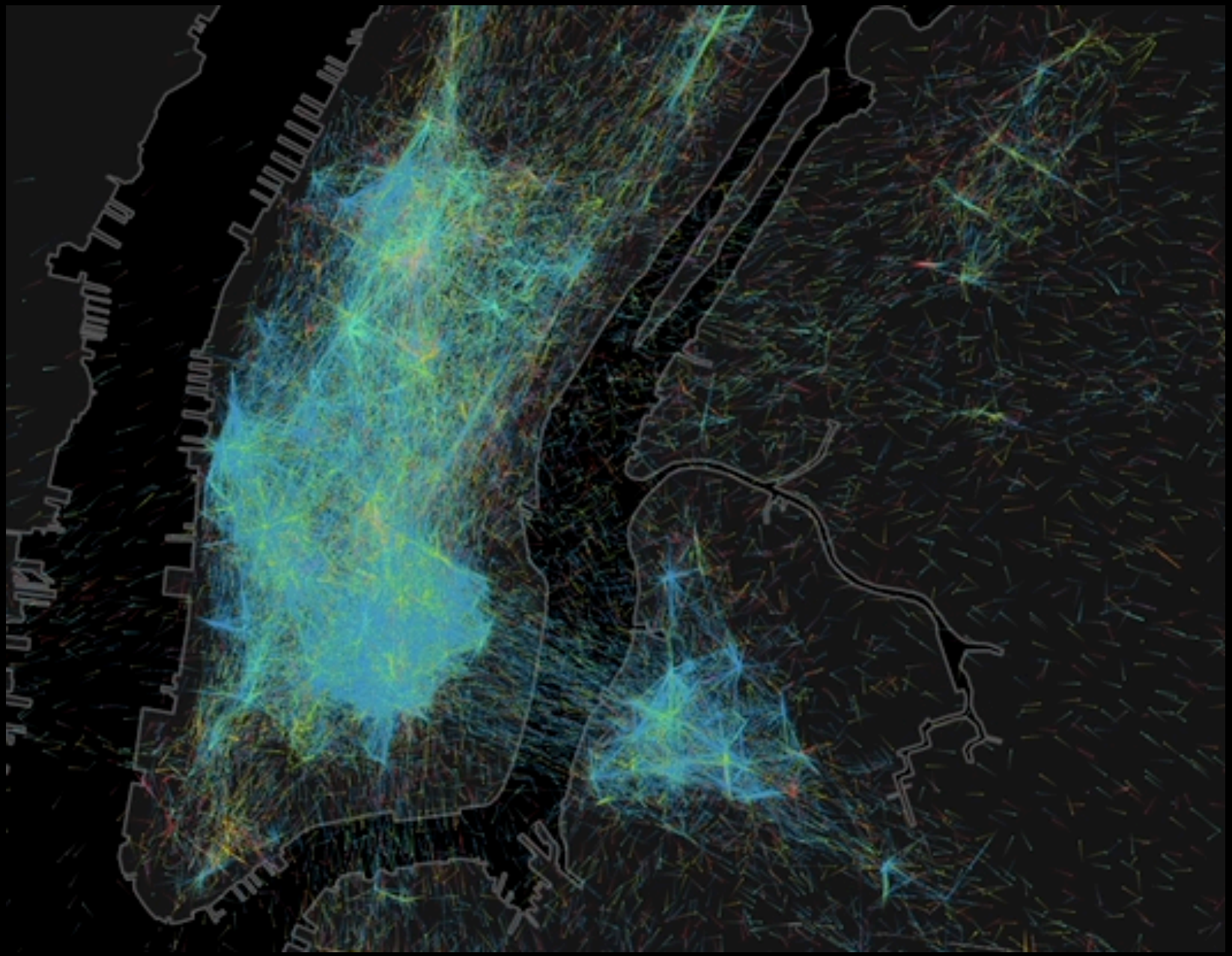


Swiss Rail

Spatial Networks by Marc Berthelemy http://arxiv.org/pdf/1010.0302v2.pdf

FOURSQUARE CHECK-INS SHOW THE PULSE OF **TOKYO**

Network of places in New York City



special thanks to Blake Shaw @ Foursquare

Geo-social networks

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Geo-social networks are social networks embedded in geographic space.

Geography and network topology are key to network's function and evolution.

Location is everywhere

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twitter

Gowalla

UBER

OpenStreetMap

foursquare

FOURSQUARE

brightkite
people. places. friends.

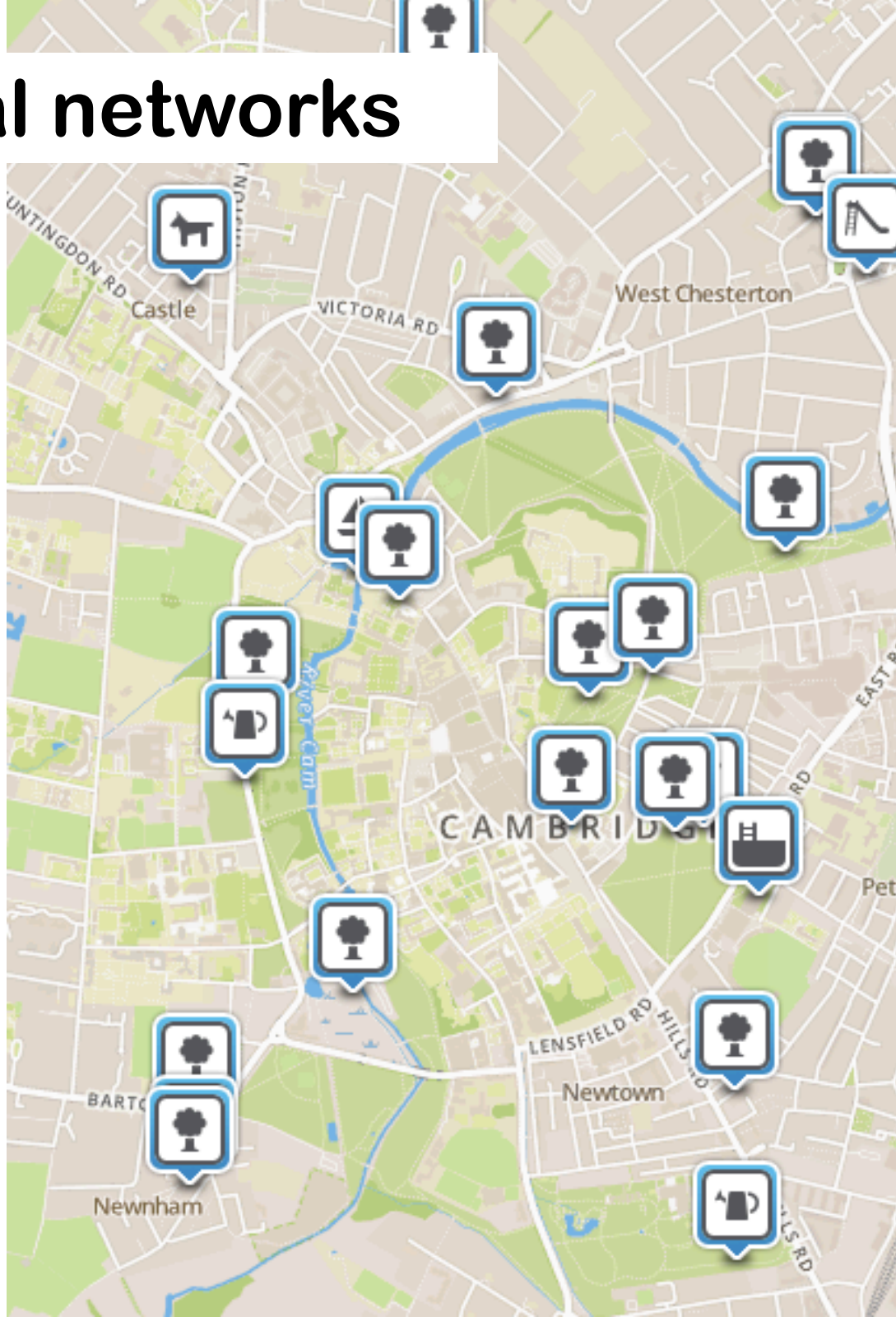
Location-based social networks

Mobile services that are focused (based) on places.

Users check in to places & connect with friends.

A social network is formed above real world places.

Popular in urban environments.



Location-based social networks

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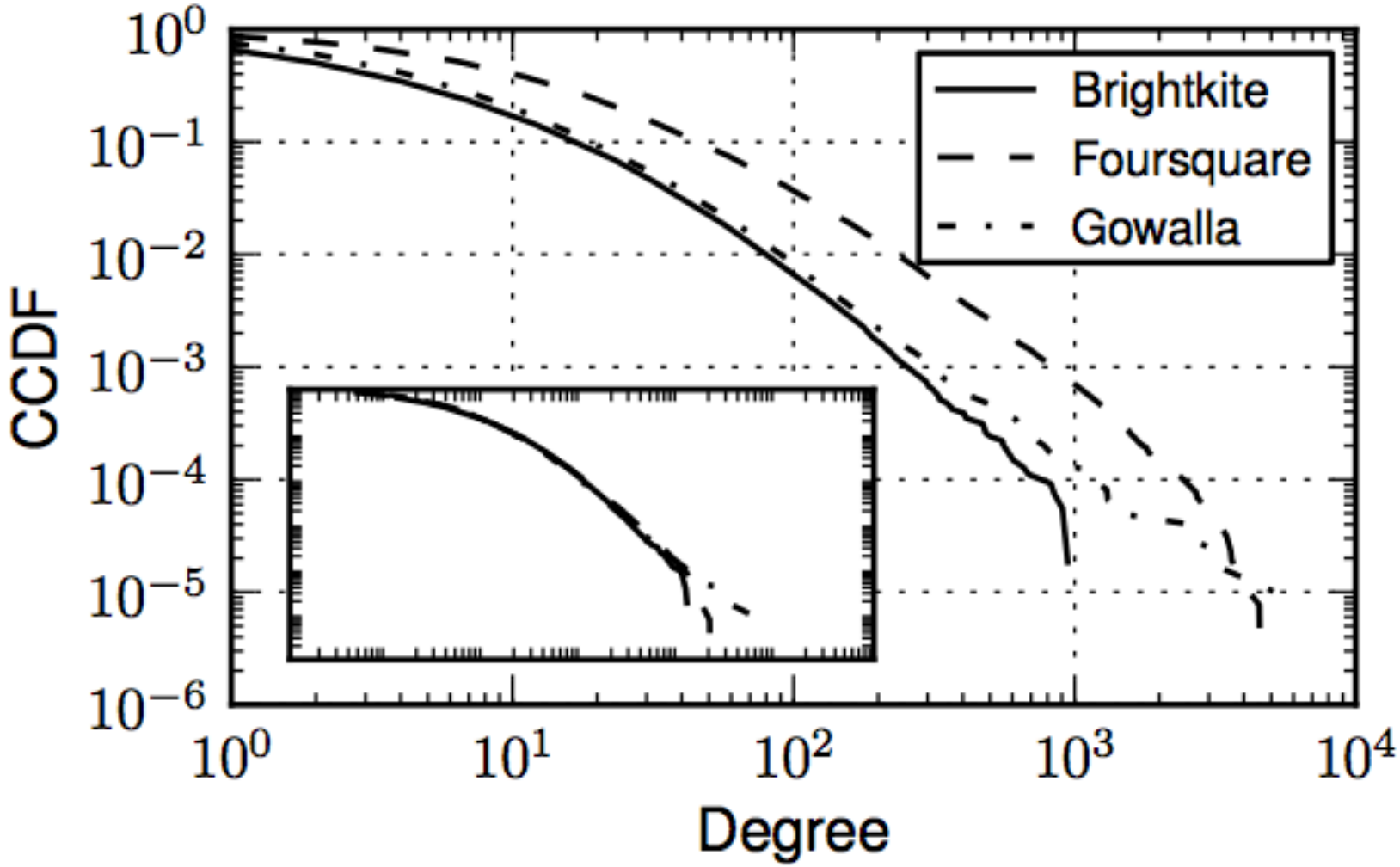

Socio-spatial properties of Online Location-based Social Networks, Scellato et al, ICWSM 2011.

Location-based social networks

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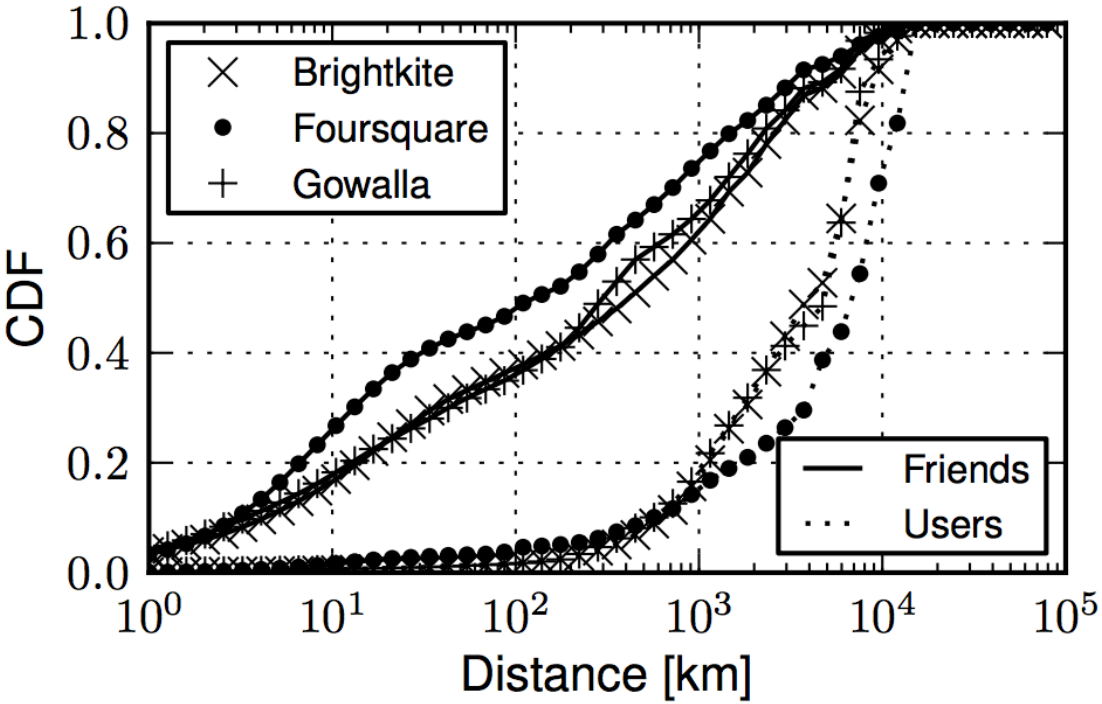
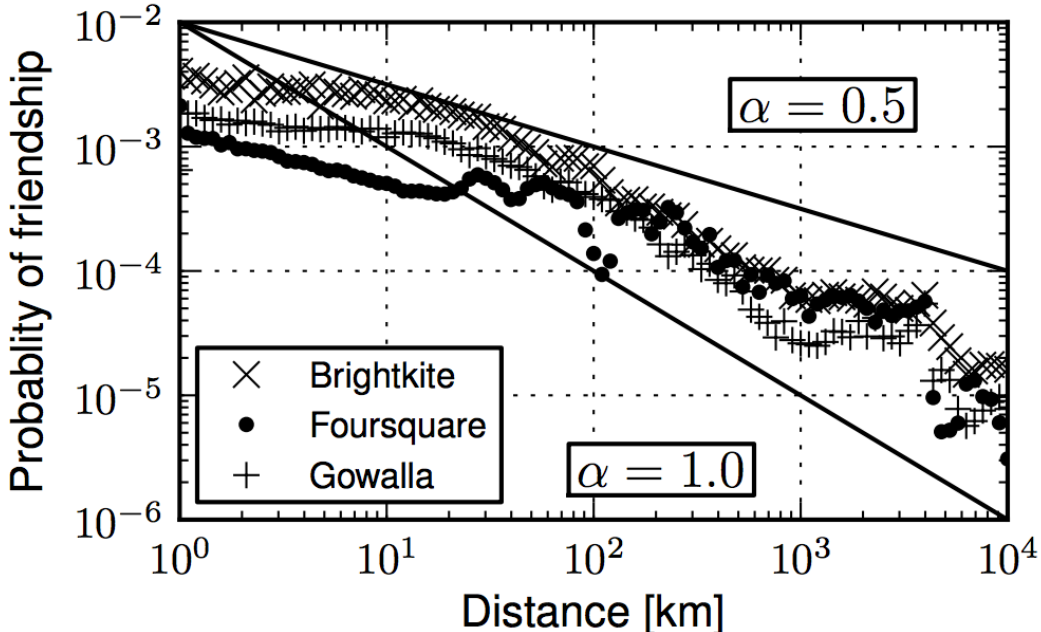


Link length distribution: friends vs random user pairs.

Probability of friendship as a function of geographic distance.



Location-based social networks

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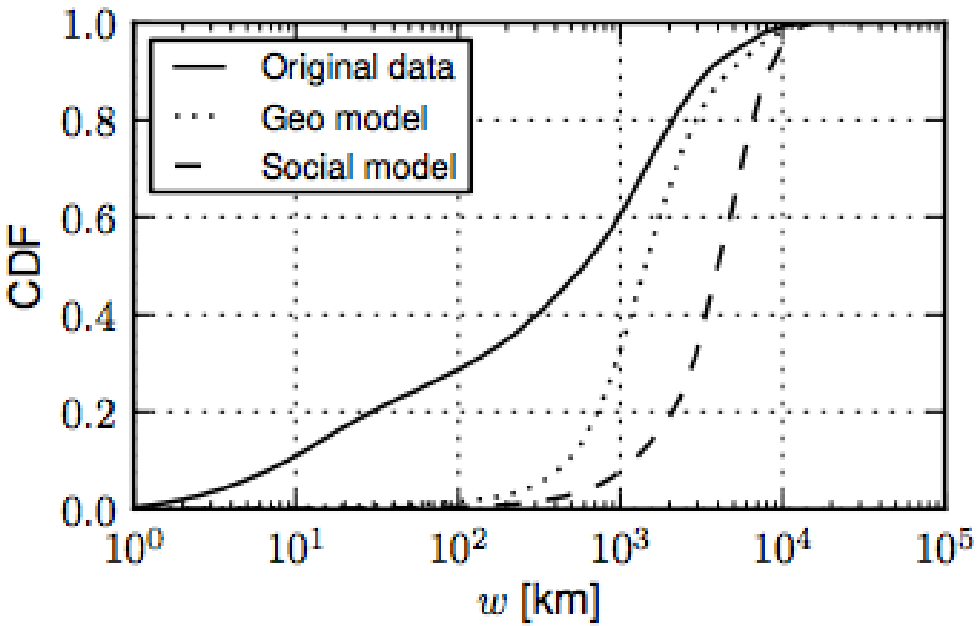
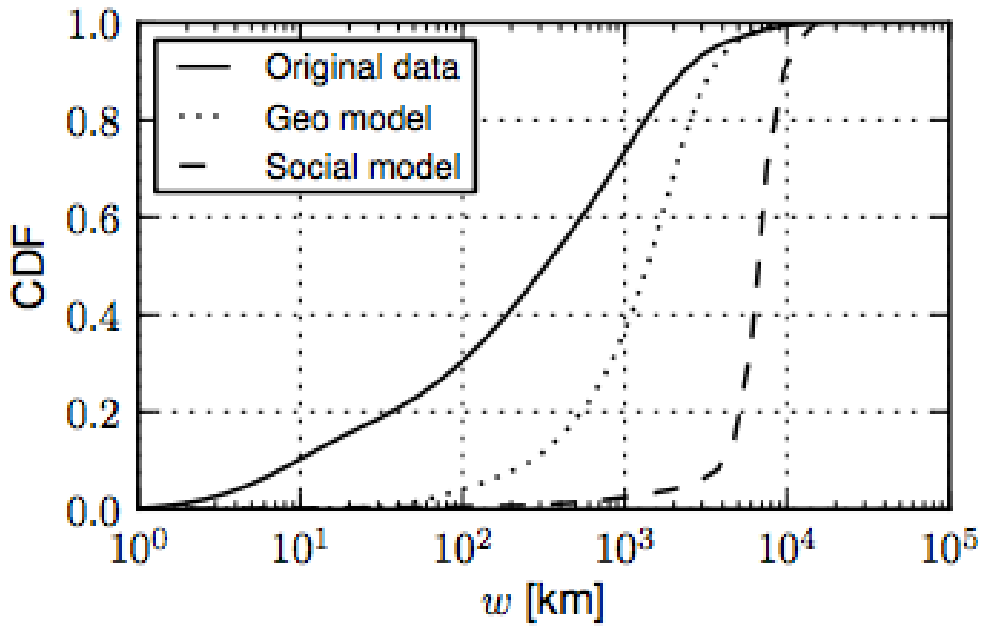


(a) Brightkite



(b) Foursquare

geo model: wire nodes based on distance.

social model: shuffle nodes' geographic location.

Geographic distance or social connectivity alone cannot explain data!

Location-based social networks

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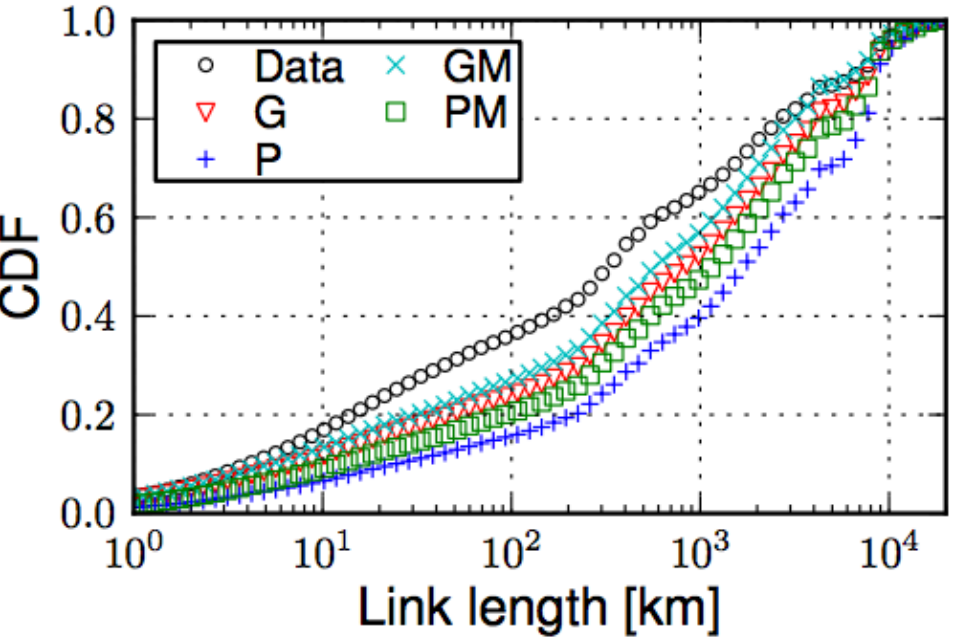
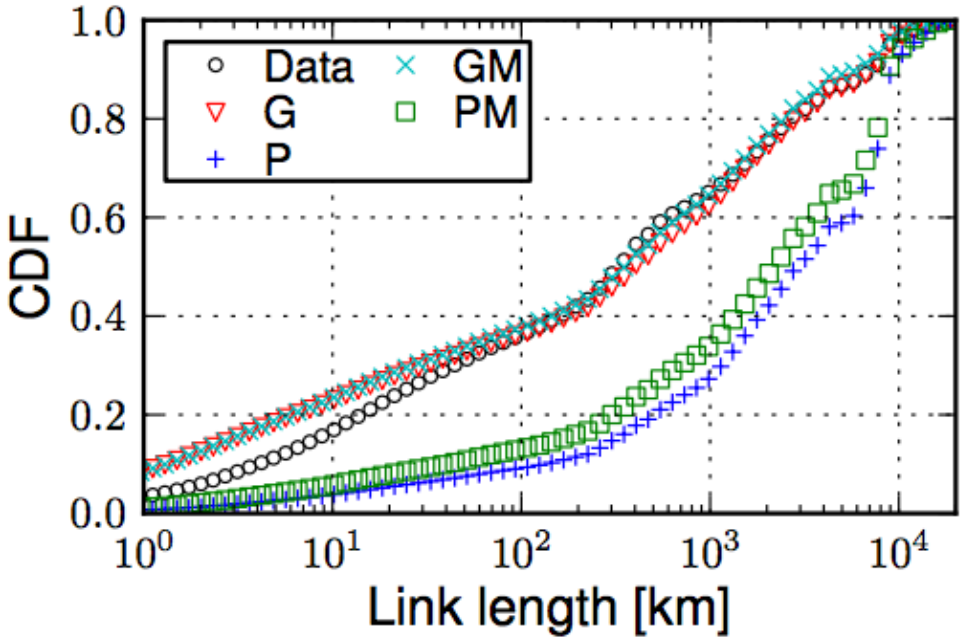


(a) Without global attachment



(b) With global attachment

$$P_g[u \to v] \propto \frac{m_u.m_v}{d(u,v)^b}$$

gravity model: attraction proportional to the degree of target node and repulsion proportional to distance.

Alamanis et. al, ICM 2012. http://www.cl.cam.ac.uk/~cm542/papers/imc2012.pdf

Friendship and geographic distance

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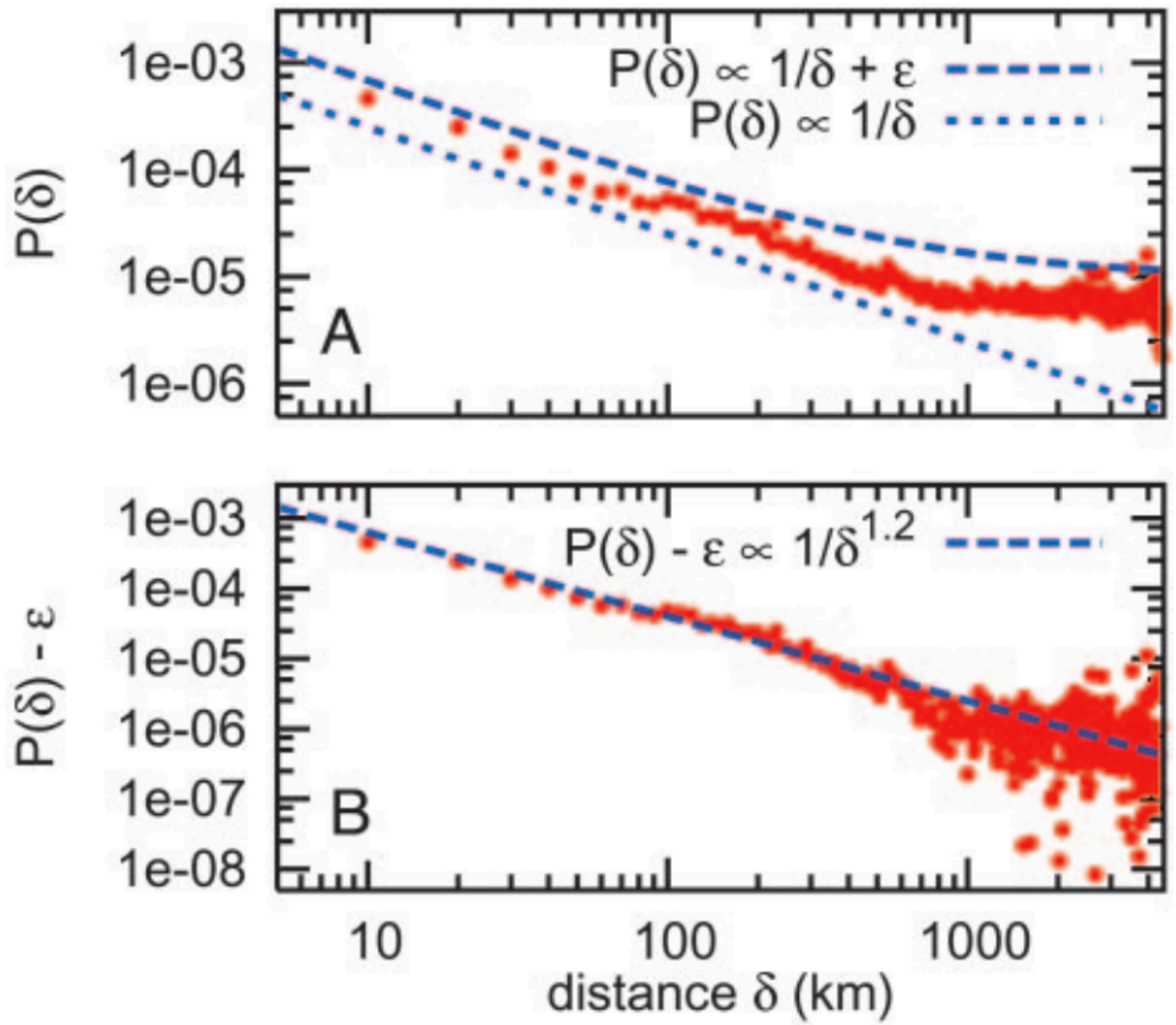
Friendship
as a function of
distance
in Livejournal.



Geographic routing in social networks Liben-Nowell et. al, PNAS 2005

Friendship and geographic distance

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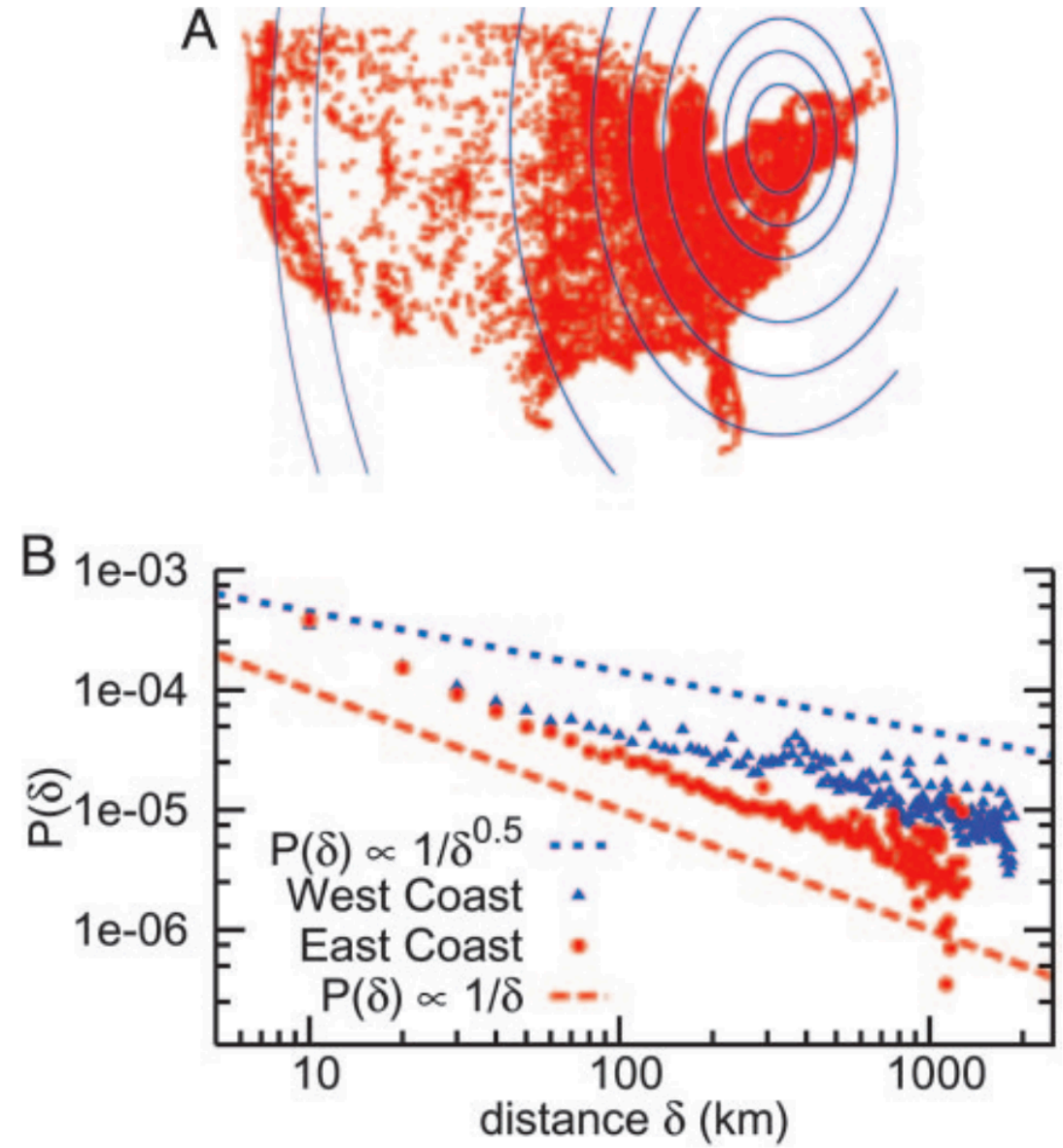
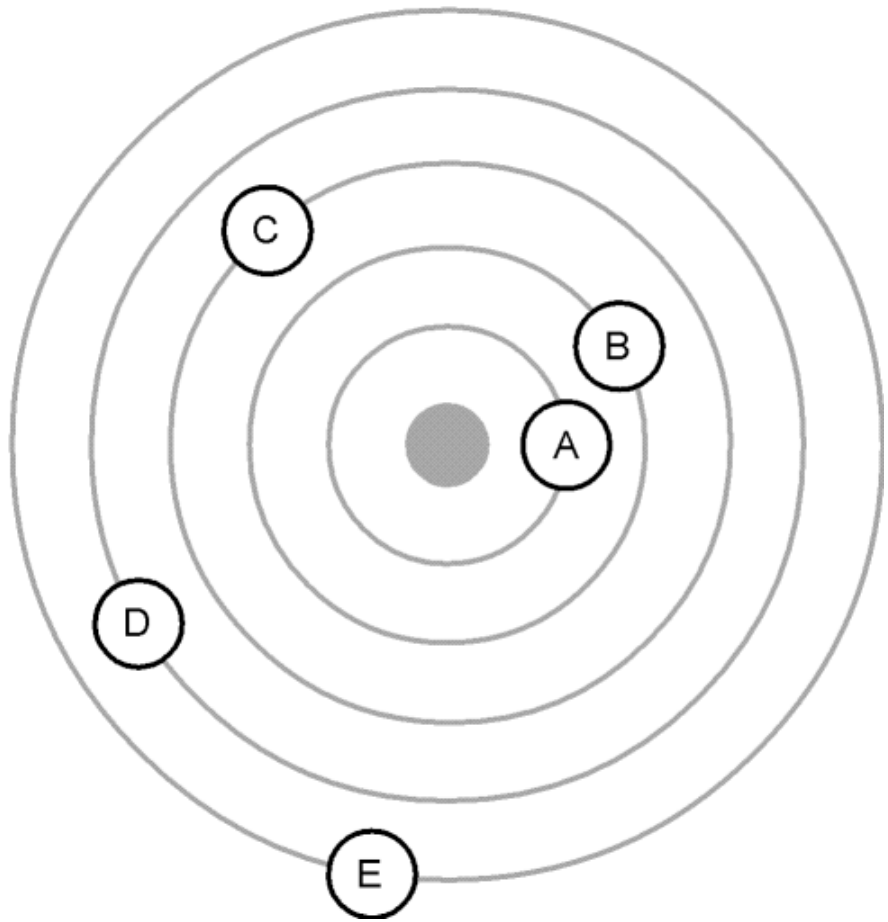
Variations in population densities and friendship probability over geographic distance.



Geographic routing in social networks Liben-Nowell et. al, PNAS 2005

Defining Rank-Distance



$$rank_u(v) = |\{w : d(u,w) < d(u,v)\}|$$

Rank universality

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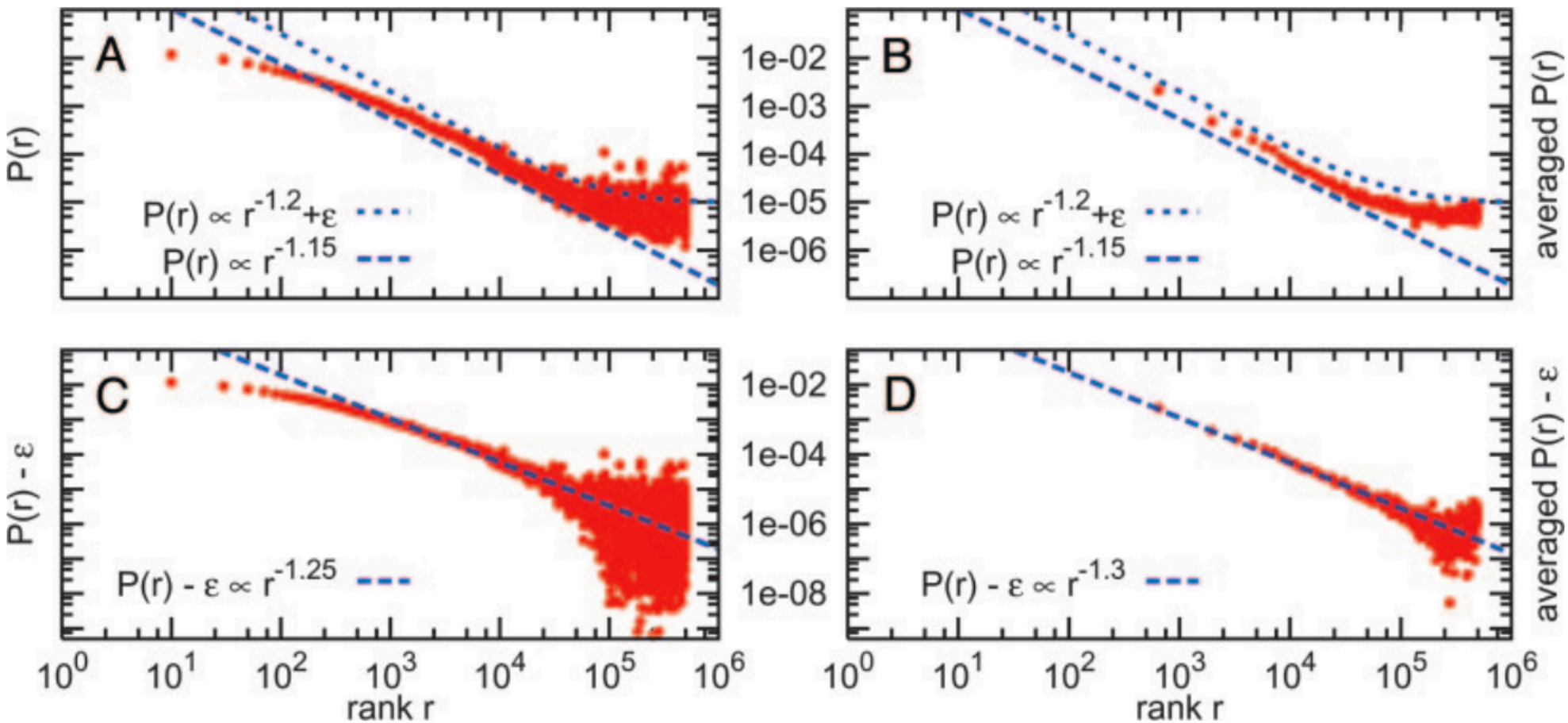
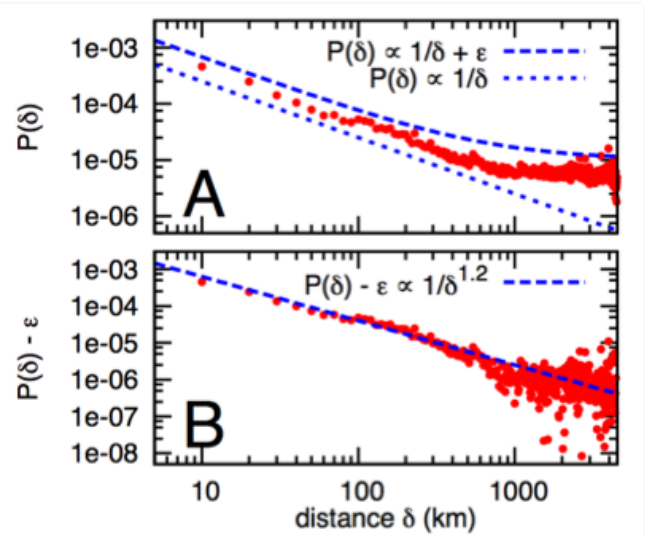


Geographic routing in social networks Liben-Nowell et. al, PNAS 2005

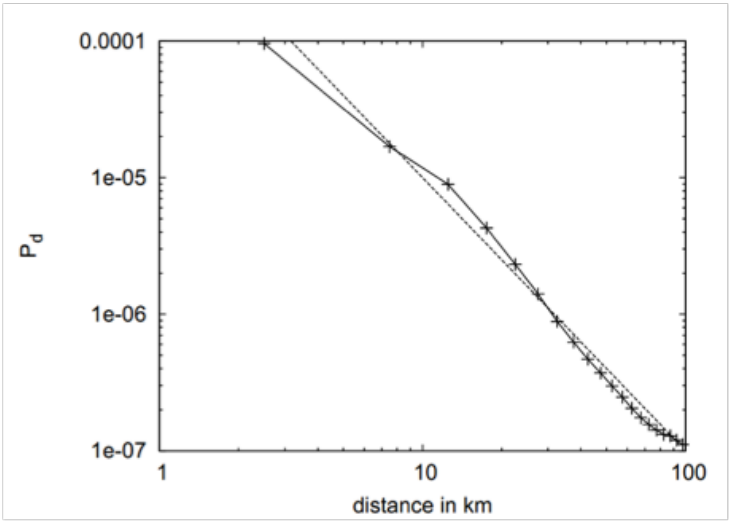
Friendship & distance across services

LiveJournal (2005)



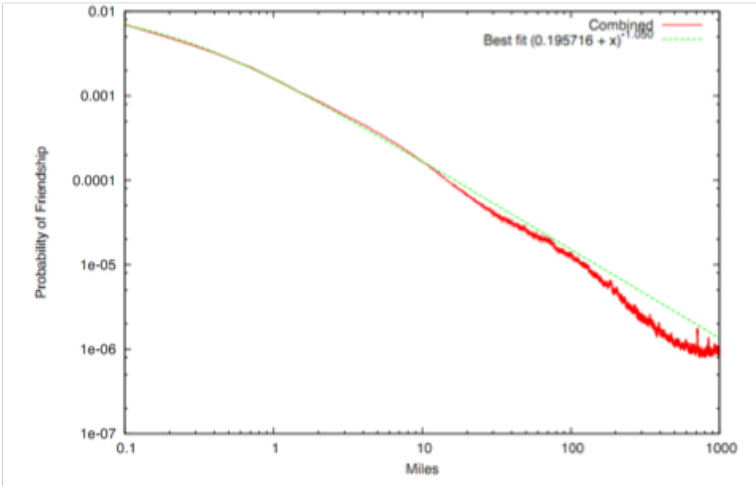
$$P(d) \propto d^{-1} + \epsilon$$

Mobile phones (2008)

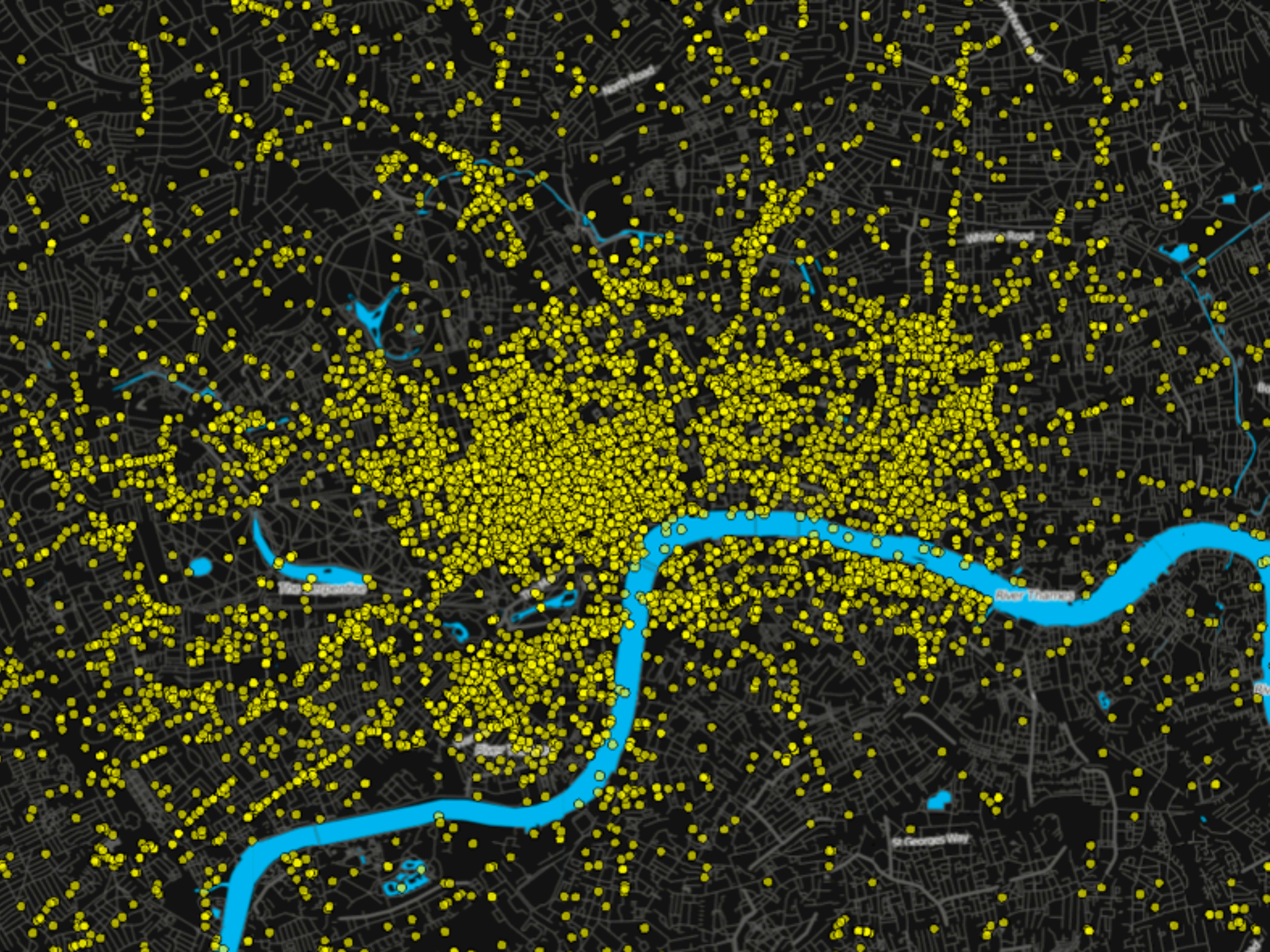


$$P(d) \propto d^{-2}$$

Facebook (2010)

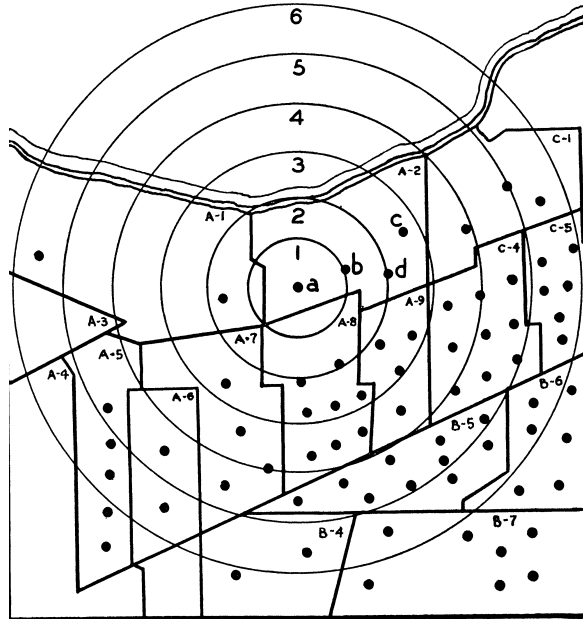


$$P(d) \propto d^{-1}$$


River Thames
St George's Way

Samuel A. Stouffer

Stouffer's **law of intervening opportunities** states, *"The number of persons going a given distance is directly proportional to the number of opportunities at that distance and inversely proportional to the number of intervening opportunities."* *

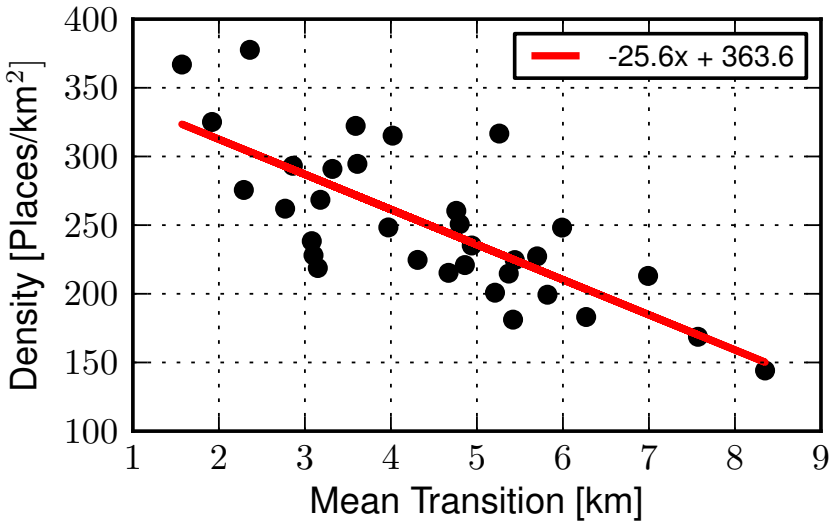


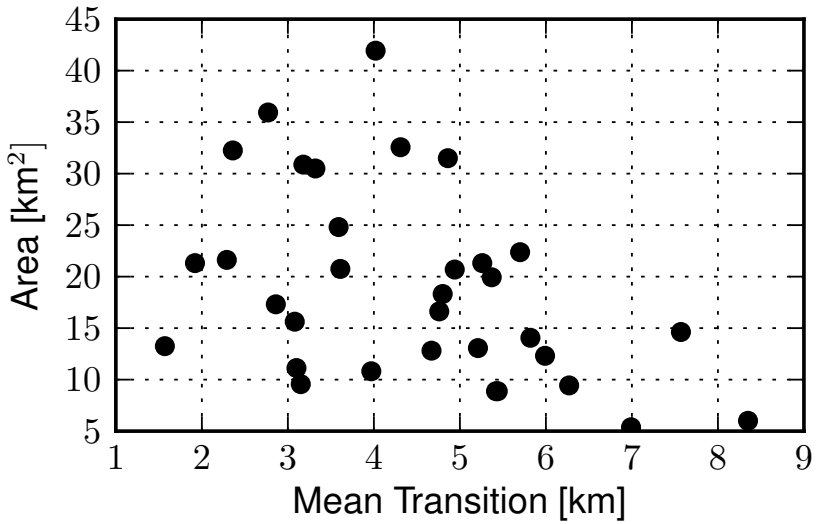
- Empirically proven using data for migrating families in the city of Cleveland.

- We investigate the plausibility of the theory for urban movements in Foursquare.

* S. Stouffer (1940) Intervening opportunities: A theory relating mobility and distance, American Sociological Review 5, 845-867

The importance of density

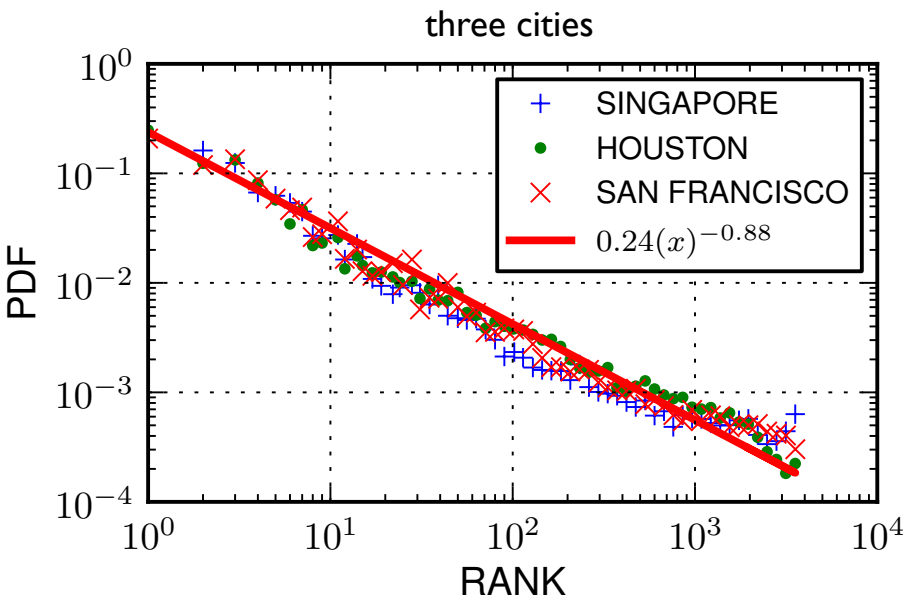


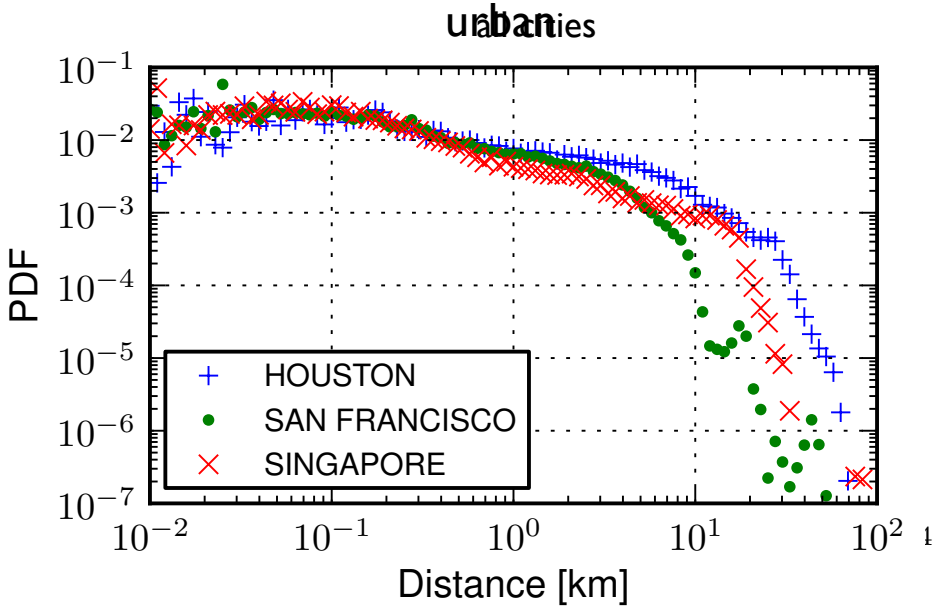


- Stouffer's Theory of Intervening Opportunities motivated us to inspect the impact of places(=opportunities) in human mobility.

- Place density by far more important than the city area size with respect to mean length of human movements (R^2 = 0.59 and 0.19 respectively).

Rank universality



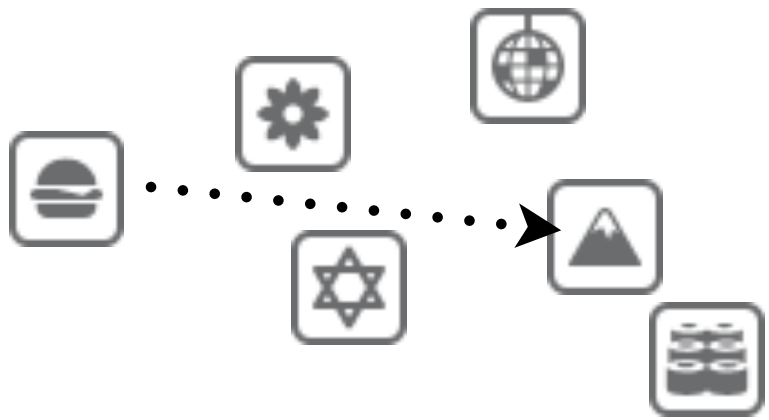


The rank of all cities collapse to a single line.

We have measured a power law exponent $\alpha = 0.84 \pm 0.07$

A new model for urban mobility

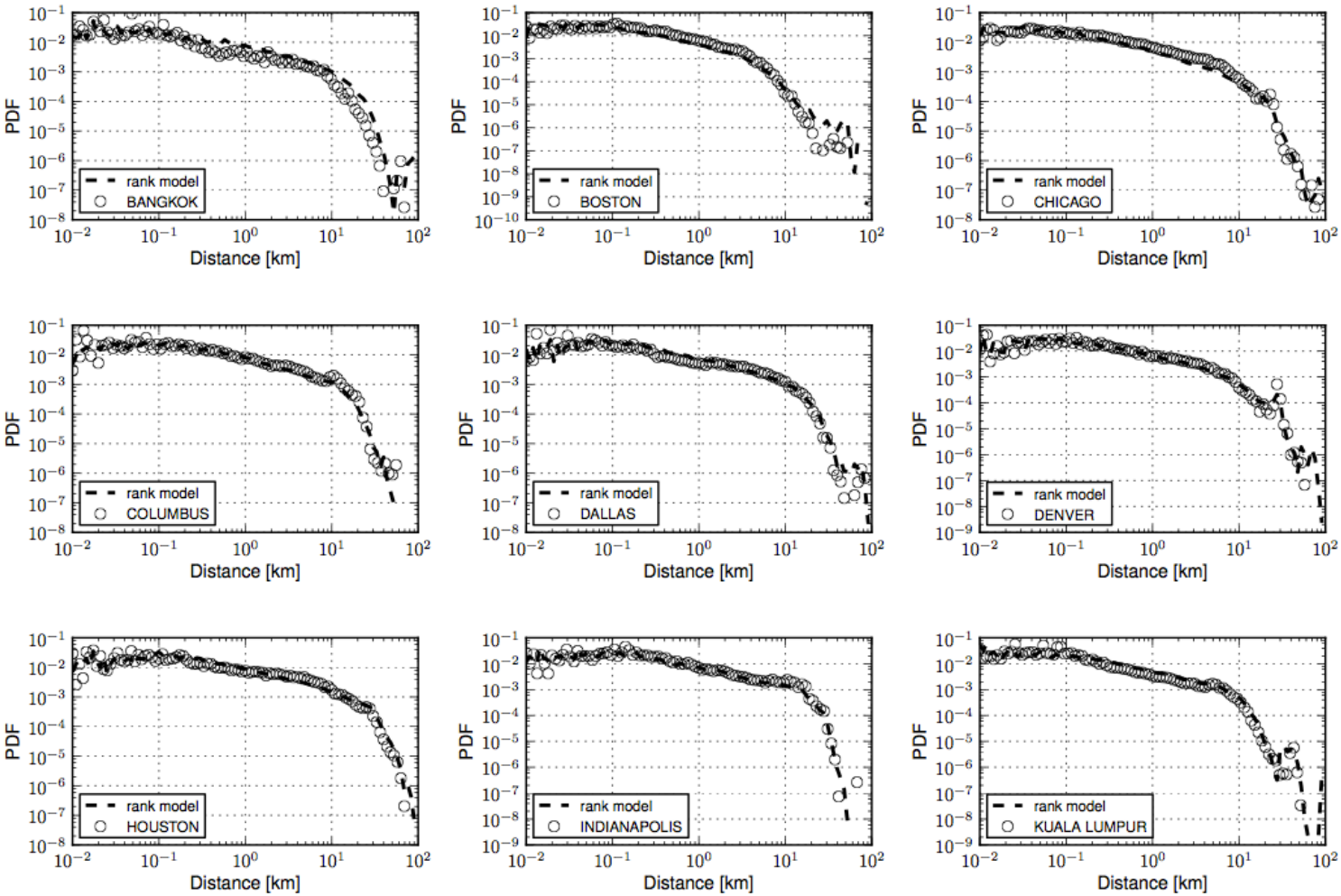
soil...



and mind!

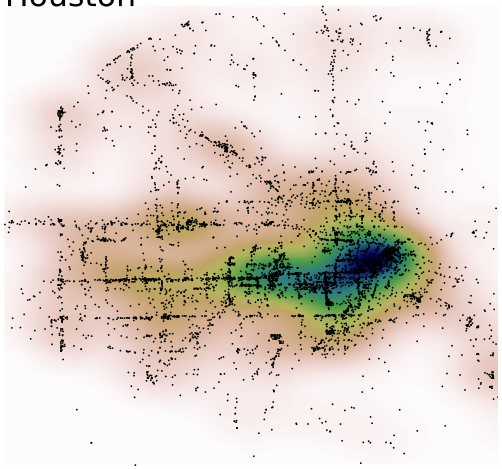
$$Pr[u \rightarrow v] \propto \frac{1}{rank_u(v)^a}$$

Simulation Results ...

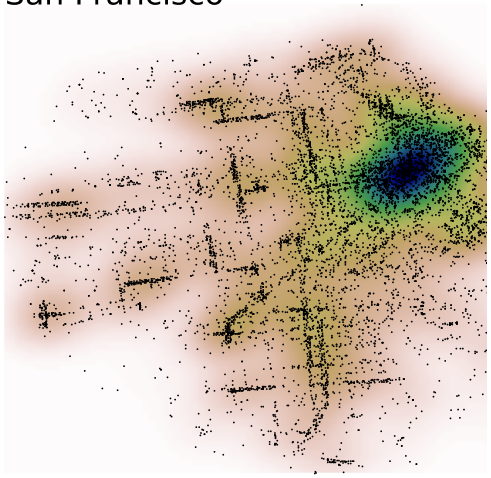


The importance of Geography

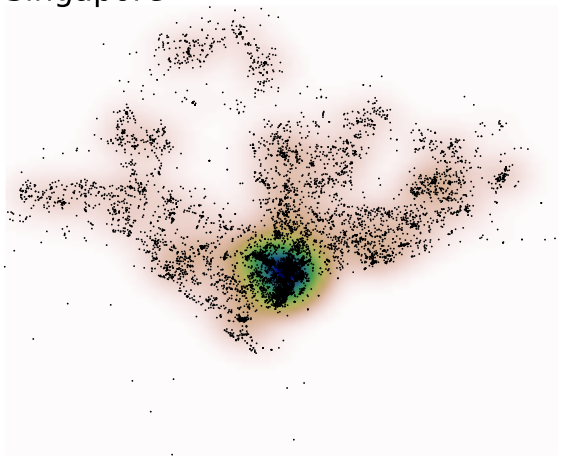
Houston



San Francisco



Singapore



Heterogeneities observed in human mobility is due to geographic variations. Cultural, organisational or other factors do not appear to play a role in urban movements.

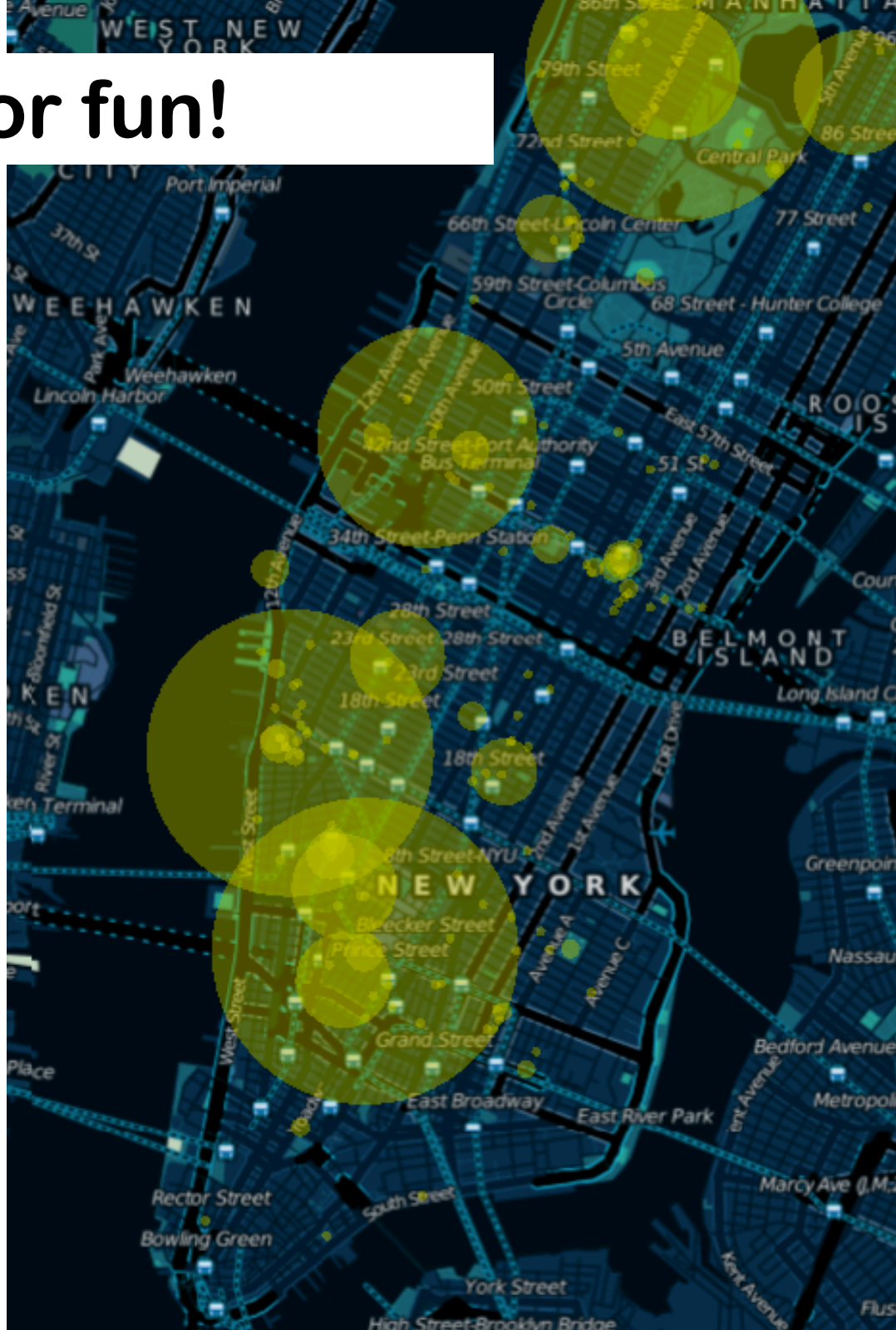
The rank model, although simple, can cope with the complex spatial variations in densities observed in urban environments.

Location is not here for fun!

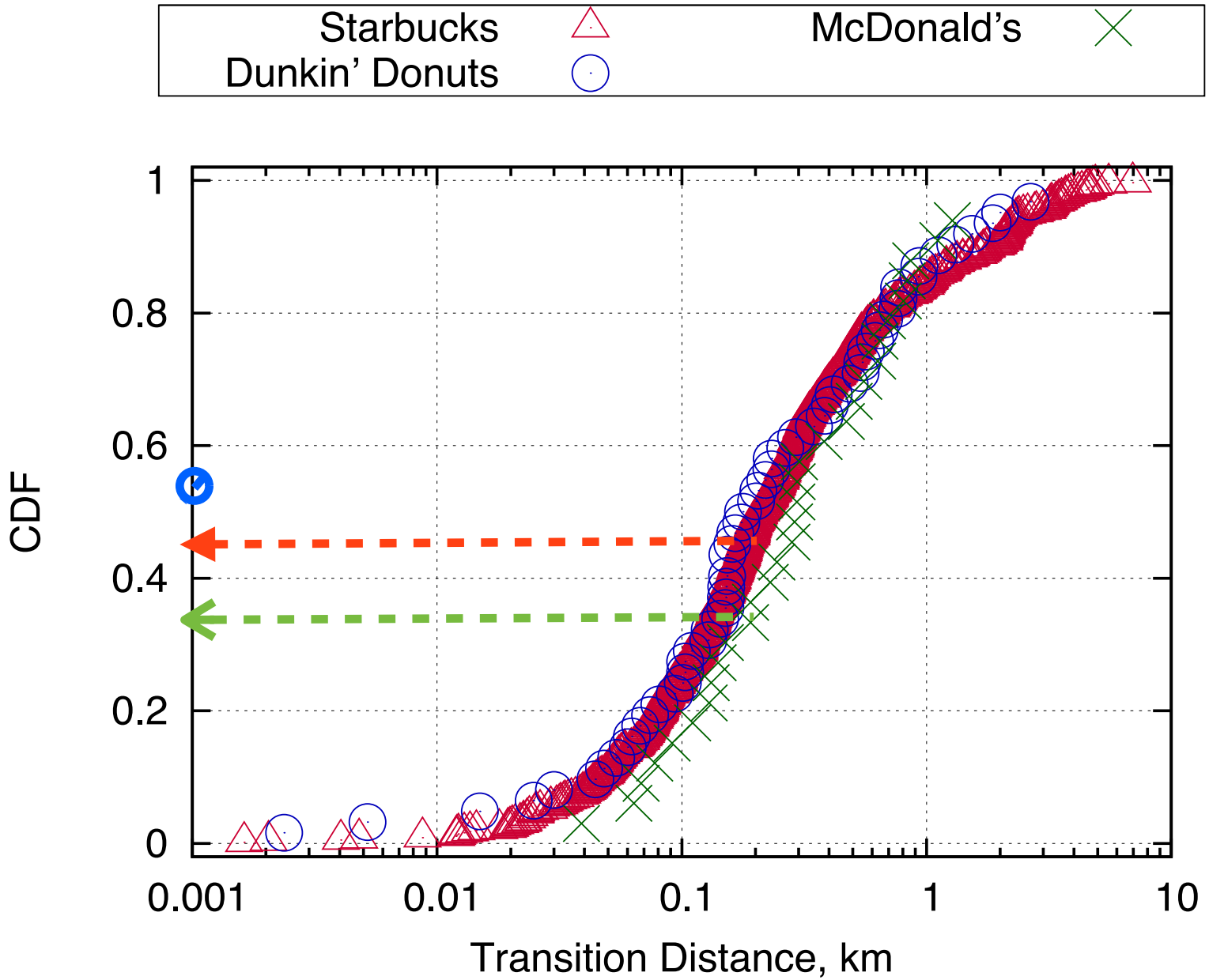
A big problem for location-based services is how to monetise.

There are a host of potential revenue channels (venue claim, geo ads, data sales..)

New location-centric services emerge and old ones constantly transform.




STARBUCKS
MCDONALD'S
DUNKIN' DONUTS
Jacqueline Kennedy Onassis Reservoir
Broadway
Palisade Ave
Kerrigan Ave
New York Avenue
15th St
Madison Street
1st Street
Grove Street
36th Avenue
GEO SPOTTING



Relatively speaking… McDonald's tend to "pull" check-ins from remote locations whereas Dunkin' and Starbucks attract local movements.

Exploit place type networks for retail area quality assessment

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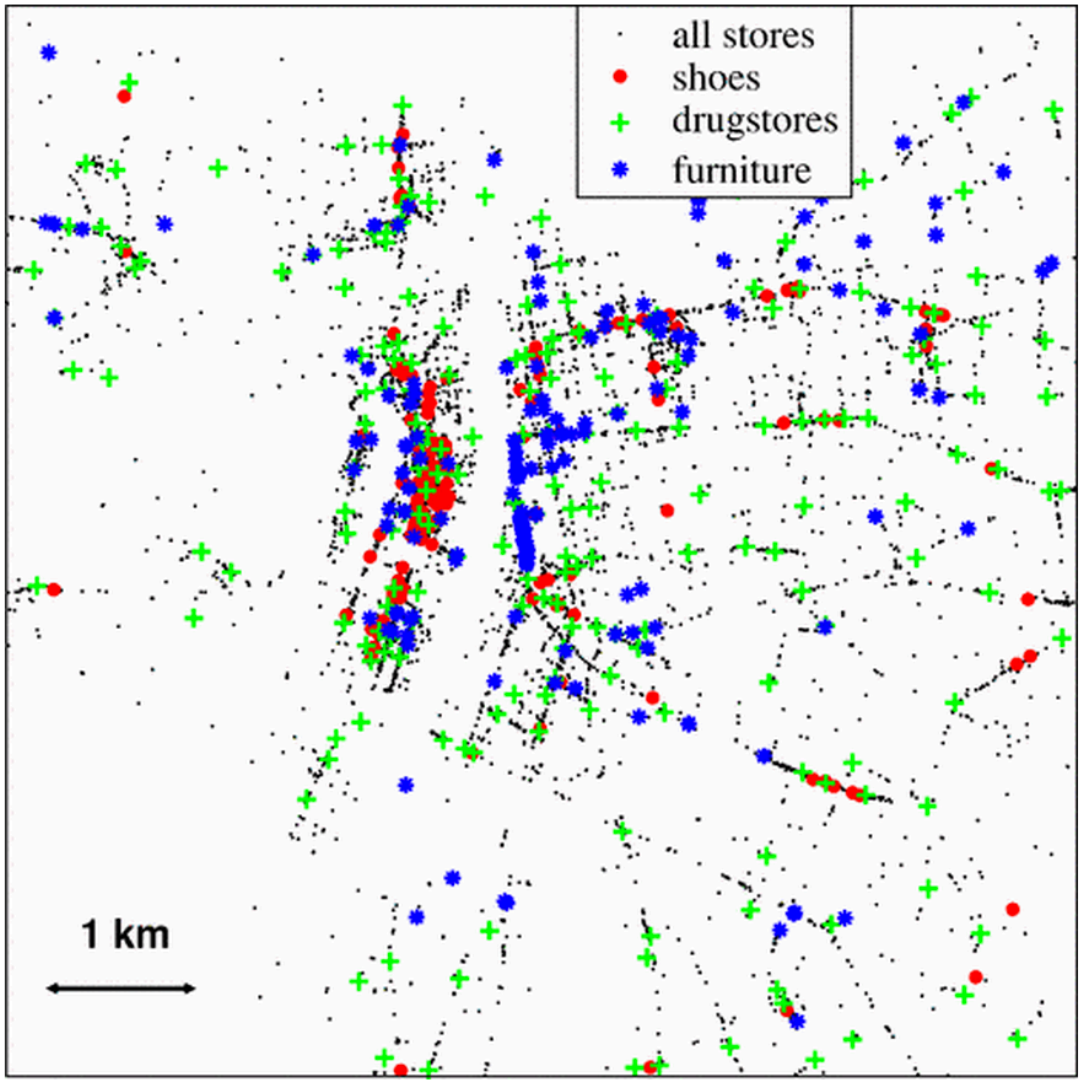
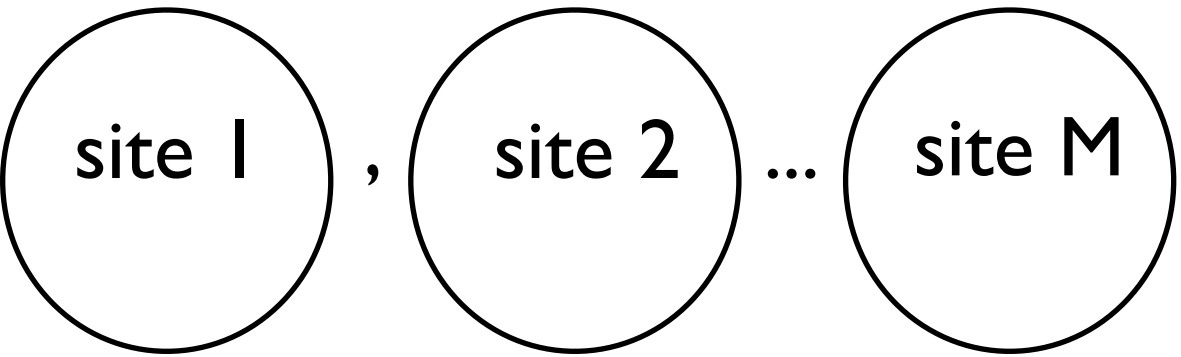
Intuition: certain place types attract each other (e.g. coffee shops at train stations)

Application: Can we exploit spatial, place-type configuration patterns to assess the retail quality of an area?



Pablo Jensen PRL E, 2006 , http://journals.aps.org/pre/pdf/10.1103/PhysRevE.74.035101

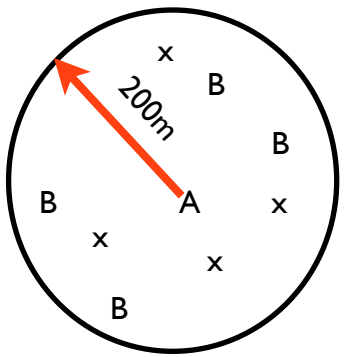
Methodology for extracting the Jensen (retail) quality of an area.



Step 1: Measure the frequency of a place type across all M sites. This can be checked for a city, a country or the locations of a chain depending on the goal of the application. Below is the normed frequency of category B:

$$N\_B/N\_tot$$

Step 2: To measure the attractiveness of a category (place type) B towards another type A do the following: iterate across all sites of A, retrieve the nearby places within a radius r, and measure the number of occurrences of B, n_B and its ratio with respect to all nearby places n_B/n_tot.



Step 3: Finally, measure for a given place type A, the average attractiveness score, M_AB, defined below. Effectively, you are measuring the chance of observing B next to A, over observing B at a random location.

$$M\_AB = \frac{<n\_b/n\_tot>}{N\_B/N\_tot}$$


East 17th Street
East 18th Street
East 19th Street
East 20th Street
2nd Avenue
1st Avenue
Stuyvesant Square Historic District
Stuyvesant Square
East 15th Street
East 16th Street
East 14th Street
East 13th Street
East 12th Street
East 11th Street
East 20th Street
Stuyvesant Loop West
Stuyvesant Loop North
PETER COOPER VILLAGE
STUYVESANT TOWN
r

Starbucks		Dunkin' Donuts		McDonalds	
Train Station	11.80	Hostel	5.02	Flower Shop	5.87
Light Rail	8.60	Gas Station	3.05	Office Supplies	3.16
Stadium	7.25	Automotive Shop	2.66	Train Station	3.08
Airport	6.24	Flower Shop	2.36	Theatre	2.84
Museum	5.10	Post Office	2.19	Light Rail	2.32
Convention Centre	4.93	Flea Market	1.84	Gift Shop	2.26
Hostel	4.82	School	1.72	Subway Station	2.21
Corporate Office	4.57	Drug Store	1.70	Department Store	2.17
Hotel	4.13	Subway Station	1.67	Bank / Financial	1.92
Bank / Financial	4.09	Bike shop	1.64	Drug Store	1.89

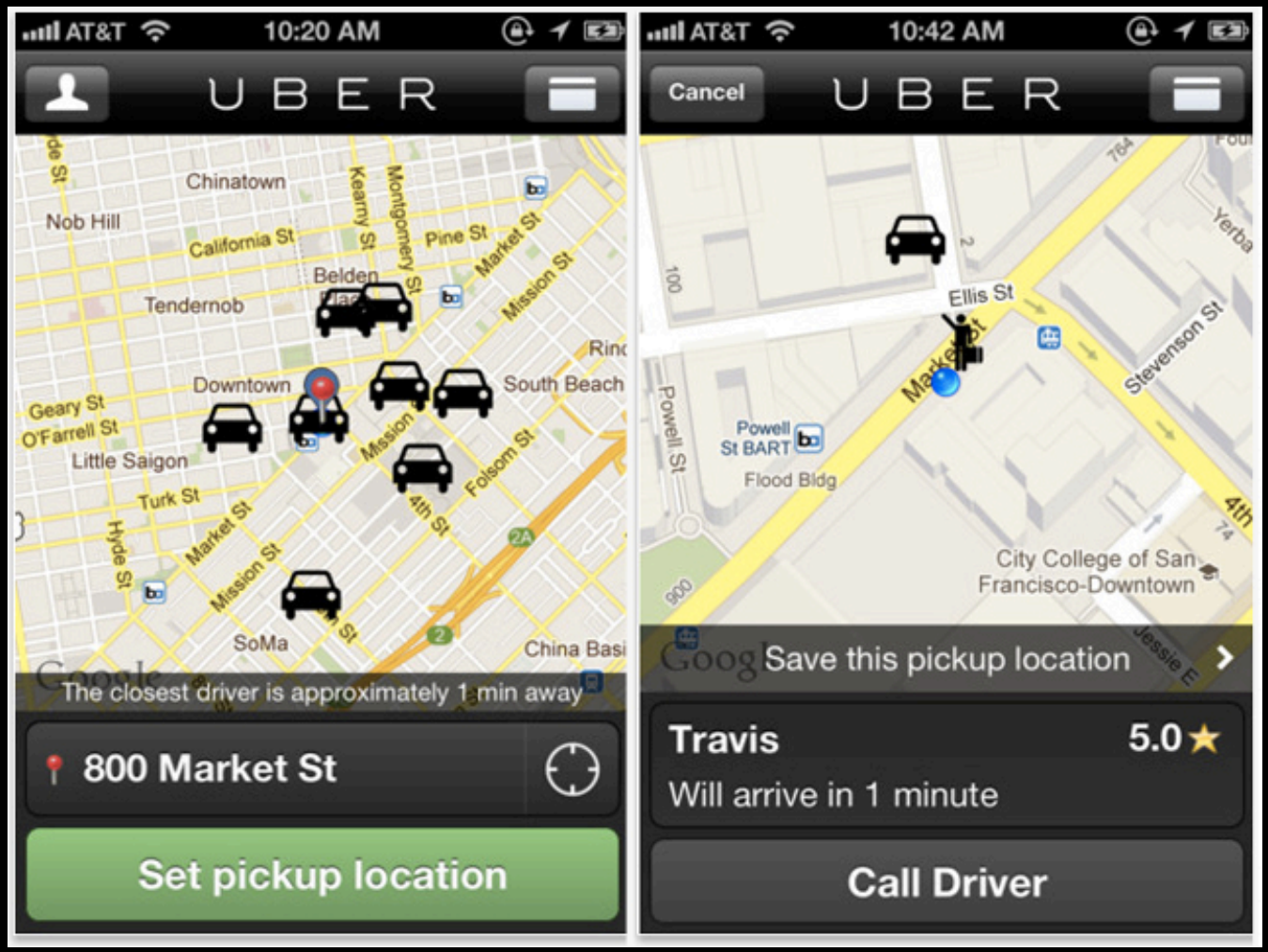
colocation

Does colocation imply movement?

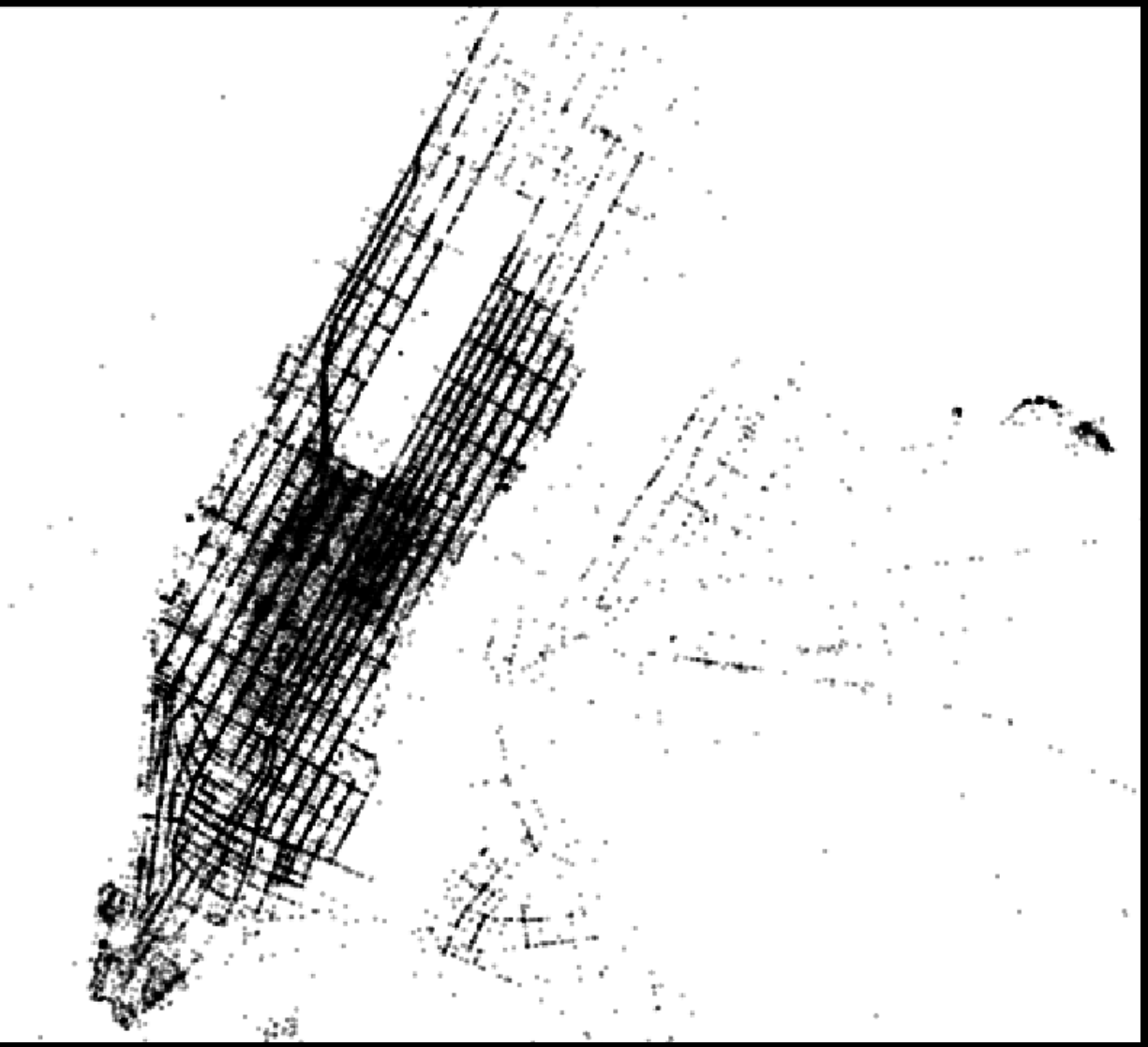
mobility

Starbucks		Dunkin' Donuts		McDonalds	
Hostel	15.75	Laundry	11.89	Parks & Outdoor	16.00
Flea Market / Fair	8.38	Drug Store / Pharmacy	5.78	Gas Station	3.72
Sculpture	8.00	Subway Station	2.16	Gift Shop	3.56
Post Office	2.34	Food Shop	1.66	Theatre	3.20
Services	2.20	Medical	1.25	Office Supplies	3.05
Drug Store / Pharmacy	2.20	Home	1.24	Bank / Financial	2.91
Quad / Commons	1.72	Apparel	1.12	Plaza / Square	2.57
Bank / Financial	1.57	Bank / Financial	1.06	Drug Store	2.37
Airport	1.52	School	1.08	Apparel	1.04
Office Supplies	1.52	Post Office	1.07	Home	1.02

THE APP: "EVERYONE'S PRIVATE DRIVER"



THE NEW YORK CITY TAXI DATASET



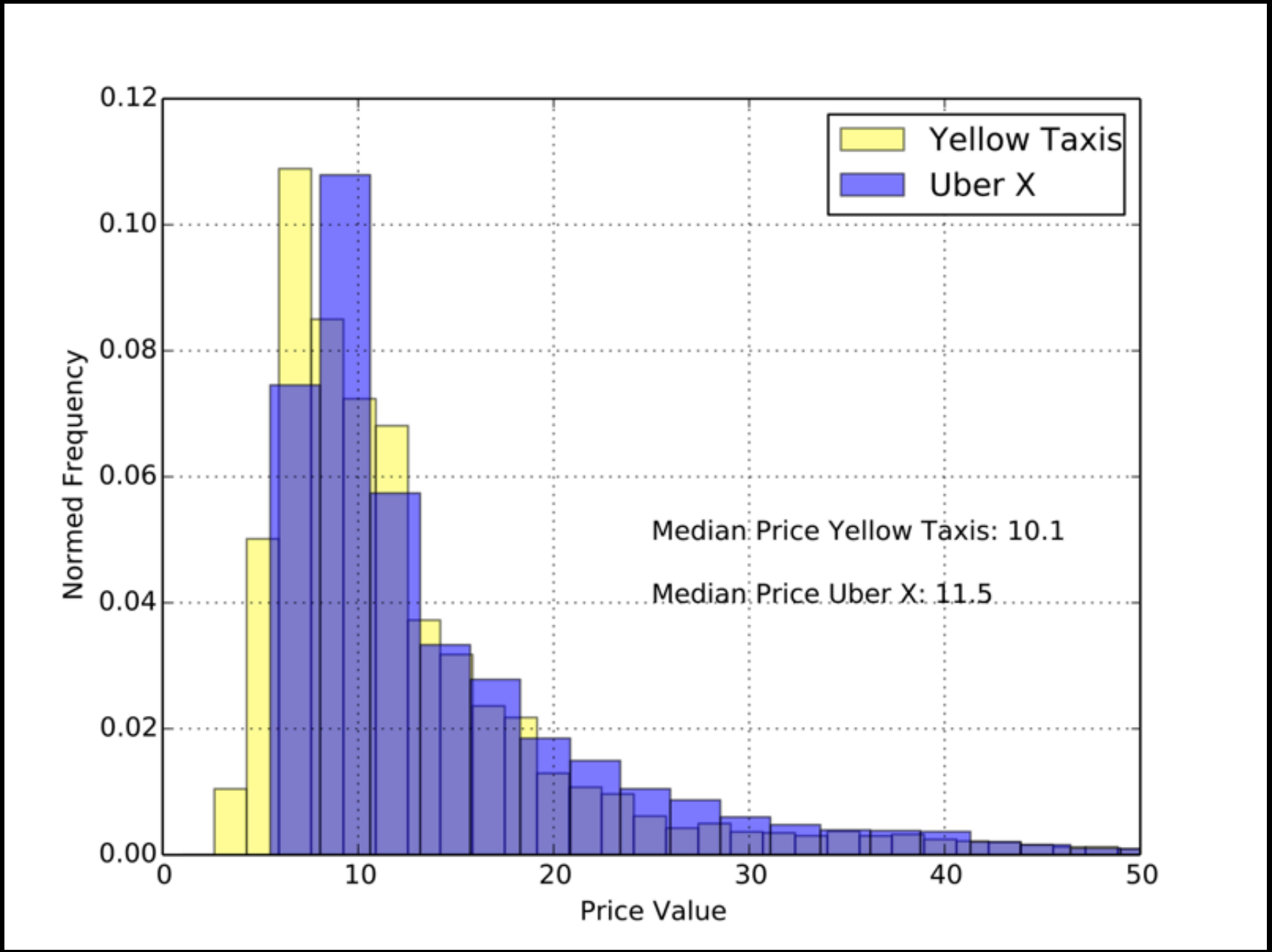
FOILing NYC's Taxi Trip Data

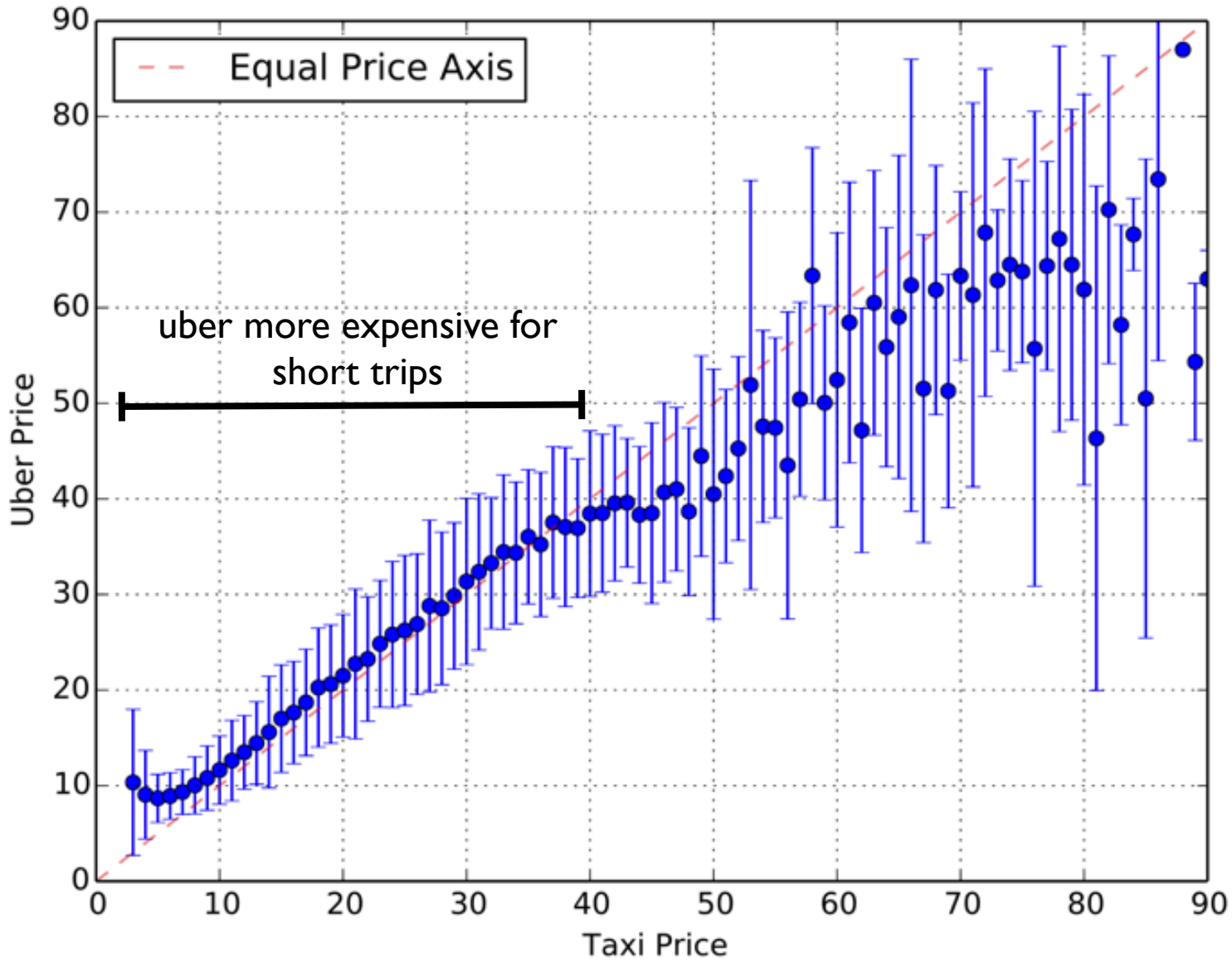
Freedom of Information Law

2013 Trip Data, 11GB, zipped!

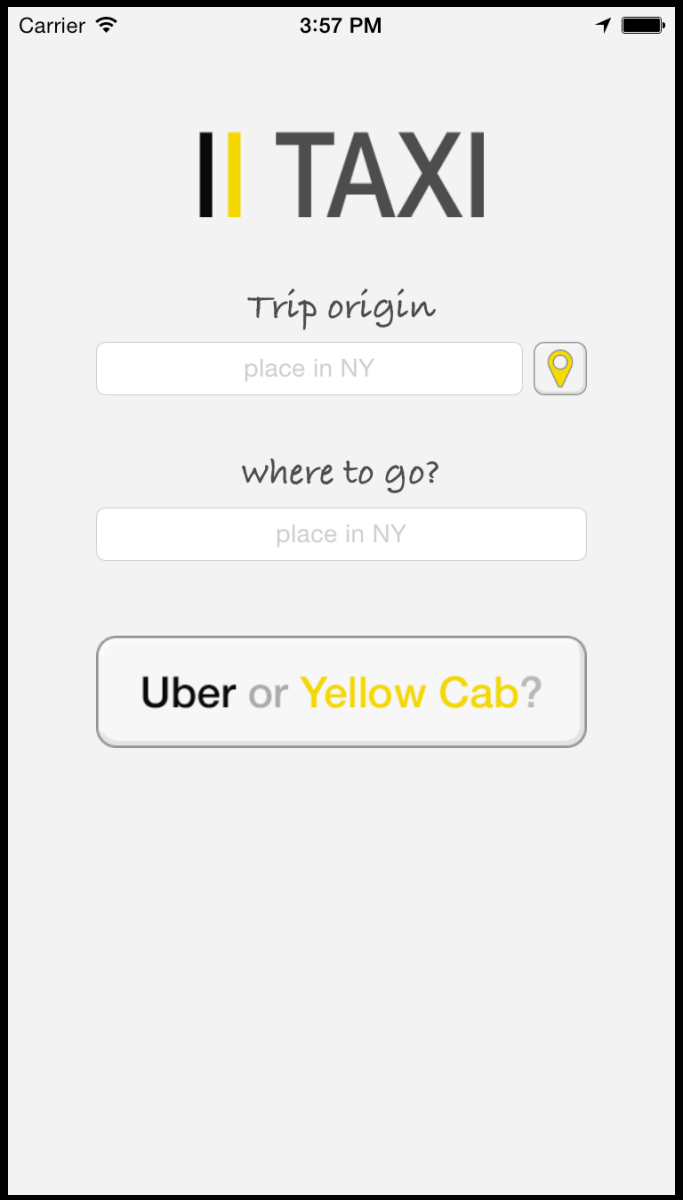
2013 Fare Data, 7.7GB

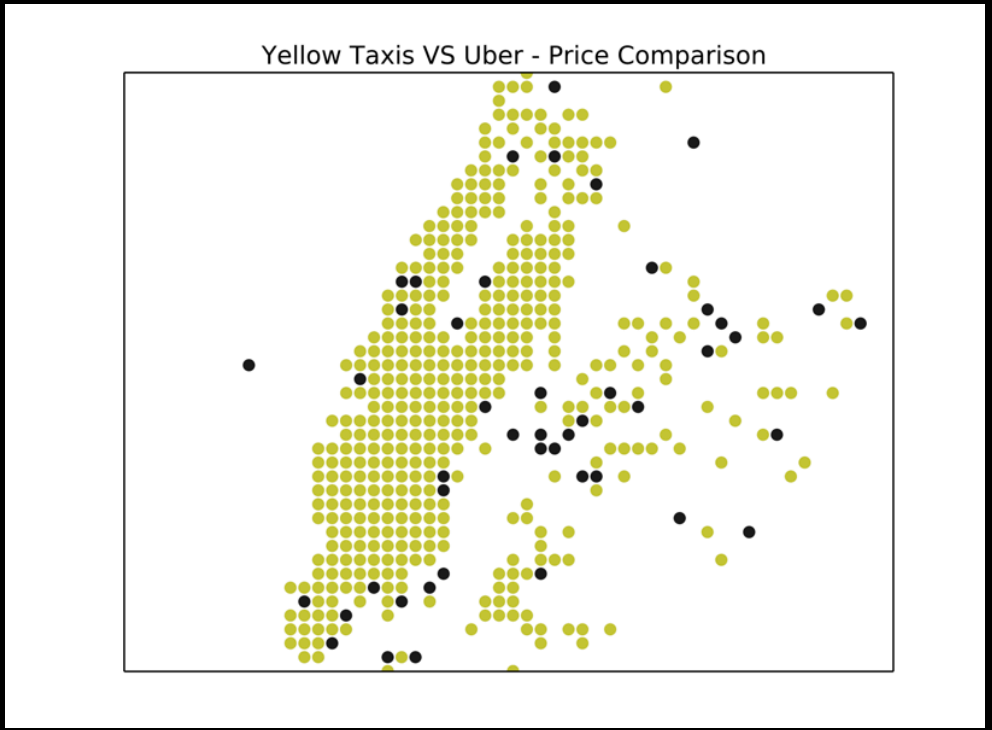
Idea: Uber Vs Yellow Taxi Price Comparison.


Yellow Taxis
Uber X
Median Price Yellow Taxis: 10.1
Median Price Uber X: 11.5
Normed Frequency
Price Value
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
10
20
30
40
50


Equal Price Axis
uber more expensive for
short trips
Uber Price
Taxi Price
0
10
20
30
40
50
60
70
80
90

AN APP TO REDUCE COMMUTER COSTS





Provide feedback on prices to users

Collect more data for research

Make cities smarter

Questions

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