La seconde révolution quantitative de la géographie se fait-elle sans les géographes ?

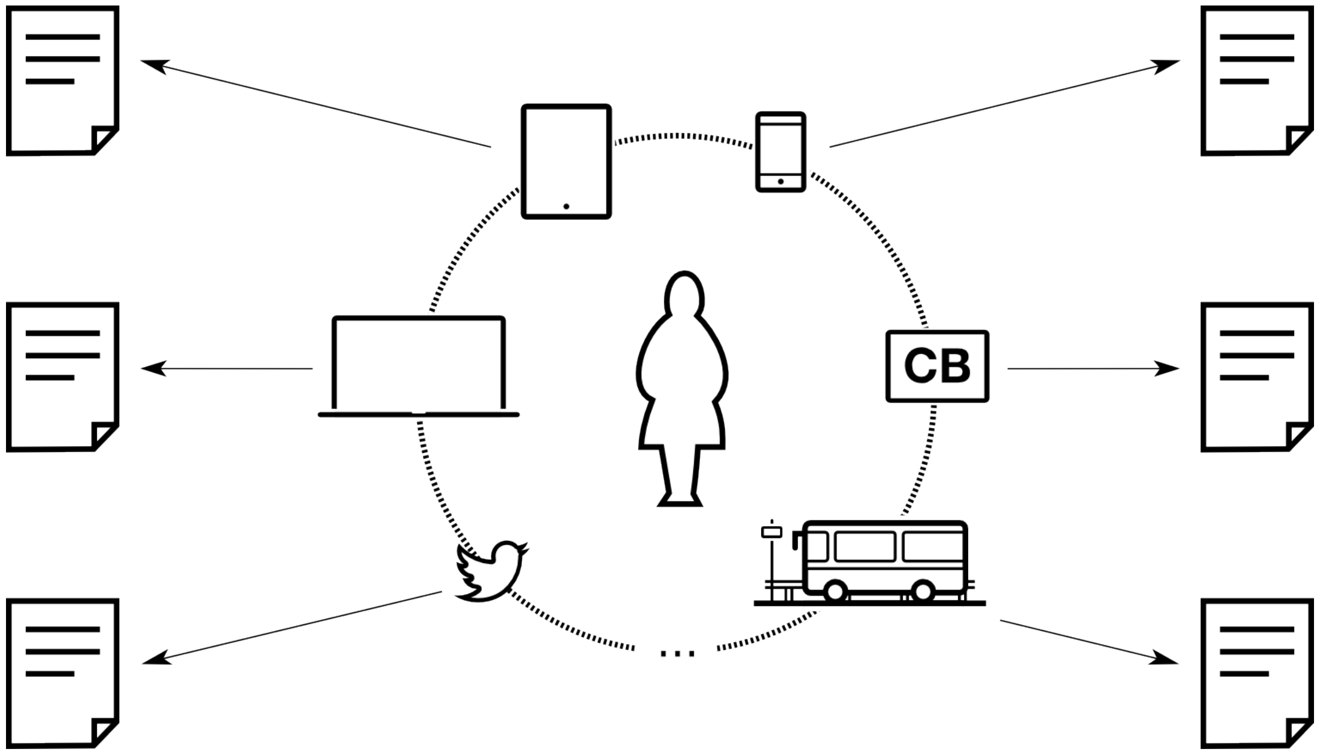
Thomas Louail

*IFISC

CSIC

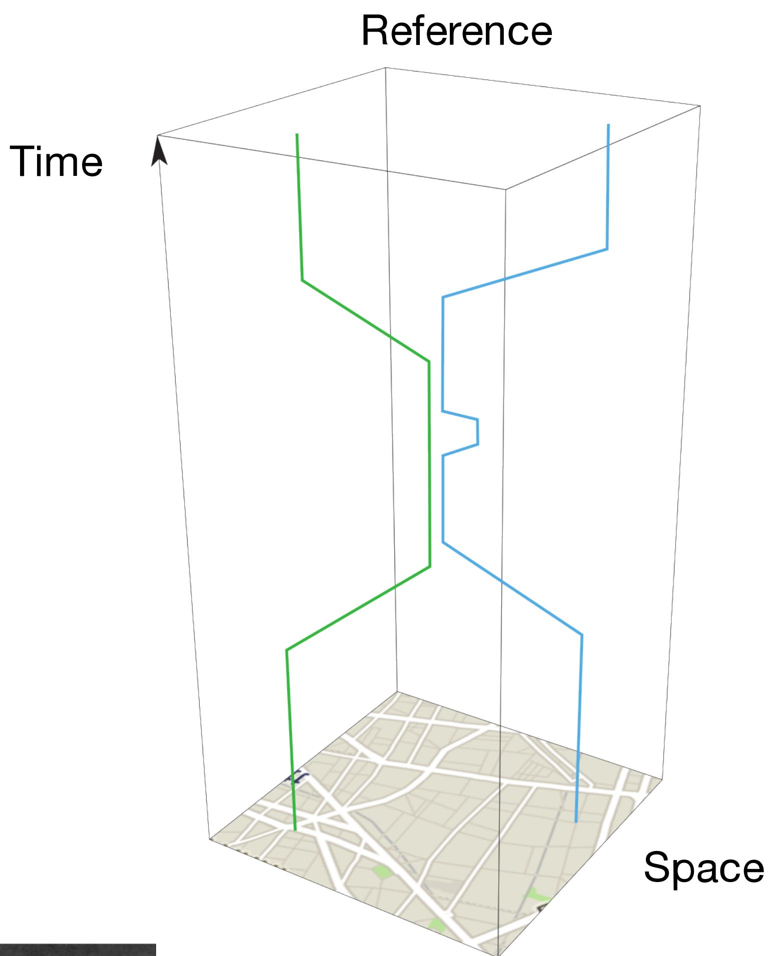
Universitat de les Illes Balears

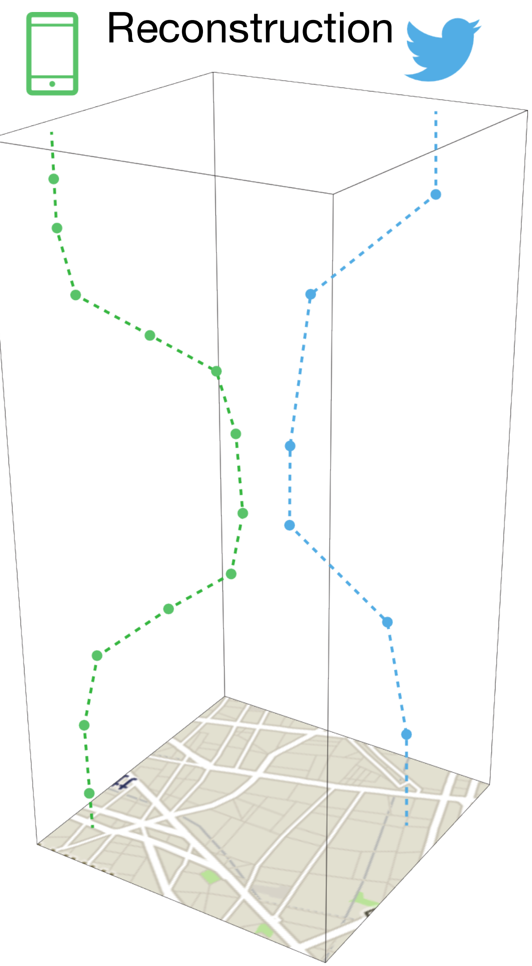
Actively : « *Volunteered geographic information* » (Goodchild, 2007)
Passively : Metadata produced by our mobile devices



> Increasingly used by researchers to study human mobility since the mid-2000's

FOLLOWING THE TRAJECTORIES OF ANONYMOUS INDIVIDUALS THROUGH SPACE AND TIME





T. Hägerstrand

What about people in regional science? (1970)

> Our geographical footprints are a (distorting) mirror for our trajectories through space and time

A PHYSICISTS LITTERATURE ON HUMAN MOBILITY
TYPICAL QUESTIONS

> Typology of systematic motifs/patterns in daily mobility
> Models of individuals mobility
> Itinerary choices (how people choose their paths: simplest, most frequent, random, etc.)

> Predictability / Uniqueness of individual trajectories

> Social networks and mobility
- To what extent you and your relatives move the same way?
- Spatial properties of social communities

> Blondel, Decuyper, Krings (2015) A survey of results on mobile phone datasets analysis
> Barthelemy (2016) The structure and dynamics of cities, Cambridge University Press
> Ghoshal et al. (2017) Human mobility : Models and applications, Physics reports

MEASURING VARIOUS PHENOMENA ASSOCIATED WITH URBAN MOBILITY

OPEN ACCESS Freely available online PLoS one

Structure of Urban Movements: Polycentric Activity and Entangled Hierarchical Flows

Camille Roth[1,2], Soong Moon Kang[3], Michael Batty[4], Marc Barthélemy[1,5]*

1 Centre d'Analyse et de Mathématique Sociales (CAMS), CNRS/EHESS, Paris, France, 2 Institut des Systèmes Complexes de Paris-Ile de France (ISC-PIF), Paris, France, 3 Department of Management Science and Innovation, University College London (UCL), London, United Kingdom, 4 Centre for Advanced Spatial Analysis (CASA), University College London (UCL), London, United Kingdom, 5 Institut de Physique Théorique, CEA, IPhT CNRS, URA 2306, Gif-sur-Yvette, France

Abstract

The spatial arrangement of urban hubs and centers and how individuals interact with these centers is a many applications ranging from urban planning to epidemiology. We utilize here in an unprecedente scale, real-time 'Oyster' card database of individual person movements in the London subway to reve organization of the city. We show that patterns of intraurban movement are strongly heterogeneous but not in terms of distance travelled, and that there is a polycentric structure composed of large flows limited number of activity centers. For smaller flows, the pattern of connections becomes richer and r not strictly hierarchical since it mixes different levels consisting of different orders of magnitude. This can shed light on the impact of new urban projects on the evolution of the polycentric configuration of structure of its centers and it provides an initial approach to modeling flows in an urban system.

< Unveiling London's **mobility structure** with **tap-in/tap-out metro cards data**

Coupling human mobility and social ties

Jameson L. Toole , Carlos Herrera-Yaqüe , Christian M. Schneider , Marta C. González

DOI: 10.1098/rsif.2014.1128 . Published 25 February 2015

Article | Figures & Data | Info & Metrics | eLetters | PDF

Previous

April 2015
Volume: 12 Issue: 105

Abstract

Studies using massive, passively collected data from communication technologies have revealed many ubiquitous aspects of social networks, helping us understand and model social media, information diffusion and organizational dynamics. More recently, these data have come tagged with geographical information, enabling studies of human mobility patterns and the science of cities. We combine these two pursuits and uncover reproducible mobility patterns among social contacts. First, we introduce measures of mobility similarity and predictability and measure them for populations of users in three large urban areas. We find individuals' visitations patterns are far more similar to and predictable by social contacts than strangers and that these measures are positively correlated with tie strength. Unsupervised clustering of hourly variations in mobility similarity identifies three categories of social ties and suggests geography is an important feature

To what extent are **your trajectories similar to those of** the members of **your social network**? >

OPEN ACCESS Freely available online PLo

A Tale of Many Cities: Universal Patterns in Human Urban Mobility

Anastasios Noulas[1]*, Salvatore Scellato[1], Renaud Lambiotte[2], Massimiliano Pontil[3], Cecilia Mascolo[1]

1 Computer Laboratory, University of Cambridge, Cambridge, United Kingdom, 2 Department of Mathematics, University of Namur, Namur, Belgium, 3 Department of Computer Science, University College London, London, United Kingdom

Abstract

The advent of geographic online social networks such as Foursquare, where users voluntarily signal their current location, opens the door to powerful studies on human movement. In particular the fine granularity of the location data, with GPS accuracy down to 10 meters, and the worldwide scale of Foursquare adoption are unprecedented. In this paper we study urban mobility patterns of people in several metropolitan cities around the globe by analyzing a large set of Foursquare users. Surprisingly, while there are variations in human movement in different cities, our analysis shows that those are predominantly due to different distributions of places across different urban environments. Moreover, a universal law for human mobility is identified, which isolates as a key component the rank-distance, factoring in the number of places between origin and destination, rather than pure physical distance, as considered in some previous works. Building on our findings, we also show how a rank-based movement model accurately captures real human movements in different cities.

< **Common statistical regularities in the way people move in cities,** whatever the city?
An analysis with a common source of data (Foursquare) in 50 cities worldwide

MEASURING VARIOUS PHENOMENA ASSOCIATED WITH URBAN MOBILITY

PNAS

Understanding metropolitan patterns of daily encounters

Lijun Sun[a,b], Kay W. Axhausen[a,c,1], Der-Horng Lee[b], and Xianfeng Huang[a,d]

[a]Future Cities Laboratory, Singapore–ETH Centre for Global Environmental Sustainability, Singapore 138602; [b]Depar Engineering, National University of Singapore, Singapore 117576; [c]Institute for Transport Planning and Systems, Swi 8093 Zürich, Switzerland; and [d]State Key Lab of Information Engineering in Surveying, Mapping and Remote Sensin China

Edited by Susan Hanson, Clark University, Worcester, MA, and approved July 3, 2013 (received for review April 5, 20

Understanding of the mechanisms driving our daily face-to-face encounters is still limited; the field lacks large-scale datasets describing both individual behaviors and their collective interactions. However, here, with the help of travel smart card data, we uncover such encounter mechanisms and structures by constructing a time-resolved in-vehicle social encounter network on public buses in a city (about 5 million residents). Using a population scale dataset, we find physical encounters display reproducible temporal patterns, indicating that repeated encounters are regular and identical. On an individual scale, we find that collective regularities dominate distinct encounters' bounded nature. An individual's encounter capability is rooted in his/her daily behavioral regularity, explaining the emergence of "familiar strangers" in daily life. Strikingly, we find individuals with repeated encounters are not

With the help of sensors and close proximity in real-world sit patterns and spreading dynamic diary-based surveys (4). Howev are generally embedded in lin scale settings such as schools (6 7), and even in prostitution (8 empirical data describing exam and joint encounter patterns (o behavior patterns individually, agent-based models) (22–24). studies on individual mobility actions are traditionally condu driving our daily encounters re

Construct a time-resolved in-vehicle social encounter network on public buses in Singapour. **How frequently do you meet your own 'familiar strangers'?**

Unravelling daily human mobility motifs

Christian M. Schneider[1], Vitaly Belik[1,2], Thomas Couronné[3], Zbigniew Smoreda[3] and Marta C. González[1,4]

[1]Department of Civil and Environmental Engineering, and [4]Engineering Systems Division, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA
[2]Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Göttingen, Germany
[3]Sociology and Economics of Networks and Services Department, Orange Labs, 38 rue du Général Leclerc, 92794 Issy les Moulineaux, France

Human mobility is differentiated by time scales. While the mechanism for long time scales has been studied, the underlying mechanism on the daily scale is still unrevealed. Here, we uncover the mechanism responsible for the daily mobility patterns by analysing the temporal and spatial trajectories of thousands of persons as individual networks. Using the concept of motifs from network theory, we find only 17 unique networks are present in daily mobility and they follow simple rules. These networks, called here motifs, are sufficient to capture up to 90 per cent of the population in surveys and mobile phone datasets for different countries. Each individual exhibits a characteristic motif, which seems to be stable over several months. Consequently, daily human mobility can be reproduced by an analytically tractable framework for Markov chains by modelling periods of high-frequency trips followed by periods of lower activity as the key ingredient.

Do our mobility exhibit a limited number of motifs ?
> Yes, and there are only 17 of them

SCIENTIFIC REPORTS

OPEN

The anatomy of urban social networks and its implications in the searchability problem

Received: 23 October 2014
Accepted: 02 April 2015
Published: 02 June 2015

C. Herrera-Yagüe[1,2,3], C. M. Schneider[1], T. Couronné[4], Z. Smoreda[4], R. M. Benito[1,5], P. J. Zufiria[2,3] & M. C. González[1]

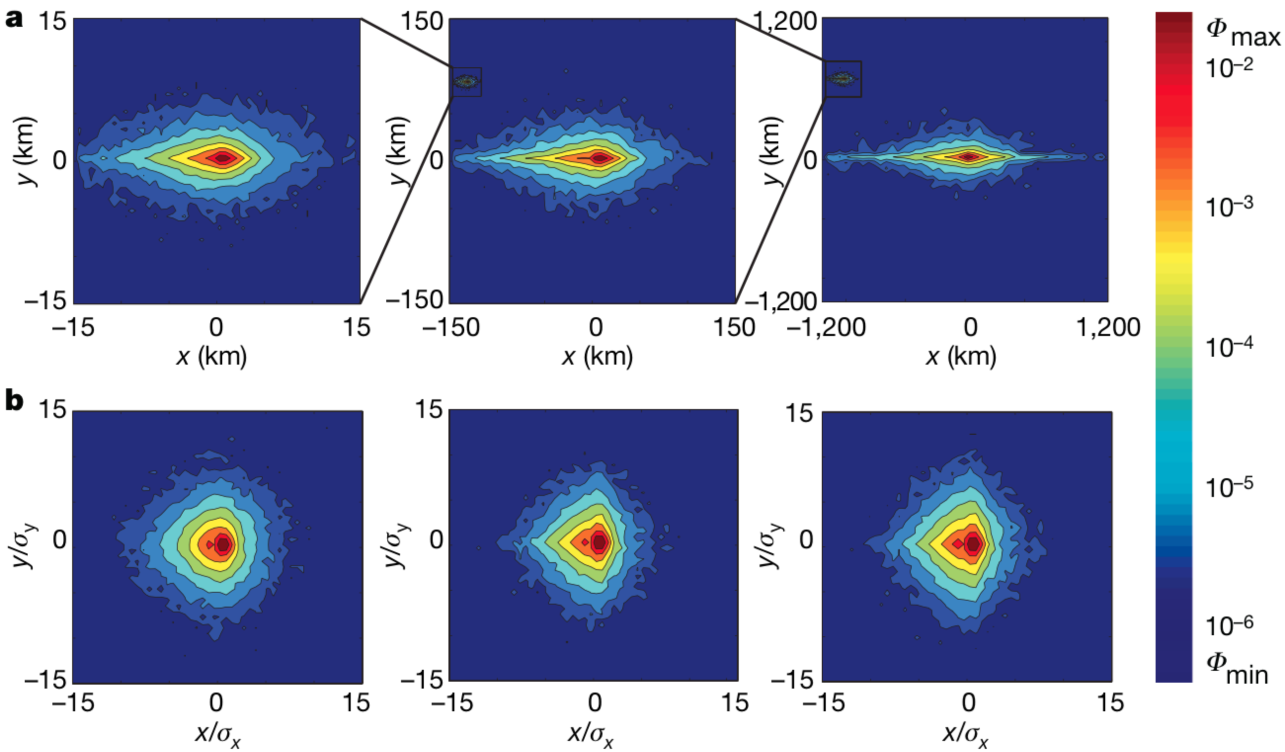
< Testing Milgram message passing exp. on mobile phone data: does the "log(P) degrees of separation" holds ? **What's the best message search/ message diffusion strategy ?**

LETTERS

Understanding individual human mobility patterns

Marta C. González[1], César A. Hidalgo[1,2] & Albert-László Barabási[1,2,3]

[Gonzalez et al., Nature, 2008]



a. Probability density function P(x, y) of finding a mobile phone user in a location (x, y) in the user's intrinsic reference frame. The three plots, from left to right, were generated for 10,000 users with increasing radius of gyration(rg):
rg < 3 (left), 20 <= rg <= 30 (middle) and rg <= 100 km (right)
b. Same function but rescaled by the standard deviation

nature COMMUNICATIONS

**[Gallotti et al.,
Nature Comms, 2016]**

ARTICLE

Received 20 Jun 2016 | Accepted 15 Jul 2016 | Published 30 Aug 2016 DOI: 10.1038/ncomms12600 OPEN

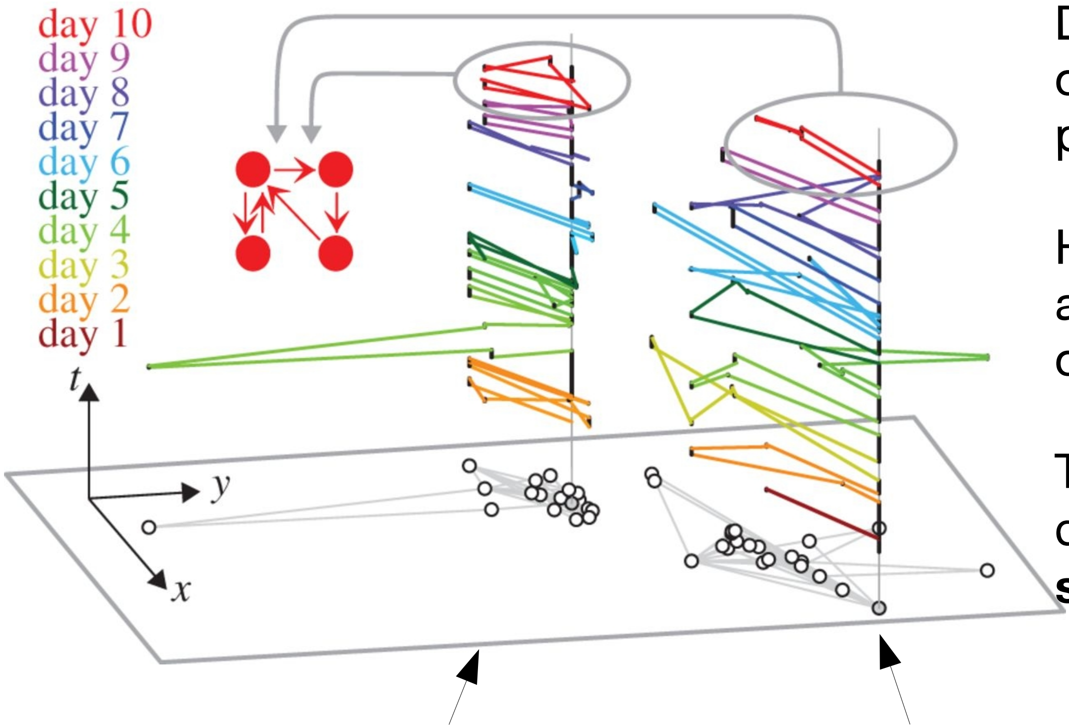
A stochastic model of randomly accelerated walkers for human mobility

Riccardo Gallotti[1], Armando Bazzani[2,3], Sandro Rambaldi[2,3] & Marc Barthelemy[1,4]

> Numerous models have been proposed in the last 10 years
> Able to reproduce an increased number of statistical properties of individual human mobility

[Schneider et al., *Interface*, 2013]

Figure from [Schneider et al., Interface, 2013]



Decomposition of the mobility profile over 10 days into daily mobility patterns for 2 mobile phone users.

Home location is highlighted and connected over the entire observation period with a grey line.

The entire mobility profiles are rather diverse, but **individual daily profiles share common features**.

Prefers commuting to one place and visits the other locations during a single tour

Prefers visiting the daily locations during one single tour

DAILY MOBILITY MOTIFS

[Schneider et al., *Interface*, 2013]

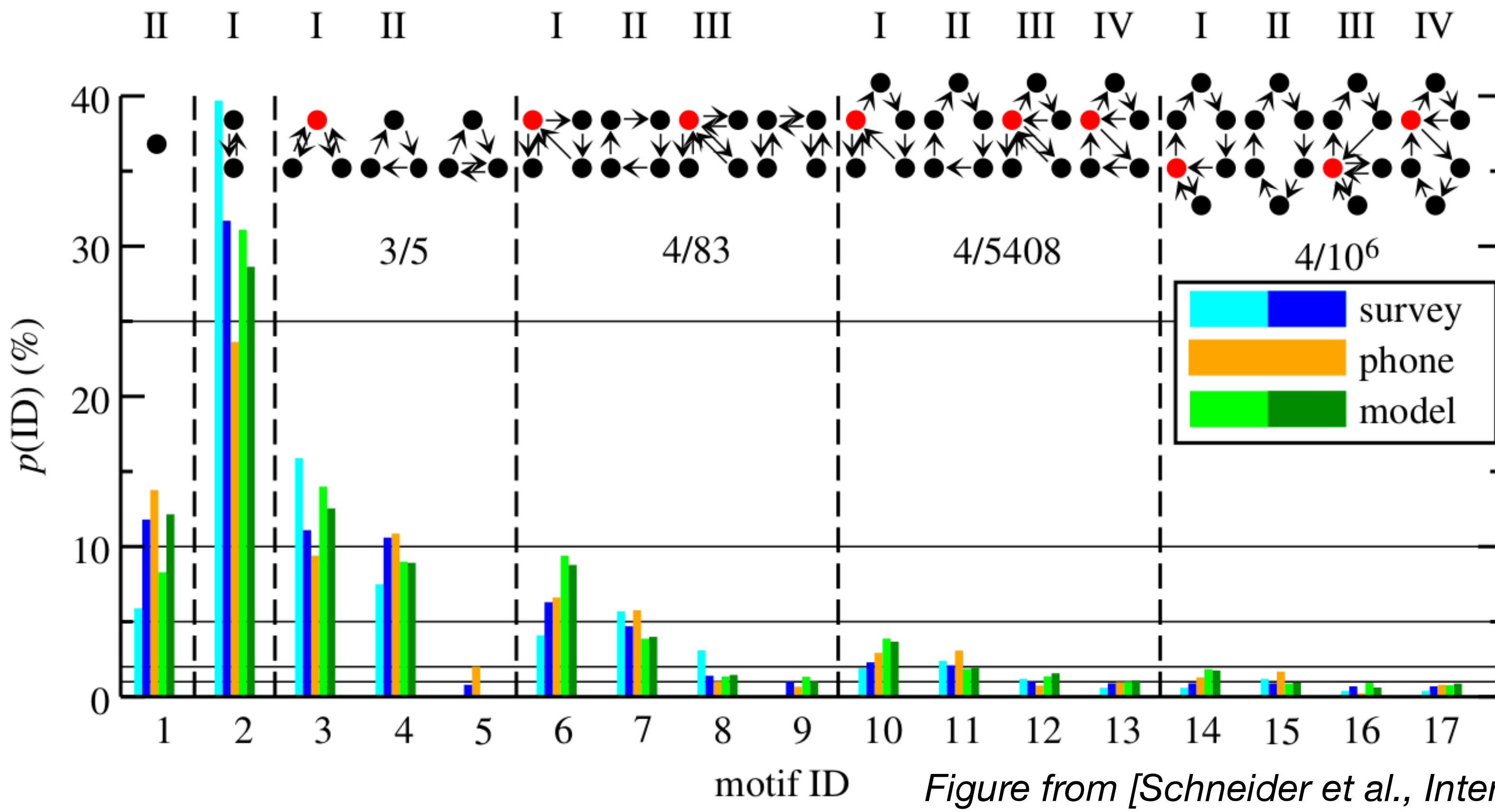


Figure from [Schneider et al., Interface, 2013]

17 different motifs describe 90% of the identified daily mobility networks

Most motifs classified by o²nly four rules:

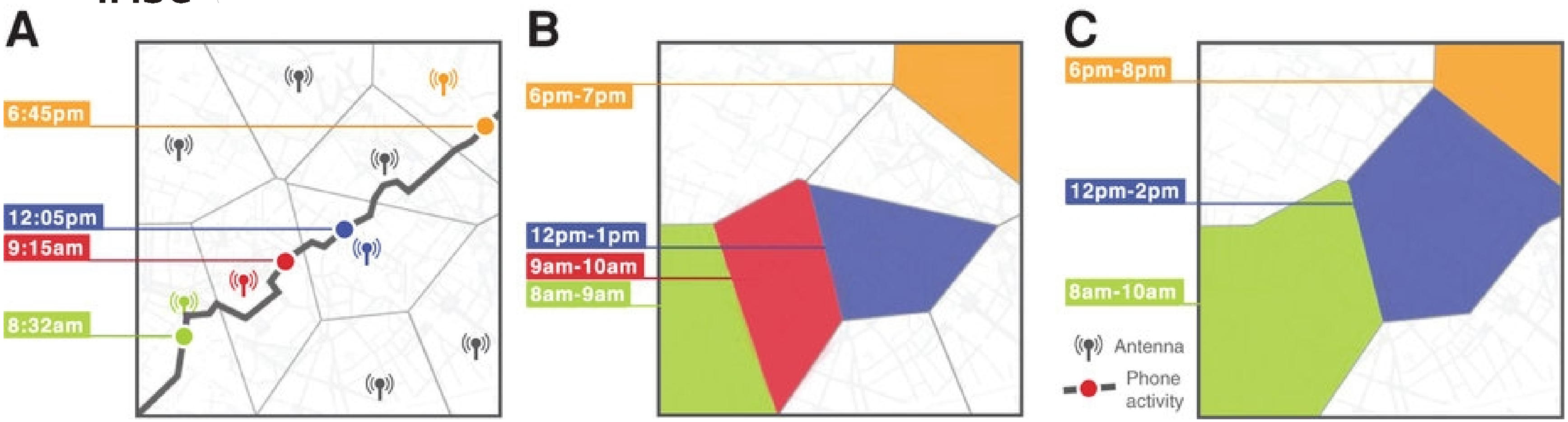
(I) motifs of size N consist of a tour with only 1 stop, and another tour with N – 2 stops

(II) motifs of size N consist of only a single tour with N stops

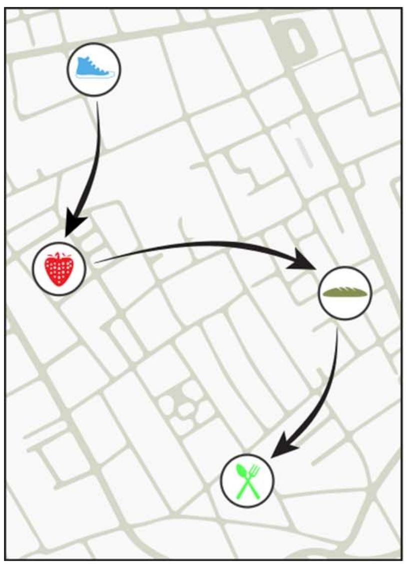
(III) motifs of size N consist of two tours : one with 1 stop and another tour with N – 3 stops

(IV) motifs of size N consist of a tour with 2 stops and another tour with N – 3 stops

UNIQUENESS OF HUMAN TRAJECTORIES



From mobile phone records
[DeMontjoye et al., *Sci. rep.*, 2013]

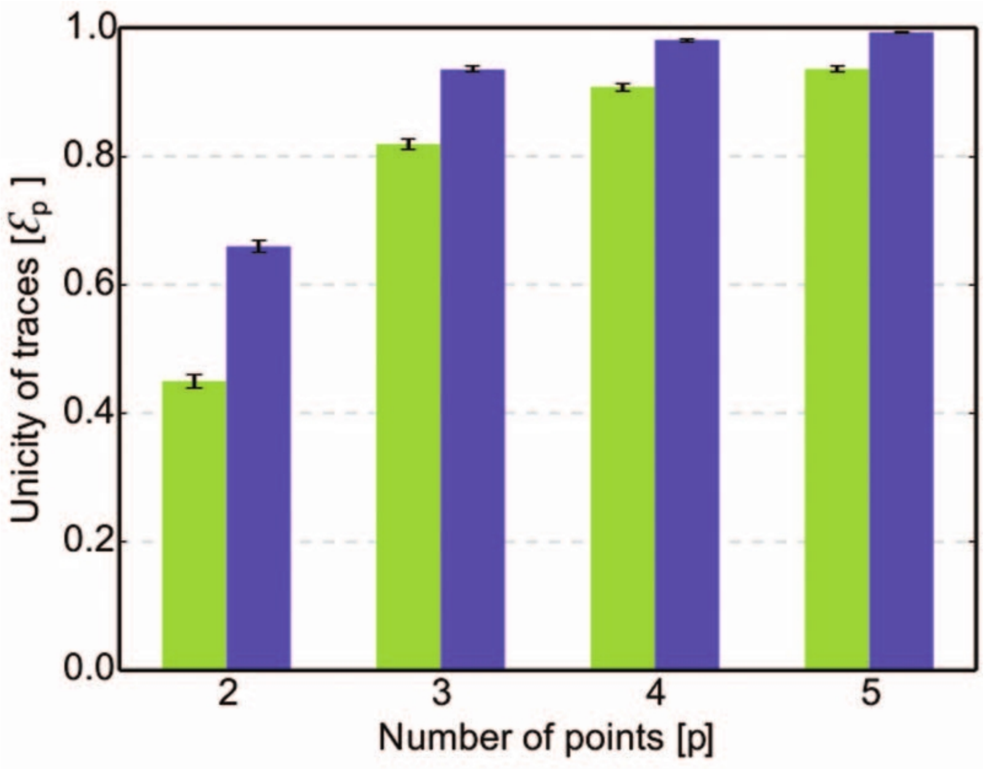


shop	user_id	time	price	price_bin
	7abc1a23	09/23	$97.30	$49 – $146
	7abc1a23	09/23	$15.13	$5 – $16
	3092fc10	09/23	$43.78	$16 – $49
	7abc1a23	09/23	$4.33	$2 – $5
	4c7af72a	09/23	$12.29	$5 – $16
	89c0829c	09/24	$3.66	$2 – $5
	7abc1a23	09/24	$35.81	$16 – $49

From credit cards data
[DeMontjoye et al., *Science*, 2015]

At given spatial and temporal resolutions, how many points (x,y,t) randomly chosen in your logs are necessary to make you unique?

[DeMontjoye et al., *Science*, 2015]



Uniqueness as a function of
the number of points considered

Green bars represent uniqueness
when only spatiotemporal info are known.
Four spatiotemporal points taken at random (p = 4) are enough to uniquely characterize 90% of individuals.

Blue bars represent unicity when using spatial-temporal-price triples.
Adding the approximate price of a transaction significantly increases the likelihood of re-identification.

> Individual mobility is highly predictable
[Gonzalez et al., *Nature*, 2008 ; Song et al., *Science*, 2010 ;
DeMontjoye et al., *Science*, 2015]

> The statistics of the small set of venues to which we frequently return
[Bagrow et al., *PlosOne* , 2012]

> Classifying the motifs/subnetworks which capture our daily mobility patterns
[Schneider et al., *Interface*, 2013]

> Mobility structure linked to the size and shape of cities
[Roth et al., *PlosOne*, 2011], [Louail et al., *Sci.rep*, 2014]
[Louail et al., *Nat.Comm.*, 2015]

> Spatial cohesiveness of social communities depends on the geographical scale
[Toole et al., Interface, 2015]

> Counter-intuitive phenomena, e.g. the hidden networks of co-presence in cities
[Sun et al., *PNAS*, 2013]