

Mobile and Sensor Systems

Lecture 7: Mobile Privacy

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Mobile Privacy

- In this lecture we will discuss some issues and solutions related to mobile systems and data privacy

Mobile Phone Data

- Mobile phones generate user data which can reveal a lot about the user
- Where does this data go?
- Initially collected by a few “trusted” companies
- More and more smaller companies have built their business model around data

App Data Gathering

- More often than not apps collect sensing data beyond its technical needs (for advertising purposes)

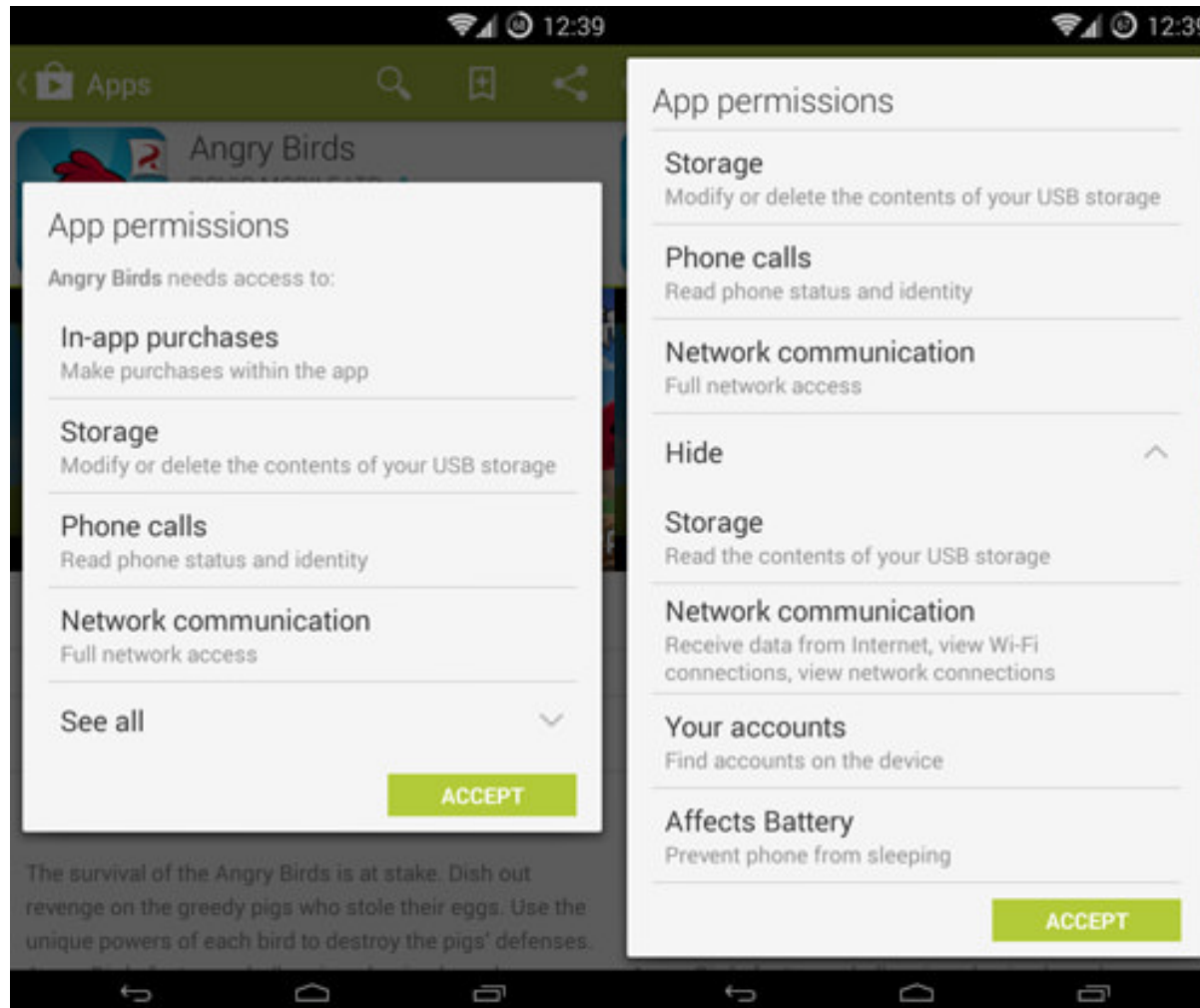


Where does the data go?

- The app collects location. Does it then go to:
 - Location services
 - Advertisers
 - Developers

- The OS does not offer support to know this...

Permissions: Android



Permissions: iOS

- Apple doing the vetting
- Now notifying users about location data usage

Privacy Data Breach Detection

- Monitor behavior of apps to determine when privacy sensitive information leaves the phone.
- Data Flow Analysis (DFA): looks for routes between data sources and sinks
 - Any of these routes without user consent is classified as leak
- Capability Leak:
 - Explicit: malicious app manages to hijack permissions granted to other trusted apps
 - eg apps can have sharedUserID: apps by same developer have same ID so permissions for that ID are shared

Sources and Sinks

Sources

Location Data: GPS, last base station location, WLAN

Unique, Identifiers: IMEI, IMSI

Authentication, Data: Cashed password data

Contact and Calendar, Contacts, address and schedule

Call State, Start and end of incoming call, number of incoming call

Sinks

SMS, Communication: data can be transferred by SMS

File Output: Applications can write data to files that are globally readable

Network: Applications can access network by sockets or HTTP

Intents, objects: applications can send data objects to other apps

Content, Resolver Apps can use API to edit shared memory of device

Dynamic Analysis: TaintDroid

- **Challenges ...**

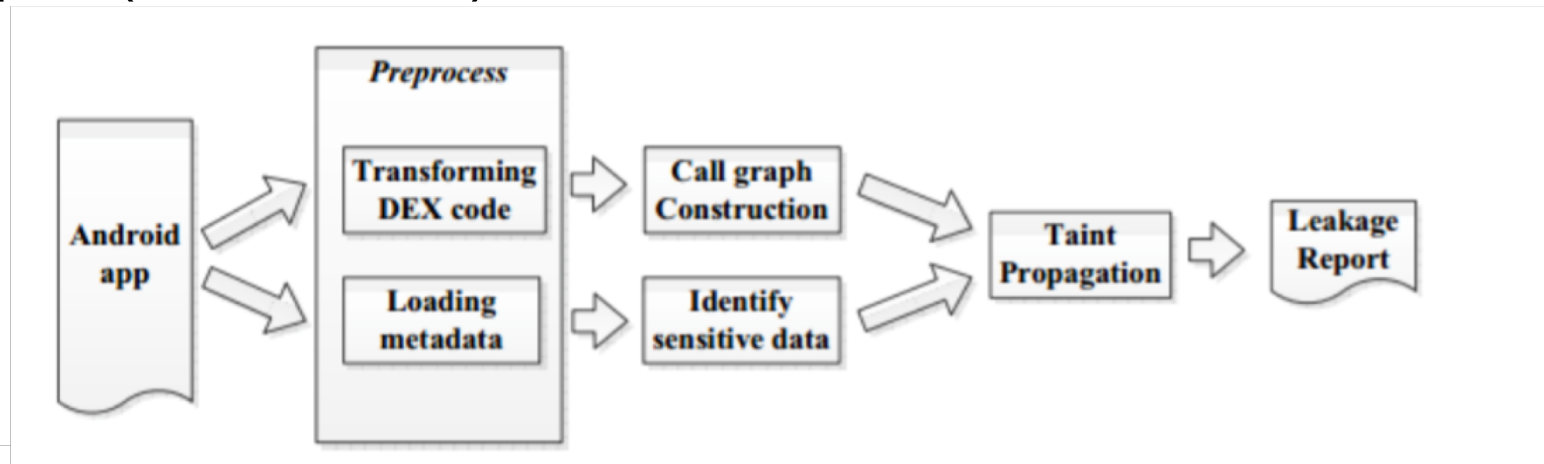
- Smartphones are resource constrained
- Third-party applications are entrusted with several types of privacy sensitive information
- Context-based privacy information is dynamic
- Applications can share information
- TaintDroid is a modification to the Android OS which allows for dynamic tracking of sensitive data movements from an app to other apps and sinks

TaintDroid

- TaintDroid automatically labels data from privacy-sensitive sources and transitively applies labels as sensitive data propagates through program variables, files, and interprocess messages.
- When tainted data are transmitted over the network, or otherwise leave the system, TaintDroid logs the data labels, the application responsible for transmitting the data, and the data destination.

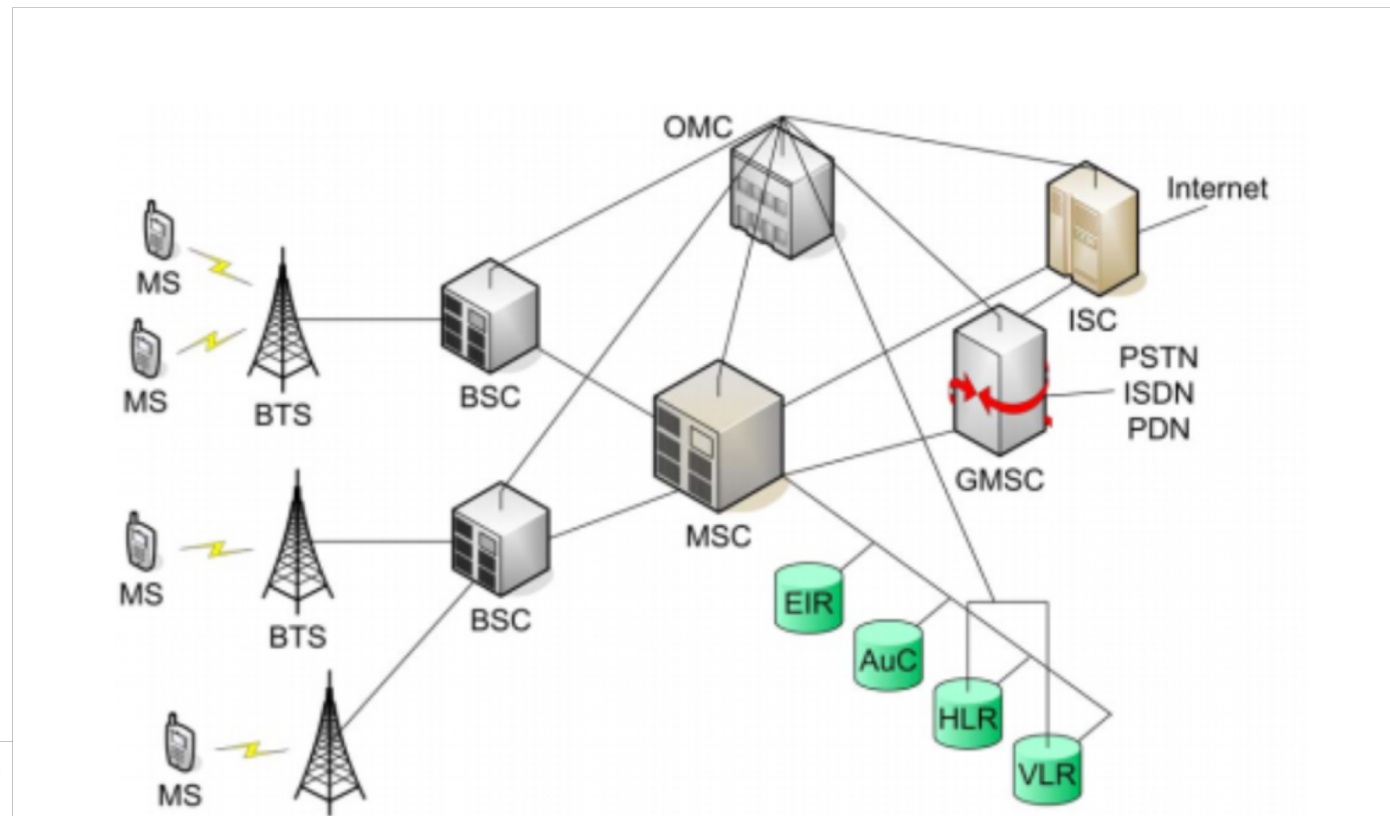
Static Analysis

- Static Analysis covers all the paths from sources to sinks
 - Takes much longer than dynamic analysis
 - No time or efficiency overhead (done offline)
 - Example (LeakMiner):



Cellular Network Leaks

- Various parts of a cellular network are prone to leaks and attacks...



Cellular Network Leaks

- Mobile devices roam around and register with BTSs: they can be identified from these records and pre-existing location profiles. One paper identifies 80% of users.
- the network interface itself can allow listening attacks/leaks (GSM).

Performance

Table 5: Performance: all four identification periods

	Dec 2004	Jan 2005
one hour	40.91%	48.98%
one day	65.15%	65.31%
one week	74.24%	75.51%
one month	77.27%	87.76%

Yoni De Mulder, George Danezis, Lejla Batina, and Bart Preneel. 2008. Identification via location-profiling in GSM networks. In *Proceedings of the 7th ACM workshop on Privacy in the electronic society (WPES '08)*. ACM, New York, NY, USA, 23-32.

WiFi based Leaks

- WLAN fingerprints can be used to infer social relation between the users.
- Mobile devices broadcast their Wi-Fi information that contain device ID or MAC address, it is possible for adversaries to track locations of devices.
- Users' names can also be detected by analyzing applications, websites and ad content in traffic data through WiFi hot-spots

WiFi based Leaks (2)

- By having WiFi connection info, applications can get the MAC address of devices, which is a unique ID. Since this ID is permanent, it allows third parties to track users.
- Applications can also learn about the last scanned list of WiFi hot spots. This includes MAC address, name, signal strength, operating channels and so on. This information can later be used to geo-locate user positions.
- It is also possible for applications to determine configured network lists on devices. Moreover, by comparing these lists, social relationship between individuals can also be inferred, such as professional, family, interest groups and the like.

Mobile Sensing Leaks

- Sensors are powerful (eg mood automatic recognition)
- Accelerometer is different on all devices (so it can be used as a “device signature”).
- Or it can be used to identify different users of same device
- Touch sensor usage behaviour, keying behaviour can give away user identity

Mobile Sensing De-anonymization

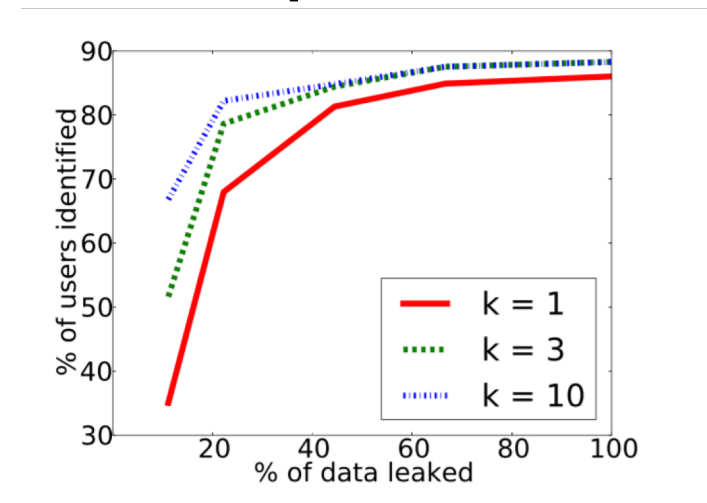
- Even in large anonymized datasets there is a risk that a user can be identified.
 - Example of the Netflix challenge
 - Mobile sensing datasets exhibit data “sparsity”
- With some user information it is possible to single out the user in a dataset that just contains activity profiles of users.

De-anonymization

- Netflix type datasets contains narrow range of behaviour (preferences of movies)
- Sensing data contain a wider range:
- Correlation of activities can be a “key”
 - Eg you go to the gym at a certain time after a train ride
 - This increases data sparsity
 - Broad range of auxiliary information which can be used by an adversary

Example

- Auxiliary information of the adversary is a collection of activities by a user.
- Aim: Identify which of the anonymized activity streams belongs to the target user.
- Auxiliary information may be collected by observing the user or from available public sources.



Location Data Privacy



Location Data Leaks

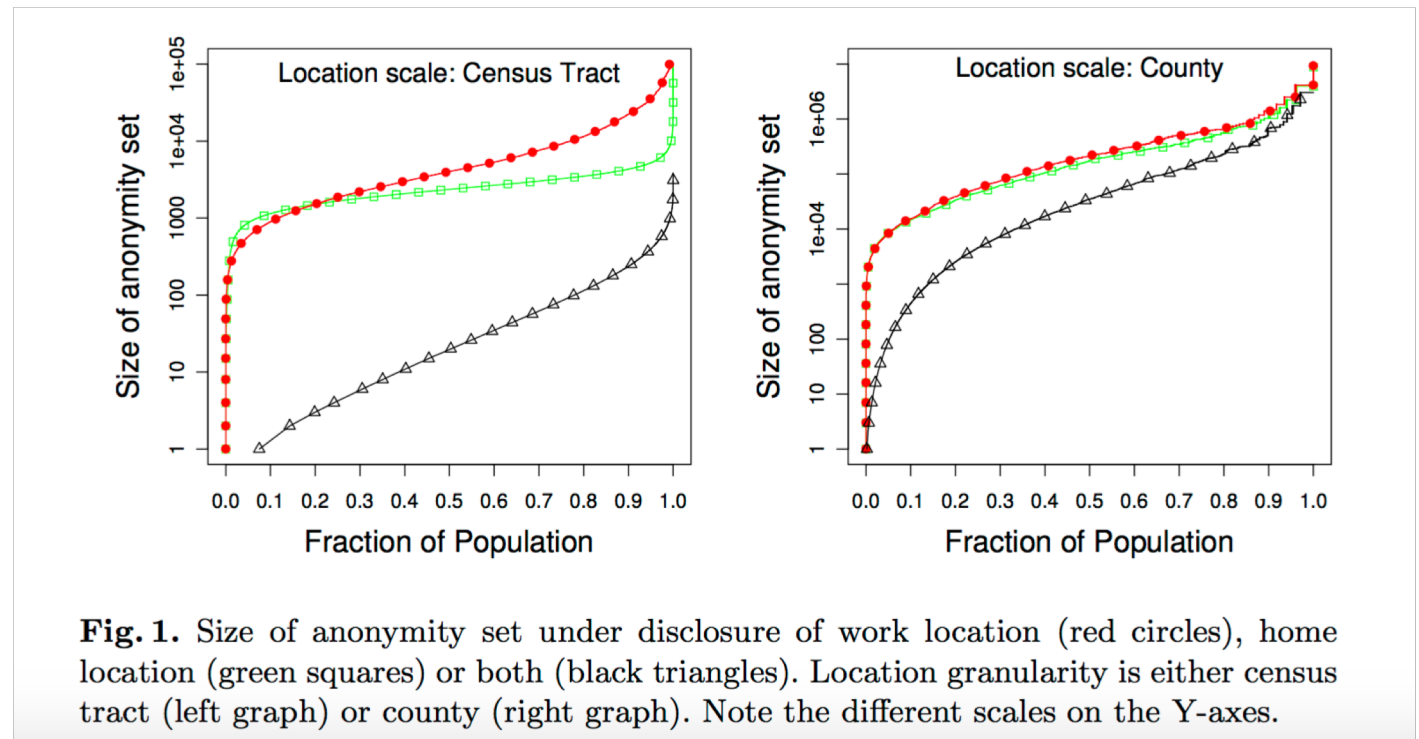
- Location aware apps collect data which is (sometimes) provided to third parties
 - Advertisement?
- Location data can be used to infer more personal information (or user identity from anonymous datasets)
- Profile of users can be built from solely location tracks

Examples

- GPS of 172 users find their home location with median error of 60m.
 - Features (last destination of day, long stay, time..)
- Similar features have been used to detect “significant places” for a user (work, gym etc)
- Speed of travelling/transport modality
- Data can be cross correlated with social network data for more deanonymization

And more

- If the approximate locations of a user's home and workplace can be deduced from a location trace, then the median size of the individual's anonymity set in the U.S. working population is 1, 21 and 34,980, for locations known at the granularity of a census block, census tract and county respectively.

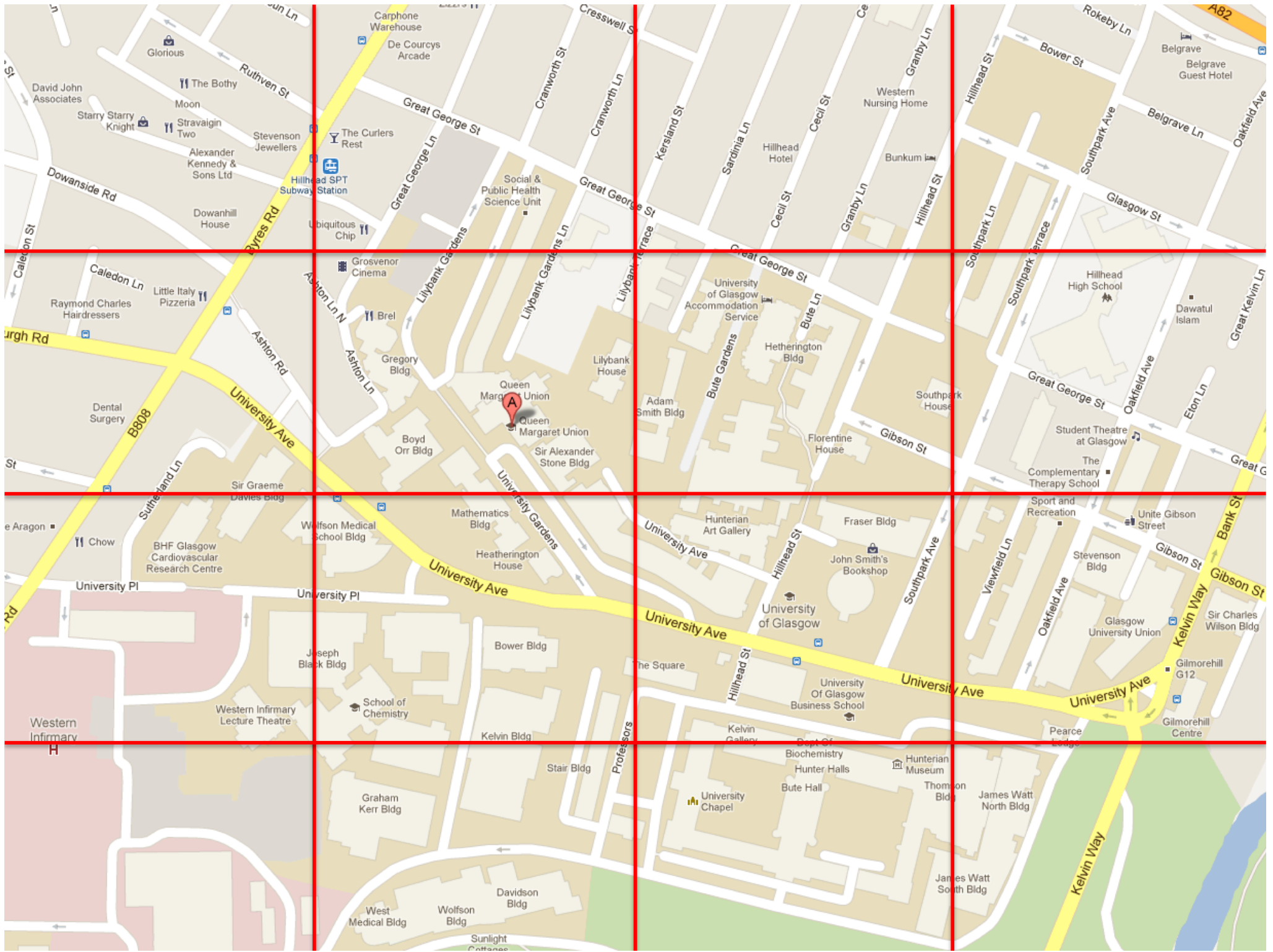


Mobility Prediction

- Given user patterns are highly regular, a user can not only be identified in a dataset but his previous patterns can be used to predict her future movements
- In addition her friends patterns if known can considerably aid this prediction

Different Types of Prediction

- Location can be:
 - Logical location (workplace, home)
 - Geographic location
 - Discrete areas (e.g., square in a grid)
 - GPS locations
- Not only *where* but also *when*
 - Spatio-temporal prediction is hard



David John Associates
Starry Starry Knight
The Bothy
Moon
Stravaigin Two
Alexander Kennedy & Sons Ltd
Stevenson Jewellers
Hillhead SPT Subway
Downan House
Glorious
De Courcys Arcade
The Curlers Rest
Social & Public Health Science Unit
Ubiquitous Chip

Raymond Charles Hairdressers
Little Italy Pizzeria
Dental Surgery
Sir Graeme Davies Bldg
Wilsom Medical School Bldg
Chow
BHF Glasgow Cardiovascular Research Centre
University Pl
University Pl

Western Infirmary
Western Infirmary Lecture Theatre
School of Chemistry
Joseph Black Bldg
Kelvin Bldg
Graham Kerr Bldg
West Medical Bldg
Wolfson Bldg
Davidson Bldg
Sunlight Cottages

Carphone Warehouse
De Courcys Arcade
The Curlers Rest
Social & Public Health Science Unit
Lilybank House
Gregory Bldg
Boyd Orr Bldg
Mathematics Bldg
Heatherington House
Wilsom Medical School Bldg

Grosvenor Cinema
Brel
Queen Margaret Union
Queen Margaret Union
Sir Alexander Stone Bldg
Mathematics Bldg
Heatherington House
University Gardens
Kelvin Bldg
Stair Bldg
Professors

University of Glasgow
University of Glasgow Business School
University Chapel
Biochemistry
Hunter Halls
Bute Hall
Thomson Bldg
James Watt North Bldg
James Watt South Bldg

Hillhead Hotel
Western Nursing Home
Bunkum
Hetherington Bldg
Florentine House
Fraser Bldg
John Smith's Bookshop
University of Glasgow
University of Glasgow Business School

University of Glasgow Accommodation Service
Hetherington Bldg
Florentine House
Fraser Bldg
John Smith's Bookshop
University of Glasgow
University of Glasgow Business School

Hunterian Art Gallery
Fraser Bldg
John Smith's Bookshop
University of Glasgow
University of Glasgow Business School
Kelvin Gallery
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Bute Hall
Thomson Bldg
James Watt North Bldg
James Watt South Bldg

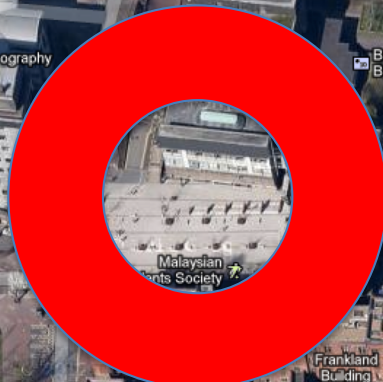
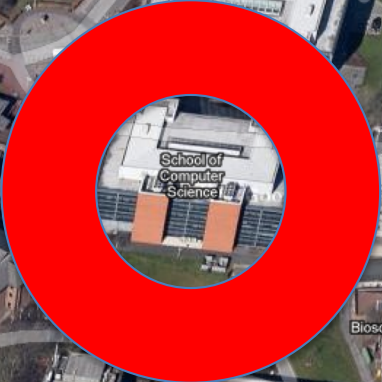
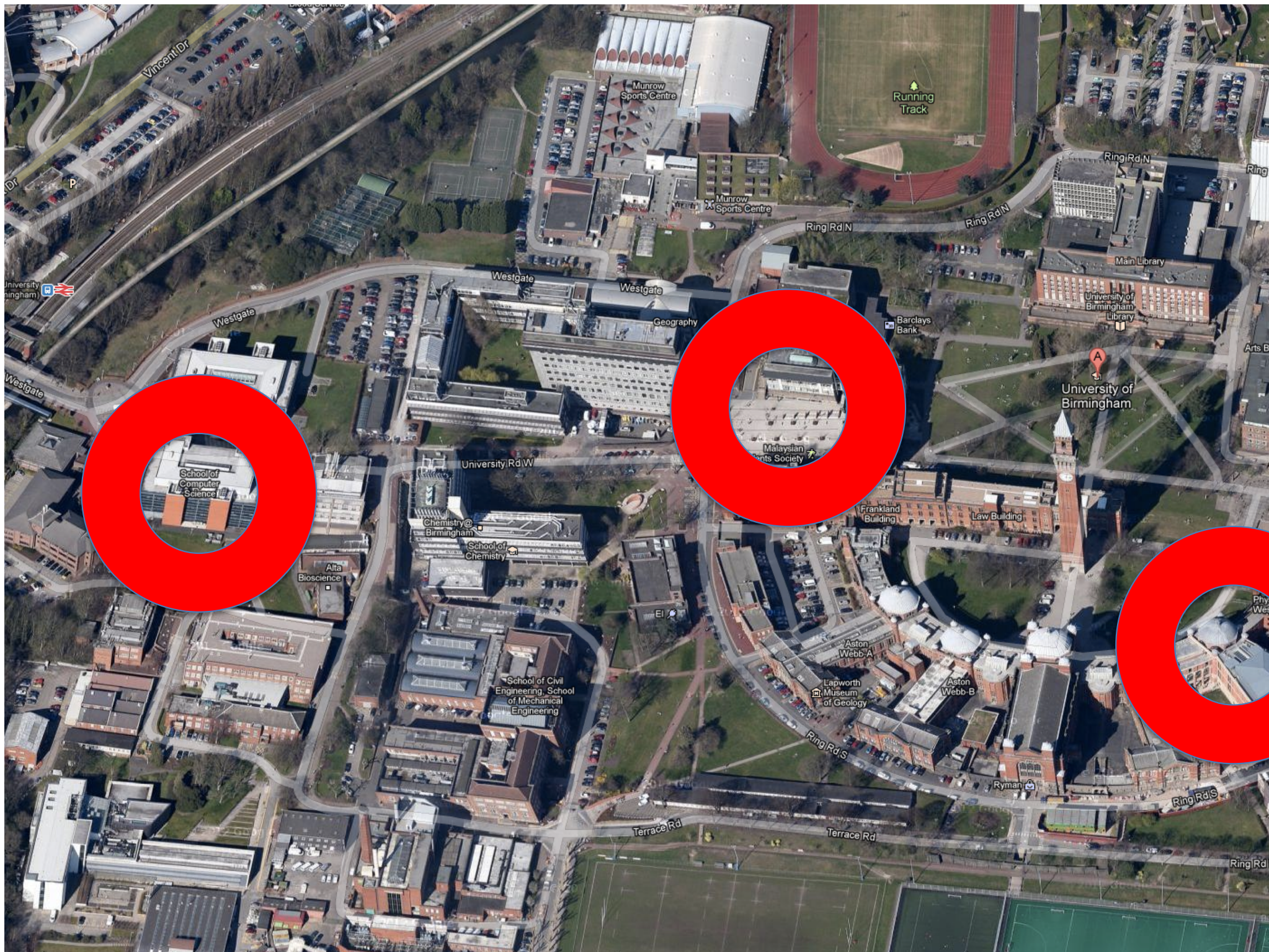
Belgrave Guest Hotel
Belgrave Ln
Oakfield Ave
Hillhead High School
Dawatul Islam
Student Theatre at Glasgow
The Complementary Therapy School
Sport and Recreation
Unite Gibson Street
Stevenson Bldg
Glasgow University Union
Gilmorehill G12
Gilmorehill Centre

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Gilmorehill G12
Gilmorehill Centre
Pearce Lodge
James Watt North Bldg
James Watt South Bldg

Transition Matrix

$$T = \begin{pmatrix} 0.1 & 0.3 & 0.2 & 0.4 \\ 0.4 & 0.2 & 0.15 & 0.25 \\ 0.1 & 0.3 & 0.4 & 0.2 \\ 0.1 & 0.2 & 0.2 & 0.5 \end{pmatrix}$$



Various Prediction Techniques

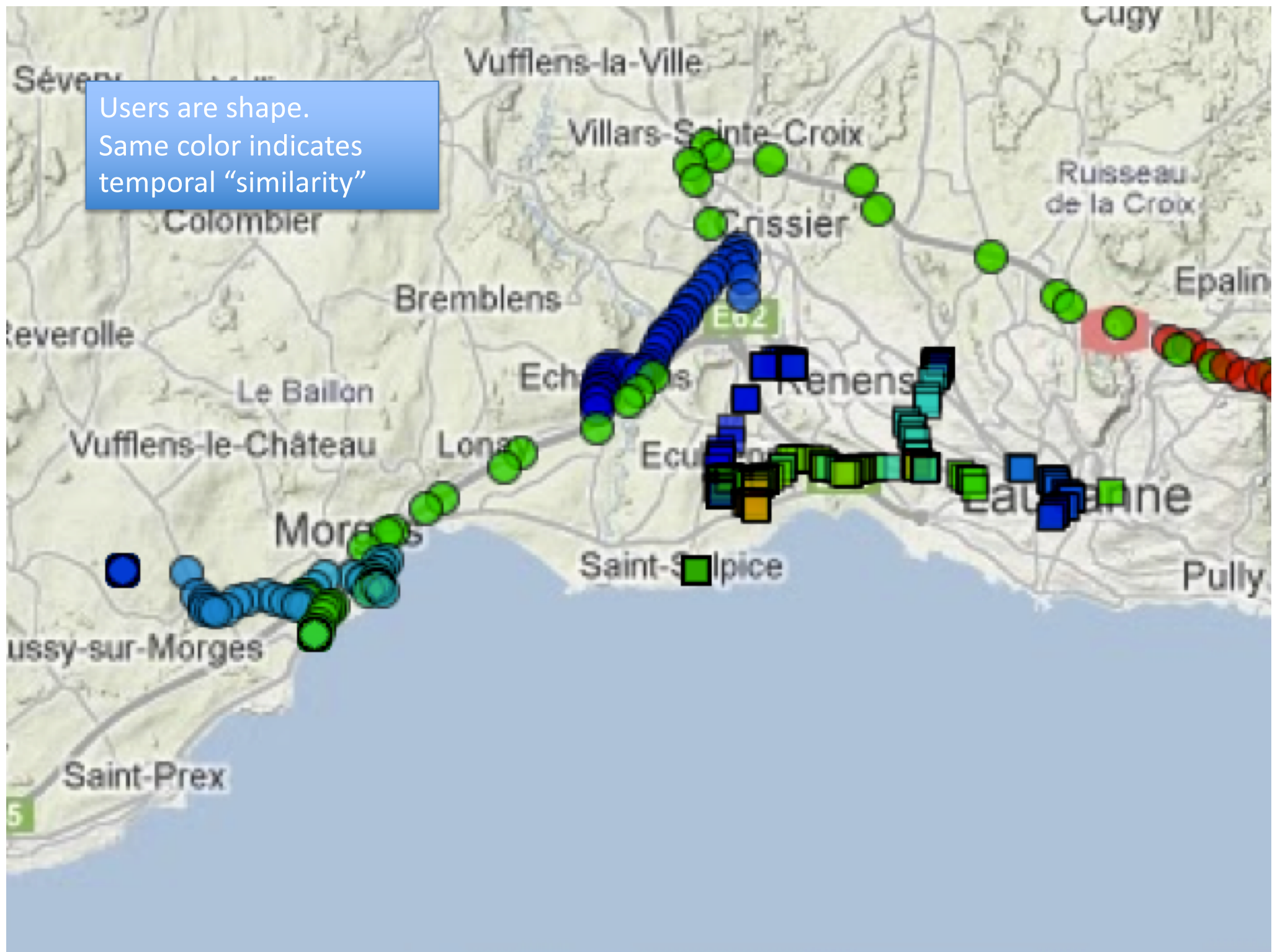
- Techniques forecast
 - the next location of a user
 - his/her arrival and residence time, i.e., the interval of time spent at that location.



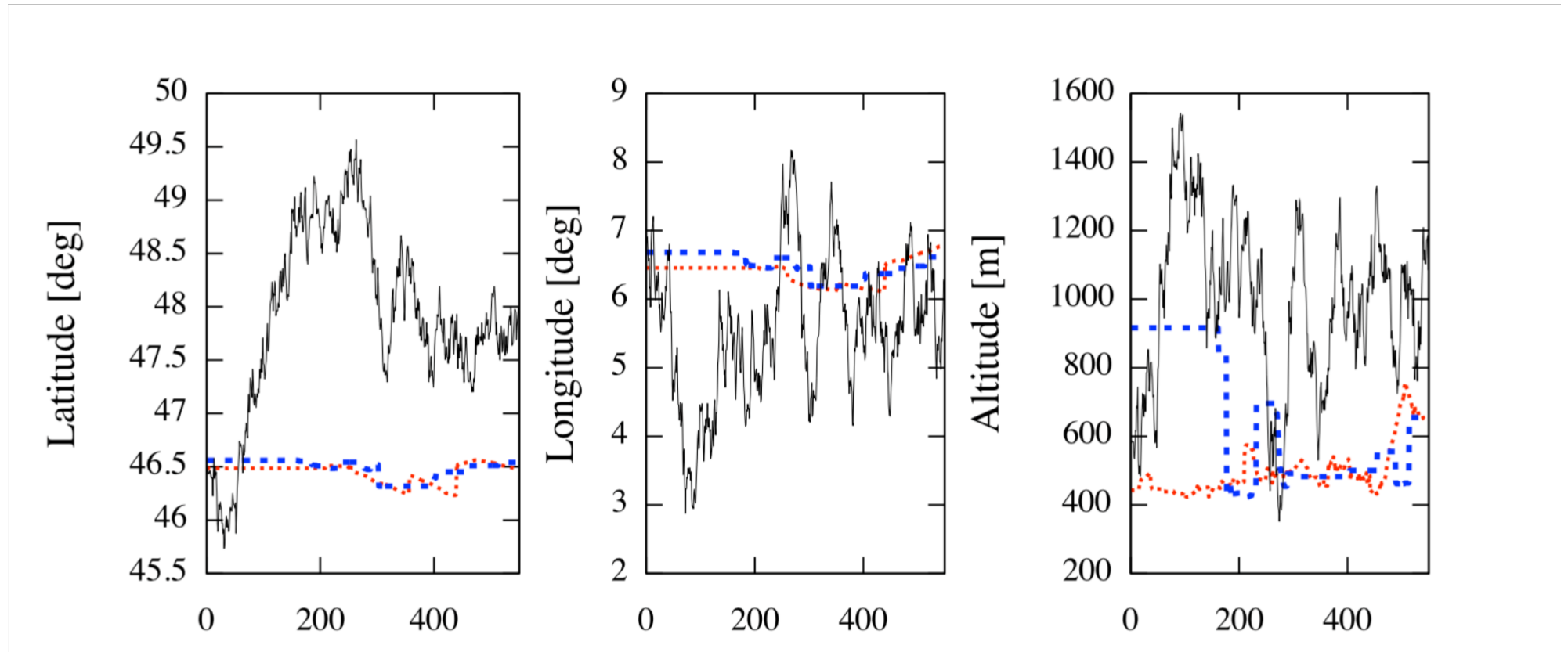
Prediction through correlated movement

- Analysis of the correlation of mobility patterns of the users
- Movement correlation is measured through **mutual information**
- The resulting network can be considered as a network of “movements”

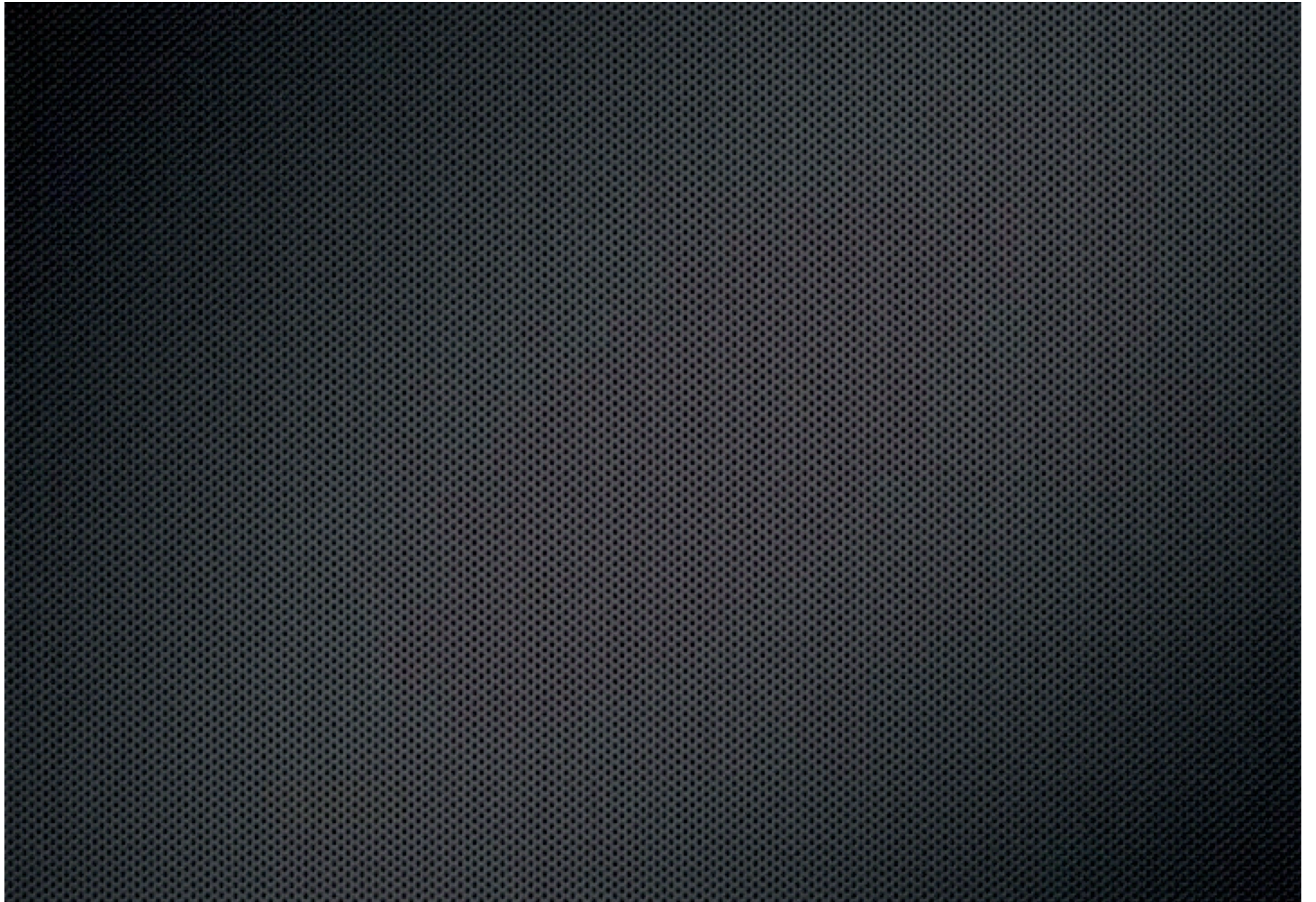
Users are shape.
Same color indicates
temporal "similarity"



Example



Blue dotted line is prediction with multivariate non linear predictor
Red line real data
Black line ARMA linear modelling



Summary

- We have described various privacy issues related to mobile devices and shown how they could be addressed.
- Challenges we discussed were
 - Systems related
 - Sensing related

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