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Spatio-Temporal Data Mining
&
Trajectory Data Mining

Reading

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- Di Wang, Tomio Miwa and Takayuki Morikawa (2020). Big Trajectory Data Mining: A Survey of Methods, Applications, and Services https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7472055/

- Yu Zheng (2015) Trajectory Data Mining: An Overview, ACM Transactions on Intelligent Systems and Technology, 6(3): 29

- Microsoft 2007. https://www.microsoft.com/en-us/research/project/trajectory-data-mining/

Outline

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- Geospatial/ Spatial-temporal data mining
  - Definitions, techniques & use cases
- Trajectory data mining

What is Spatial?

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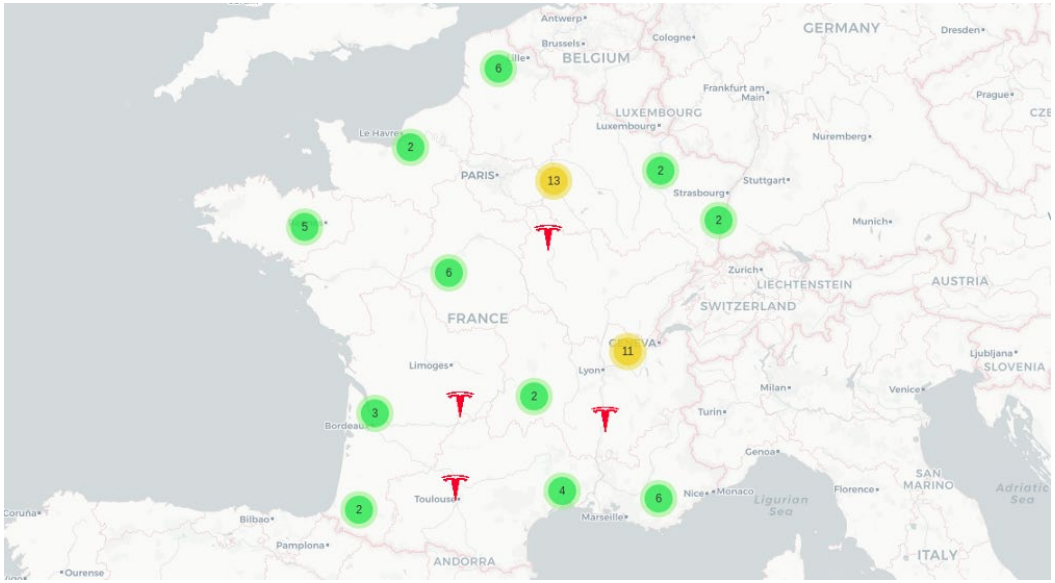
- Relating to or existing in space only
- Take a look at https://blog.locale.ai/



What is Spatio-Temporal?

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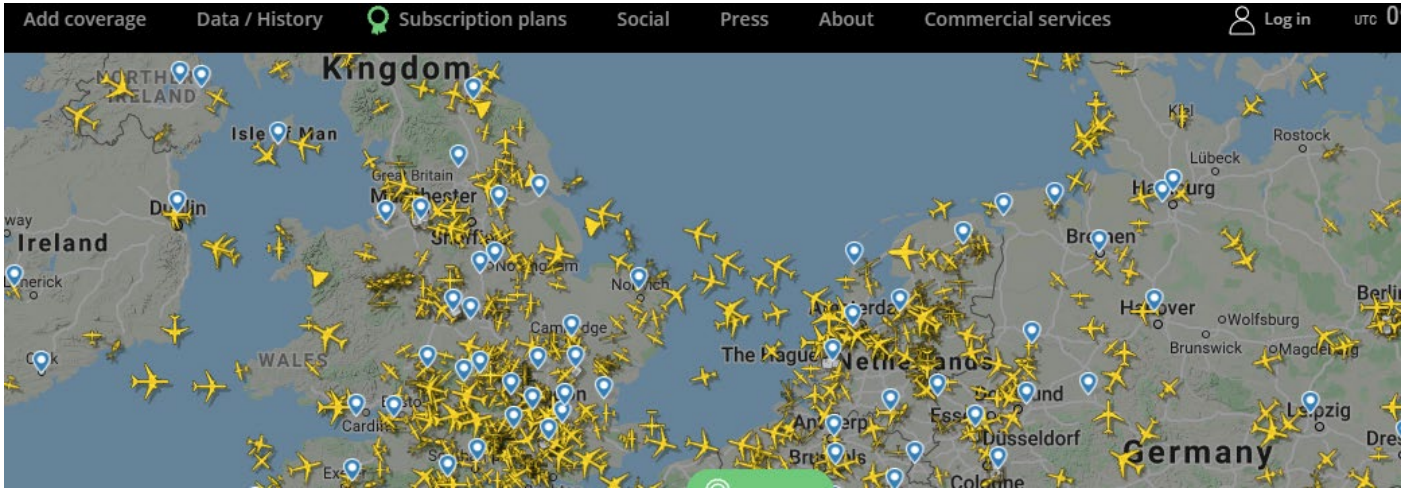
- Relating to *both space and time*
- Spatial (location) and temporal (time) attached
- Changes and movements over time

https://www.flightradar24.com/51.5,-0.12/6



Geo-Spatial data

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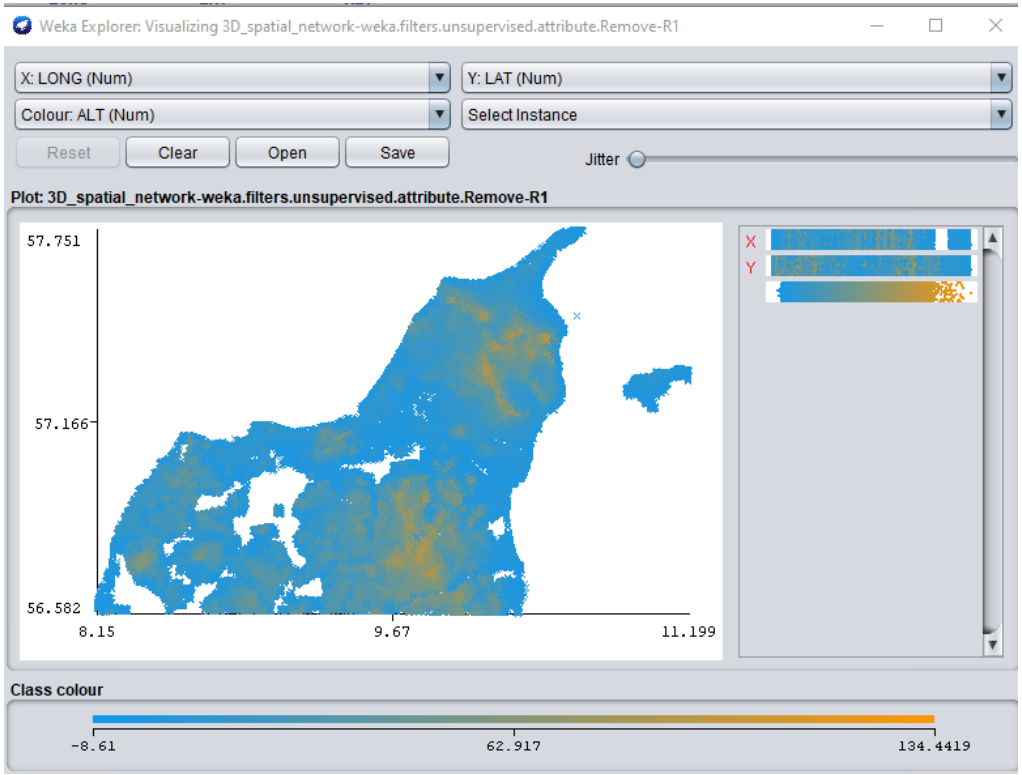
- An eg. of the data

VOLCANX020	NAME	LOCATION	LATITUDE	LONGITUDE
509	Baker	US-Washington	48.7767982	-121.8109970
511	GlacierPeak	US-Washington	48.1118011	-121.1110001
513	Rainier	US-Washington	46.8698006	-121.7509995
515	St.Helens	US-Washington	46.1997986	-122.1809998

Geospatial data



We have looked at it before!
3d_spatial.arff in Lab 4.1

Spatial-temporal Data

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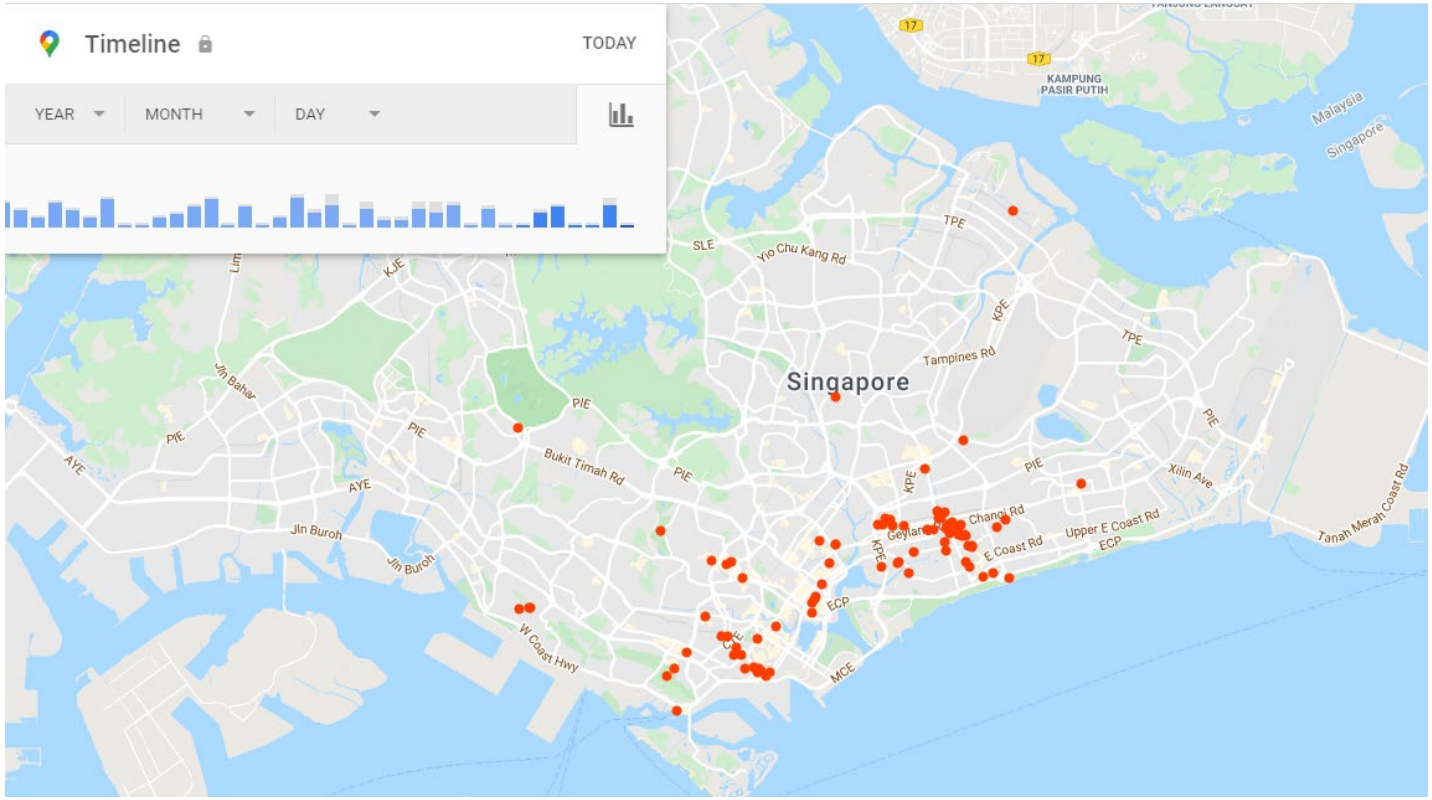
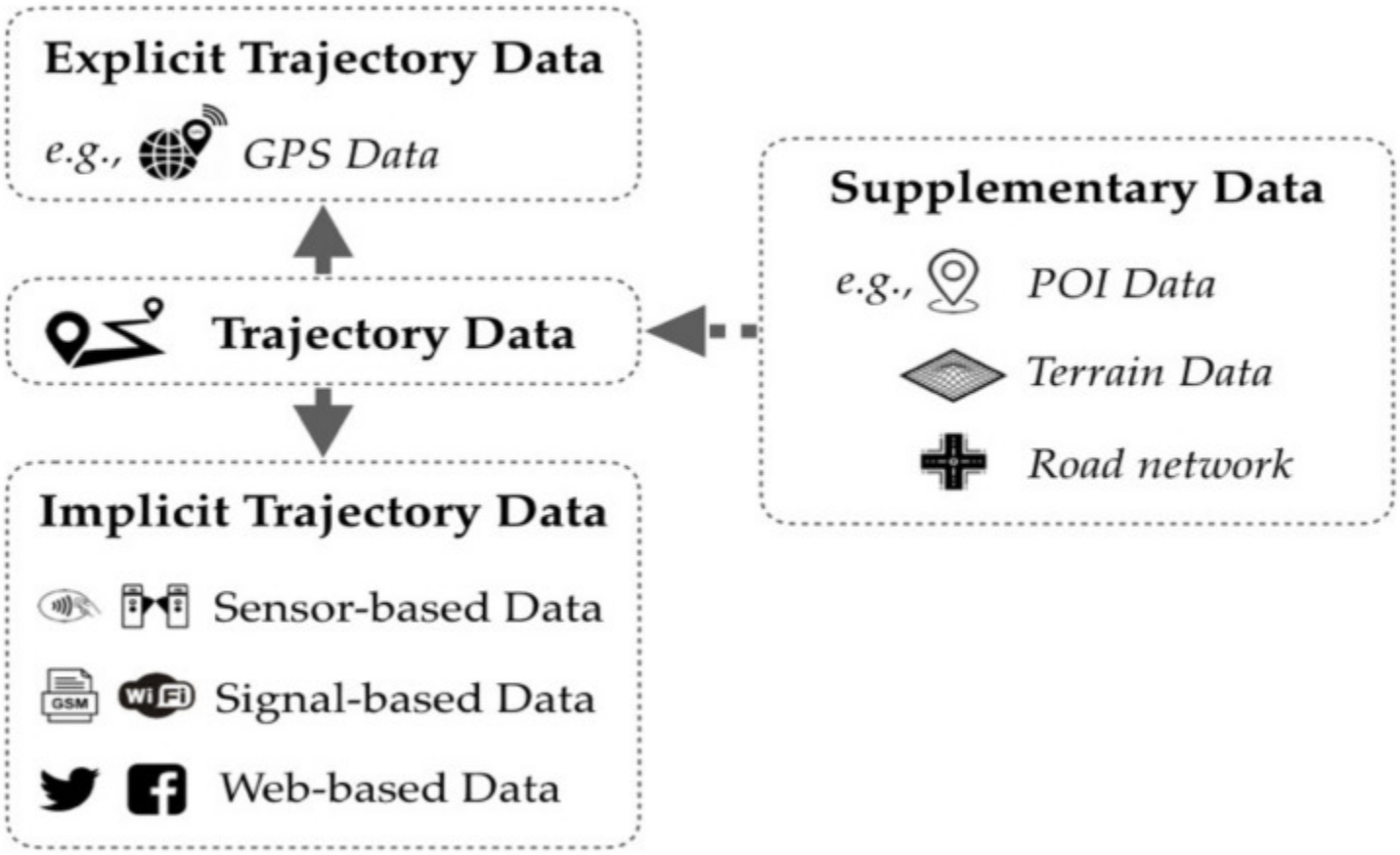
- Best example: google maps timeline



Data sources



Use of Spatio-Temporal Mining

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- Space and time are ubiquitous aspects of reality
- We are living in a space with time dimension…
- Thus basically all human (things) related data are spatio-temporal in nature
- Advances in automatic (semi-automatic) data generators (sensors, RFID tags, GPS receivers, mobiles etc) result in MASSIVE spatio-temporal data
- It is believed that more than 95% of business data are spatial or spatio-temporal

Trajectory Data Mining

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- Geospatial -> space only
- Geospatial temporal -> space and time
  - *Trajectory data mining* => + ***Movement***
  - "a trace generated by a moving object within a certain spatiotemporal context and is generally represented by a series of chronologically ordered points." (Zhang 2014)

Trajectory Examples

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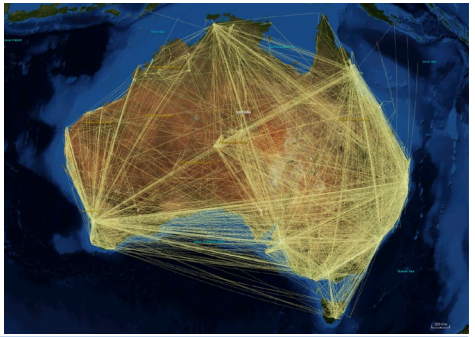
- Vehicle trajectories (cars, buses, trucks etc)
- Animal movements (birds, sharks etc)
- People movements (tourists, photo-takers, students etc)
- Mouse click movements (HCI, software design etc)

Can you name other egs?



Understanding Movements

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- Animal movements
  - Cows frequent visits to shades, but rare visits to grazing areas => indication of sickness?
  - Bees periodic visits to hive from flowers => useful for beekeeping
- Human movements
  - Frequent visits to fast food restaurants but rare visits to gyms/parks/beaches => indication of health risk
  - Frequent visits to Indian/Korean/Japanese restaurants => Asian?

Moving Objects

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Questions to ask: Where, when, why, what?

Raw GPS Trajectory

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dog_walk.txt

```
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```
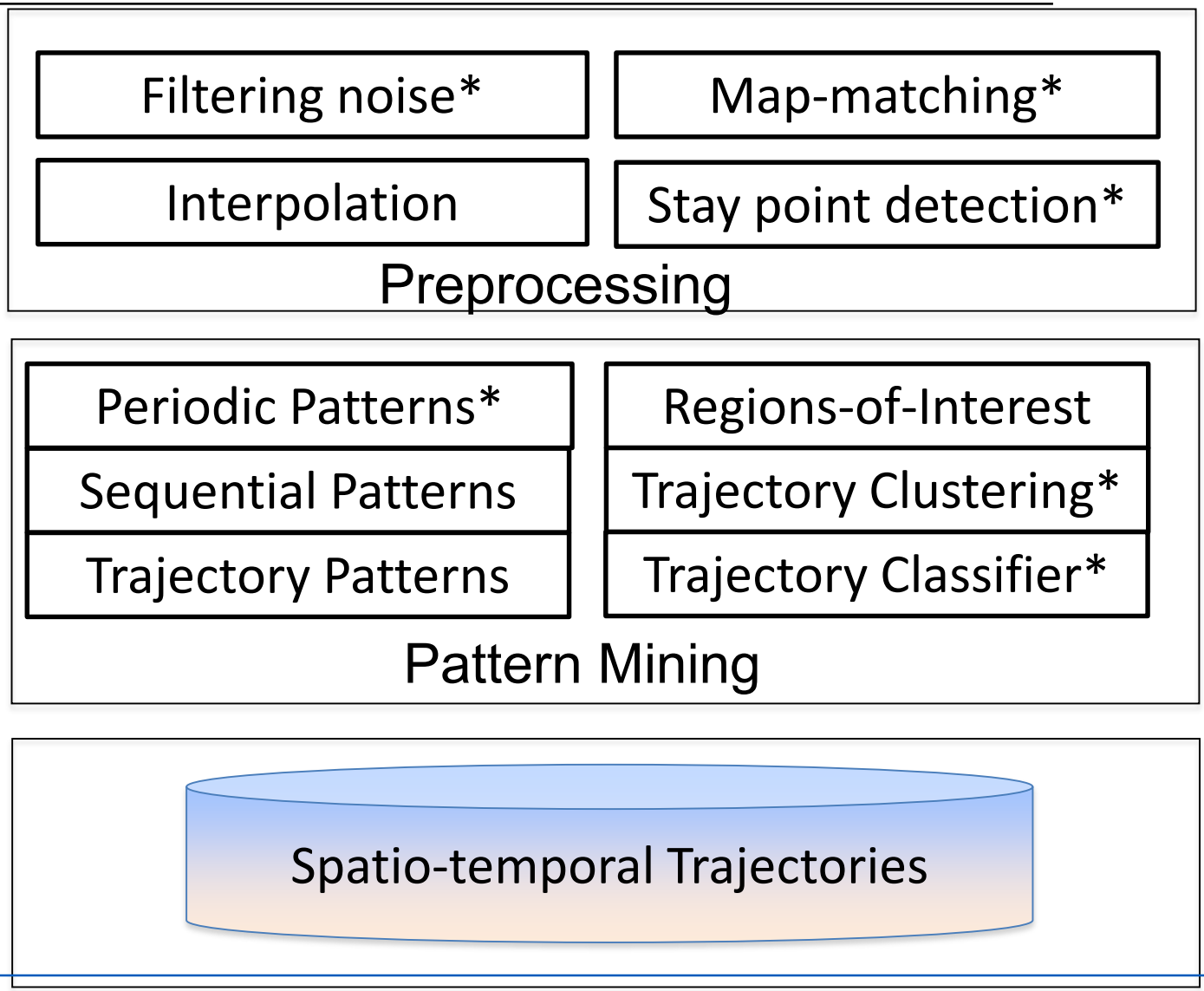

How the data looks like?

Overview of Trajectory Data Mining



TDM Noise Filtering

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- What?
  - The process of fitting raw trajectory recordings onto an underlying map structure before data mining
- How?
  - Very different from ‘structured data’
  - The idea is how do you combine location (map) with time data?
  - Noisy with GPS etc.

Issues with GPS Trajectories

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- Spatial uncertainties
- Errors and noisy
- Irregular
- Could be too densely recorded or too coarsely recorded

→ Preprocessing

Trajectory Simplification

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- Aim
  - Reduce the complexity of an input trajectory
  - Sensors capture as much movement details as possible by oversampling but still want to preserving the motion of the tracked entity
- Performance metrics
  - Reduce processing time
  - Reduce Error measure
- What error measure?
  - Criteria include perpendicular Euclidean distance and time synchronized Euclidean distance

Illustration of Error Measures

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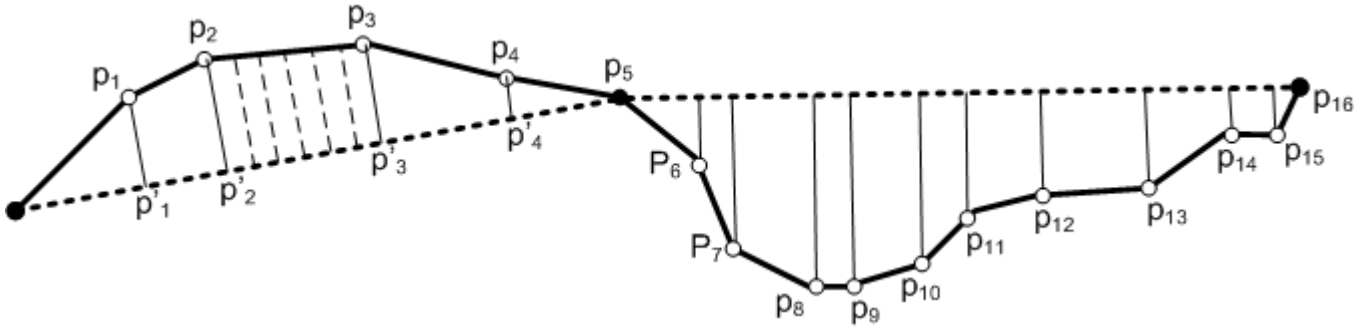
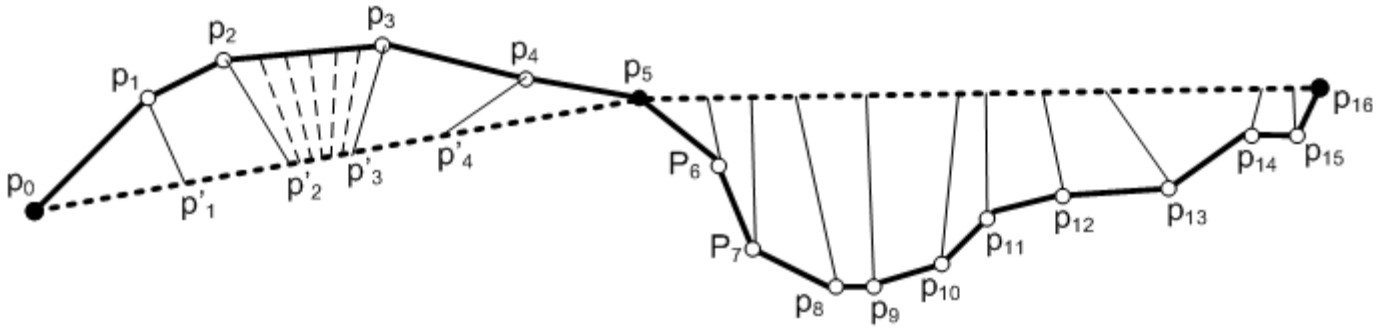
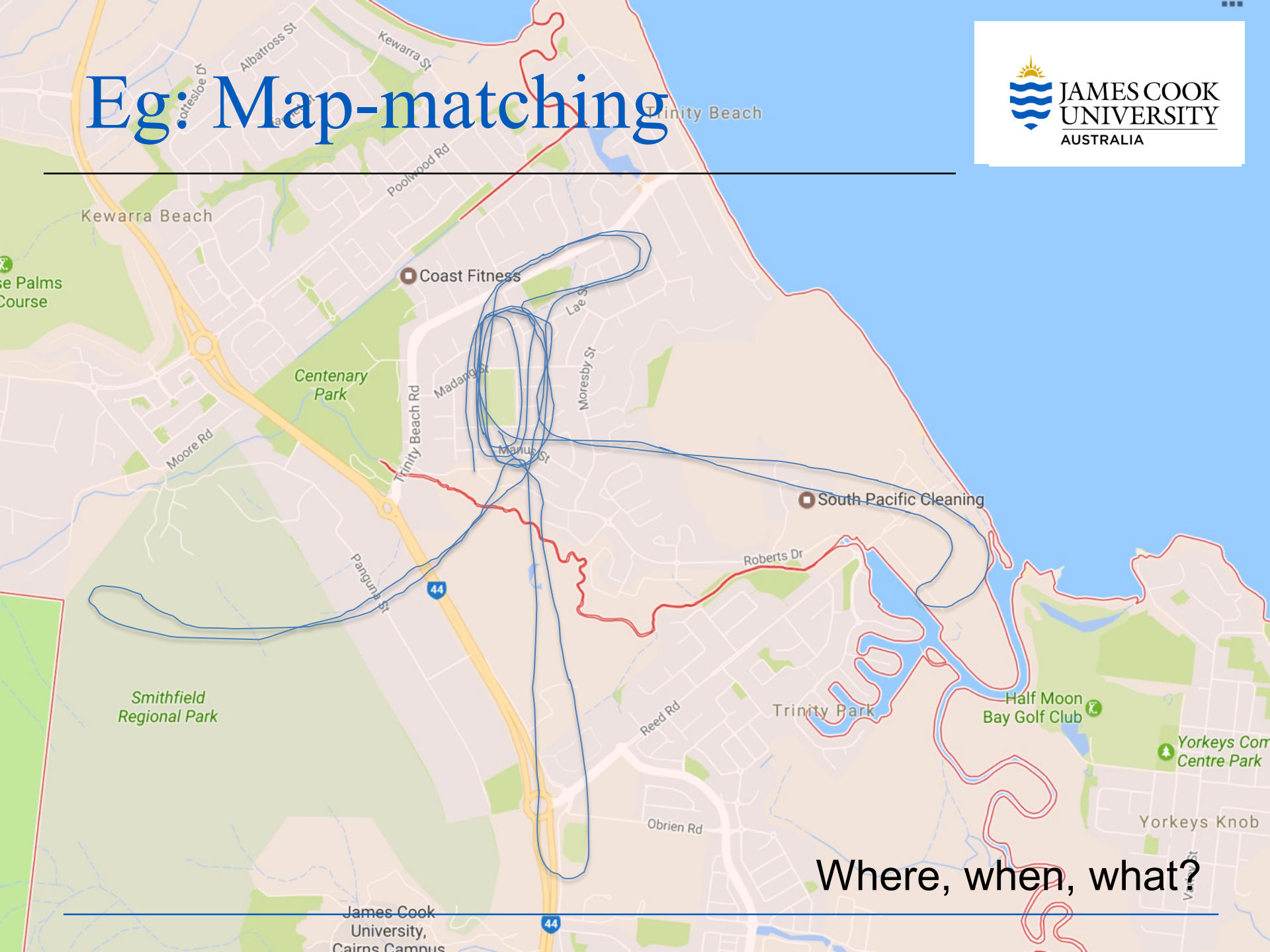
- Perpendicular Euclidean Distance



- Time Synchronized Euclidean Distance

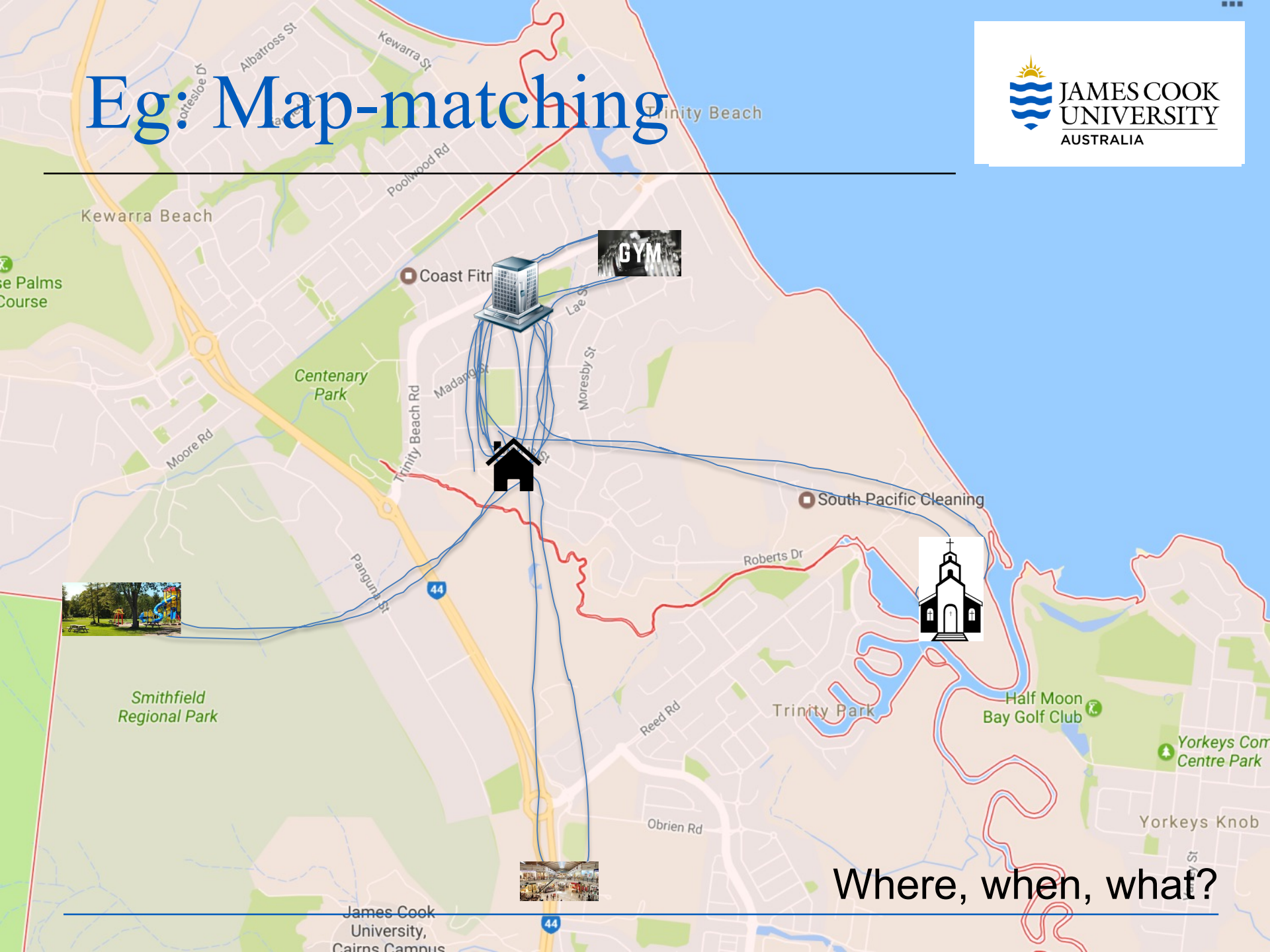


Eg: Map-matching



Where, when, what?

Eg: Map-matching



Where, when, what?

Eg: Map-matching

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Monday, Wednesday 12pm

Monday, Wednesday 1pm

9am 5pm

Sunday 11am

Sunday 12pm

Saturday 4pm

Saturday 5pm

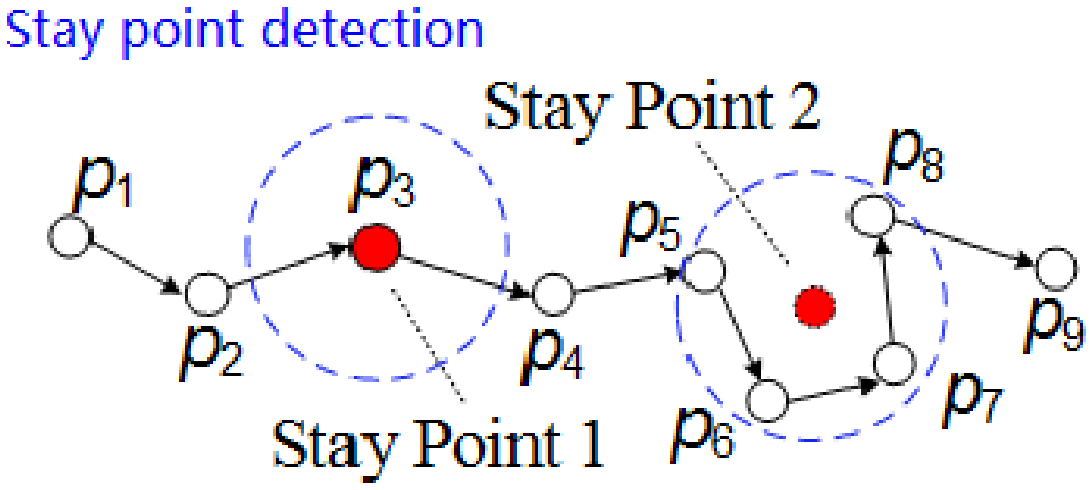
Thursday 8pm

Thursday 6pm

Where, when, what?

Stay Point Detection

- The identification of a location a moving object has stayed for a while within a certain distance threshold
- These stay points can indicate interesting insights for eg. at a restaurant/ shopping mall.
- Uses clustering technique studied earlier eg DBSCAN



Stop/Move Representation

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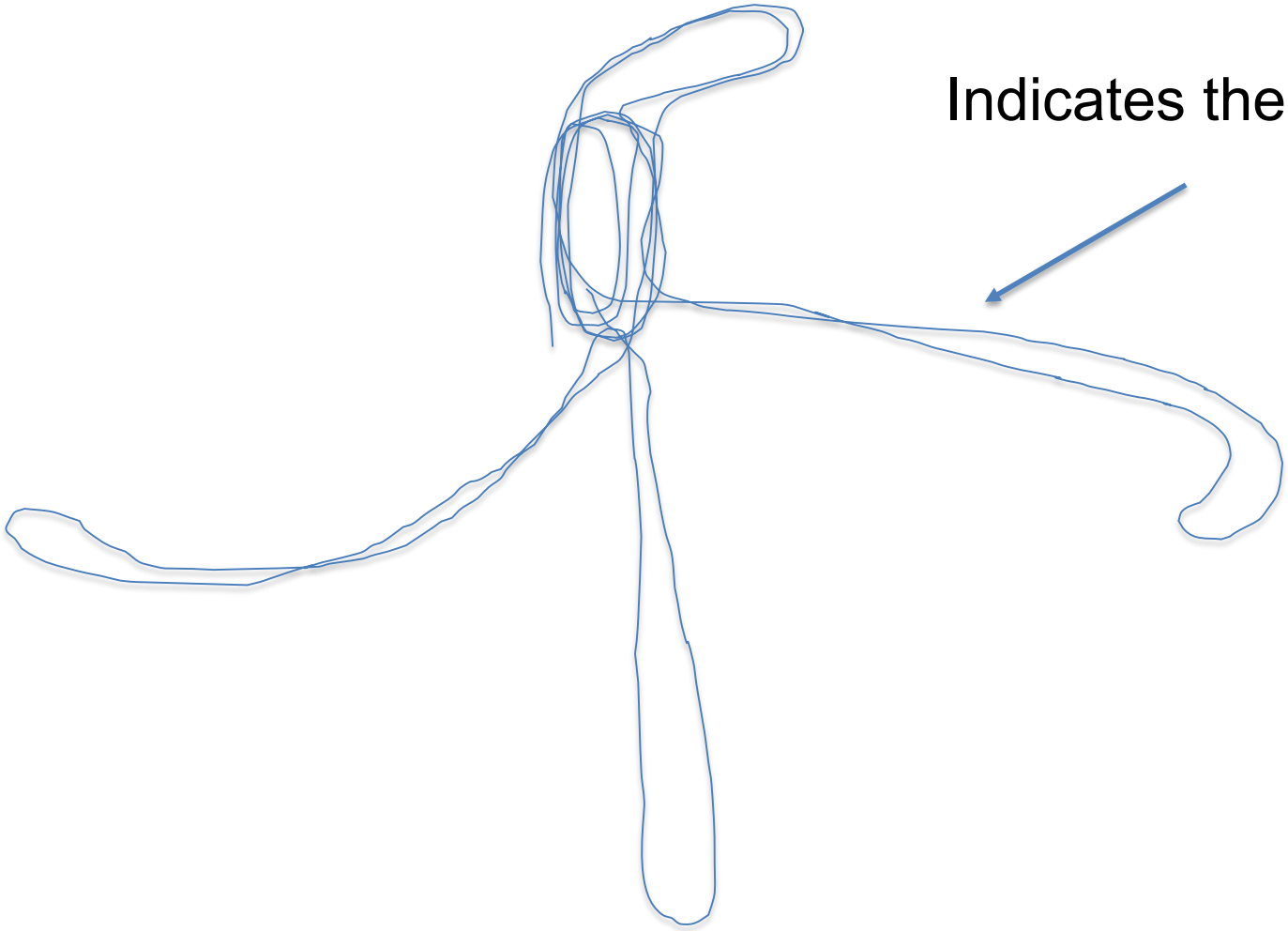

Stop/Move Representation

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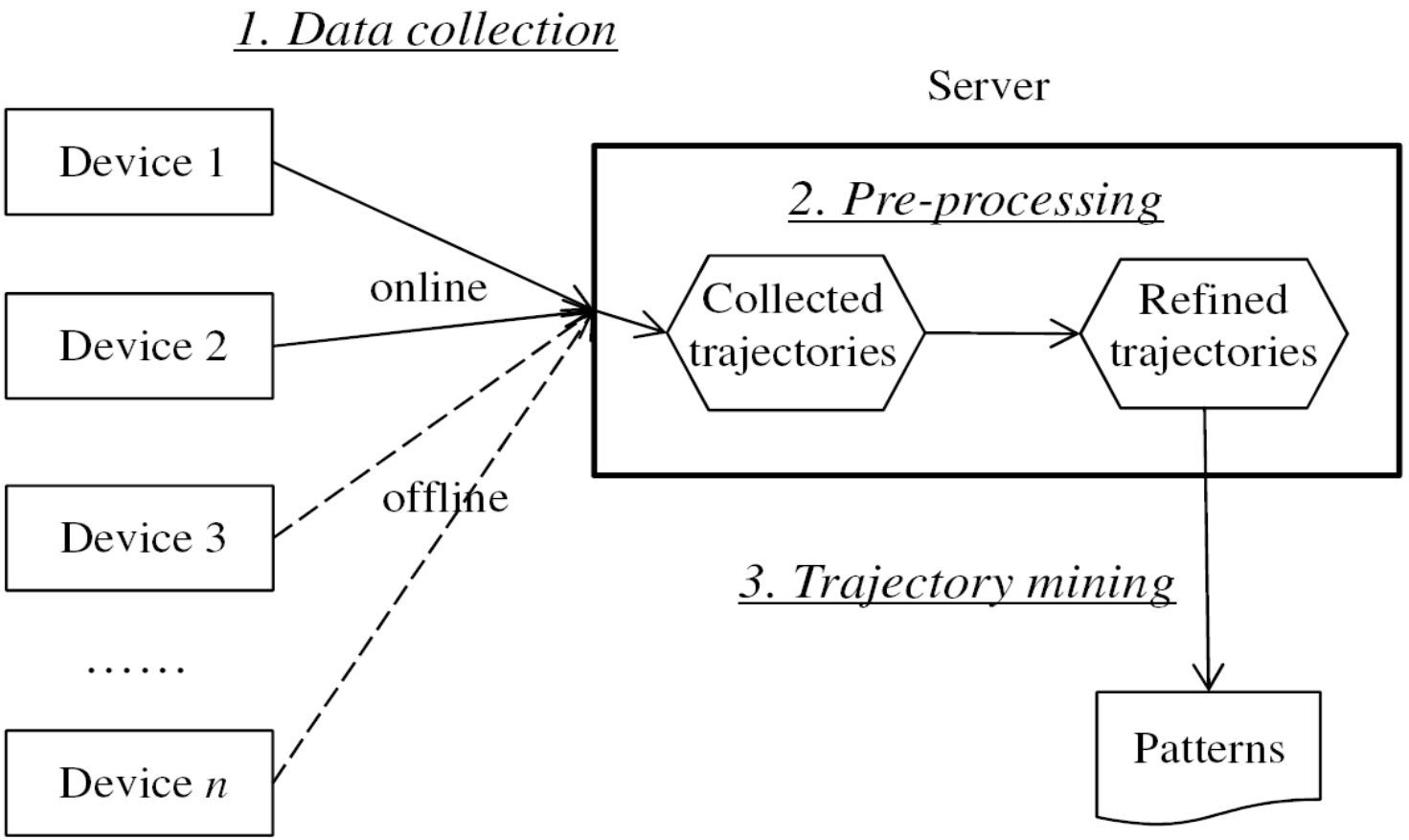
Trajectory Data Mining



Trajectory Data Mining

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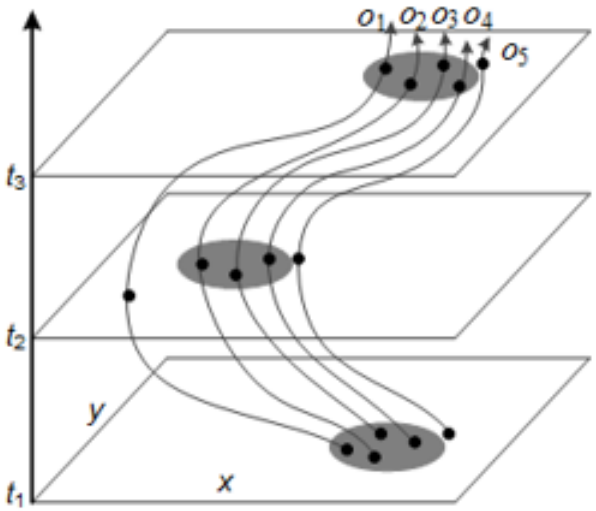
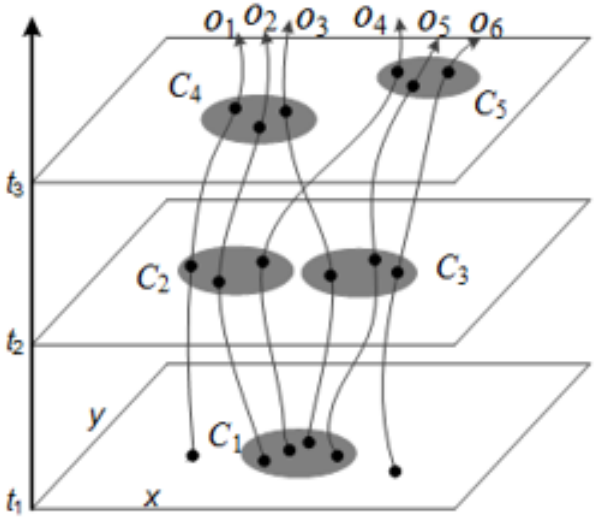
- Categories of patterns:
  - moving together patterns,
  - trajectory clustering,
  - periodic patterns and
  - frequent sequential patterns



A) Flock, convoy and swarm



B) Gathering

Trajectory Clustering

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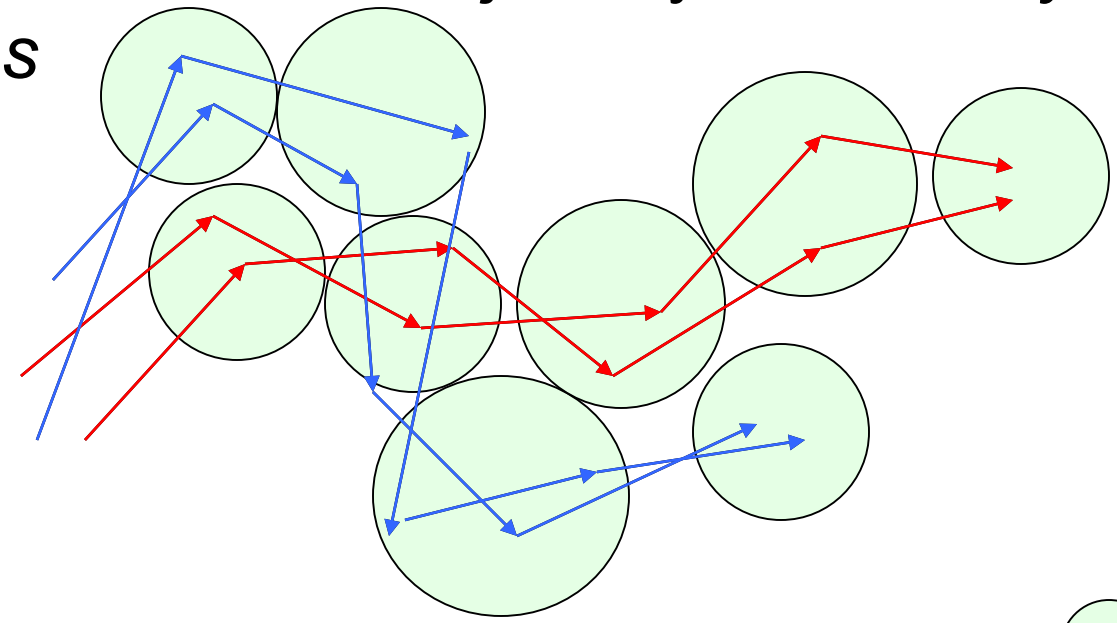
- Group similar trajectories geometric proximity in spatial/spatiotemporal space.
- Find a representative trajectory from *many trajectories*



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Trajectory Clustering

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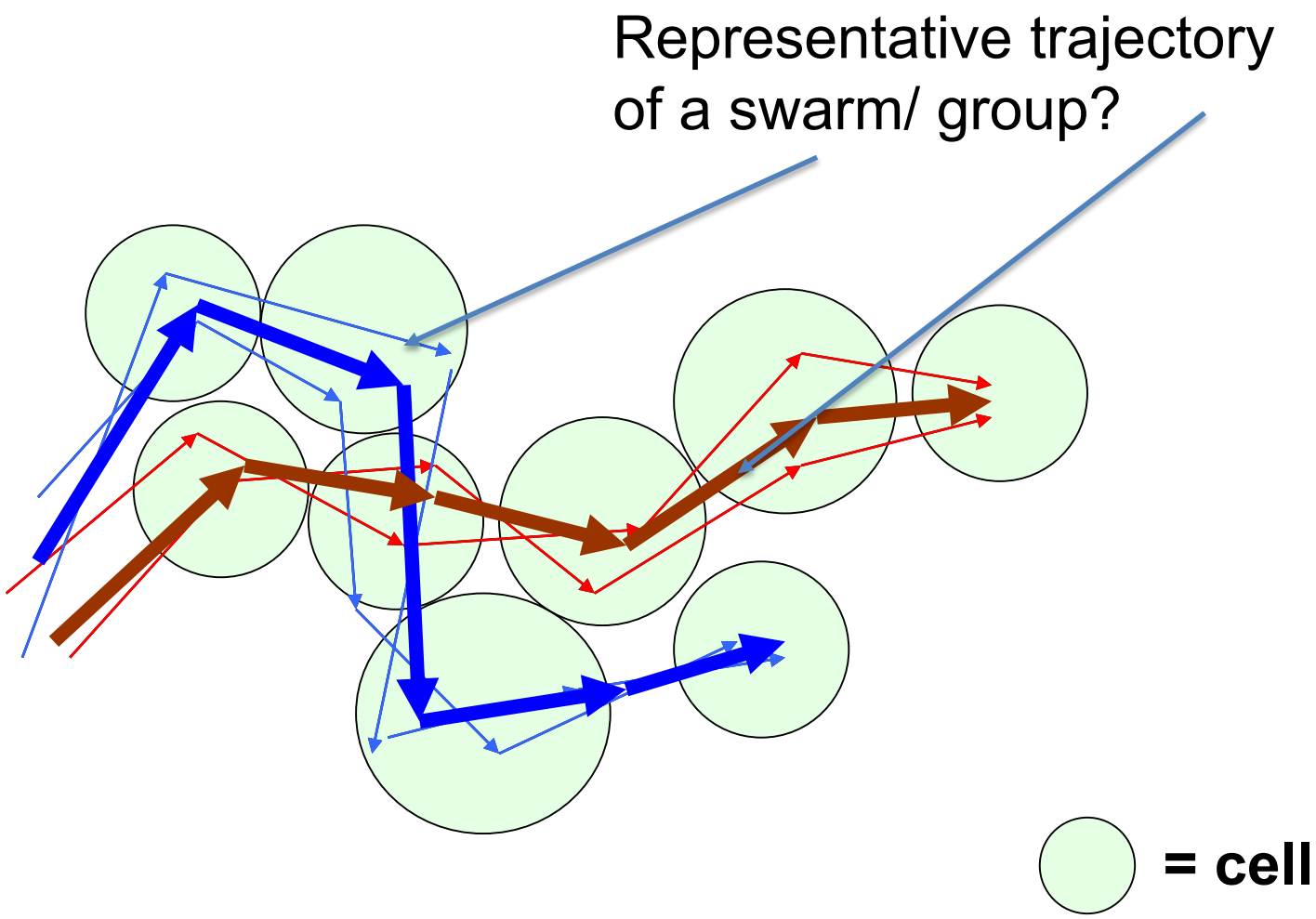

Trajectory Classification

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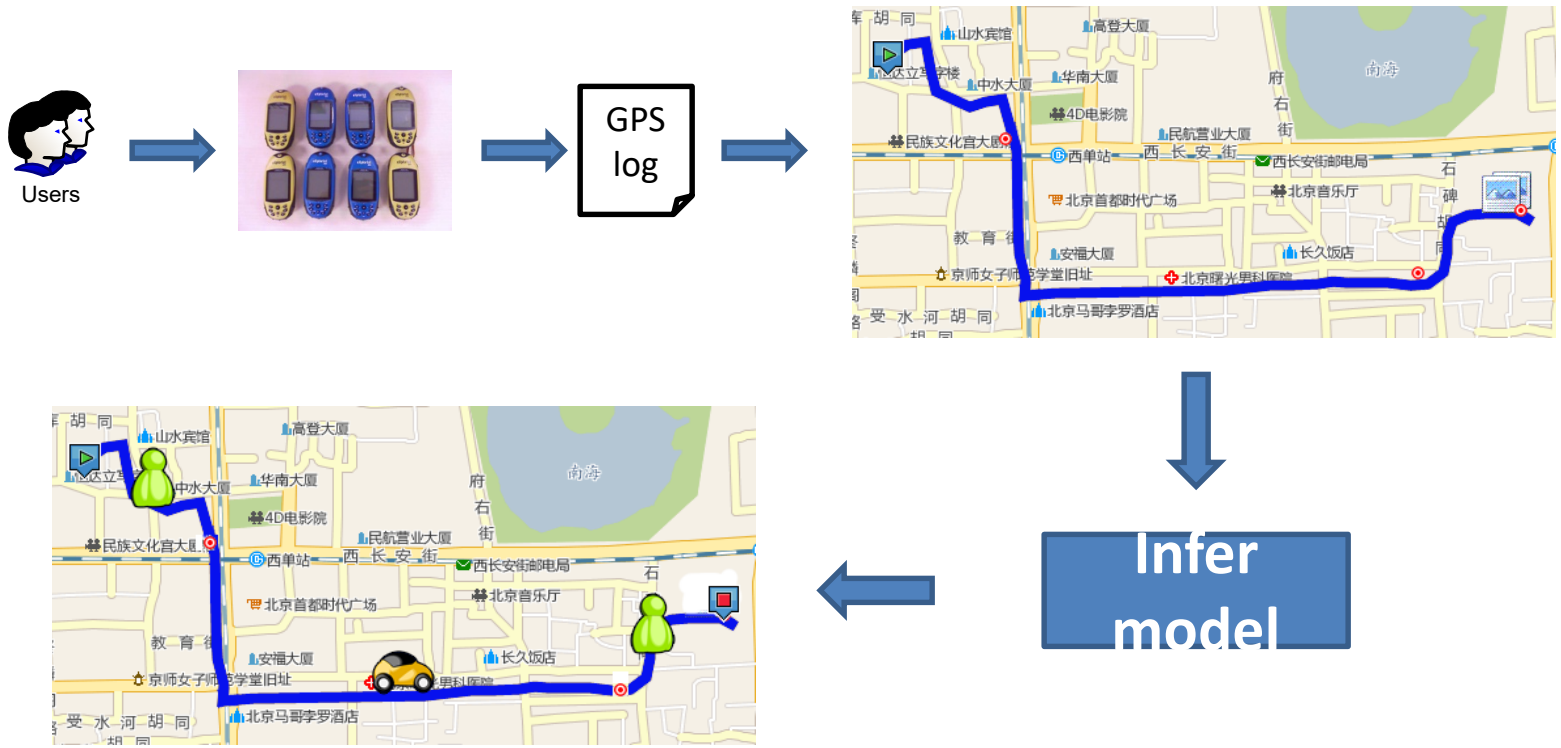
- With supervised learning, classify trajectories into activities like hiking/ dining or different modes (walking/ driving)



Trajectory Classification

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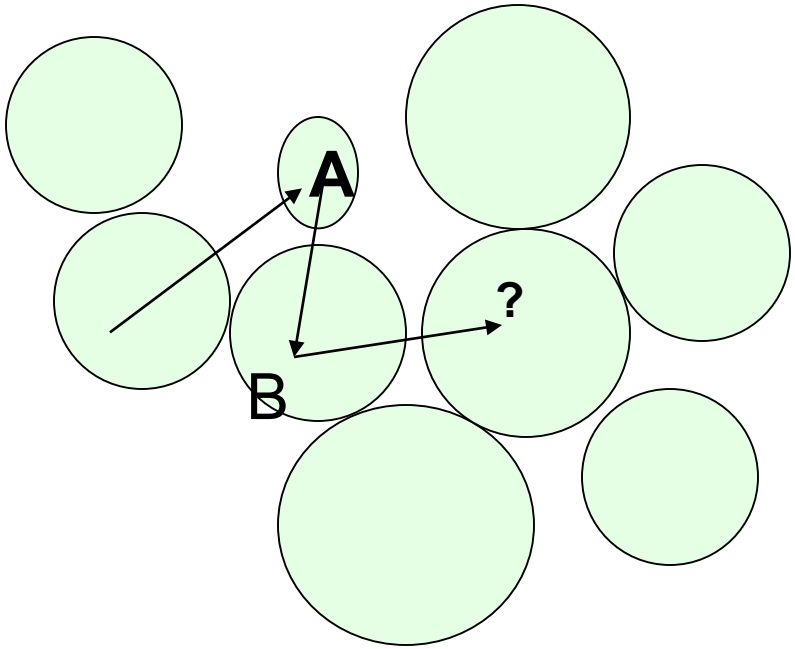
- Predict next move.
  - If it is driving activity, where is next place of interest after A / B?



Trajectory Classification

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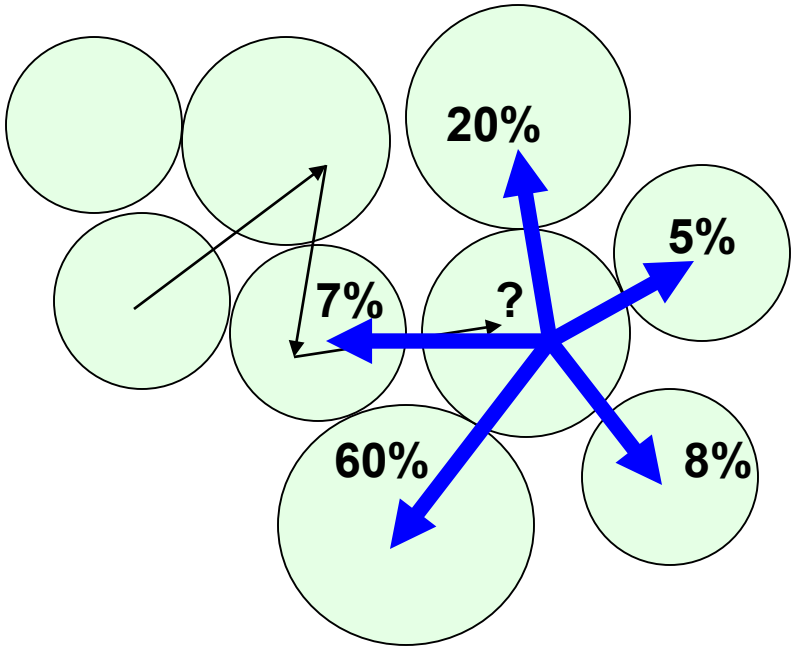
- Obtain next destination with probability.
  After drinks and eating, next?



Spatio-Temporal Periodic Pattern Mining

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- Periodic patterns are trajectories periodically executed by a moving object. For eg. regular movement patterns from office staff, which are rather similar each working day.
- There are 2 main approaches:
  - Fixed Period Approach
  - Reference Spot Approach

Spatio-Temporal PPM

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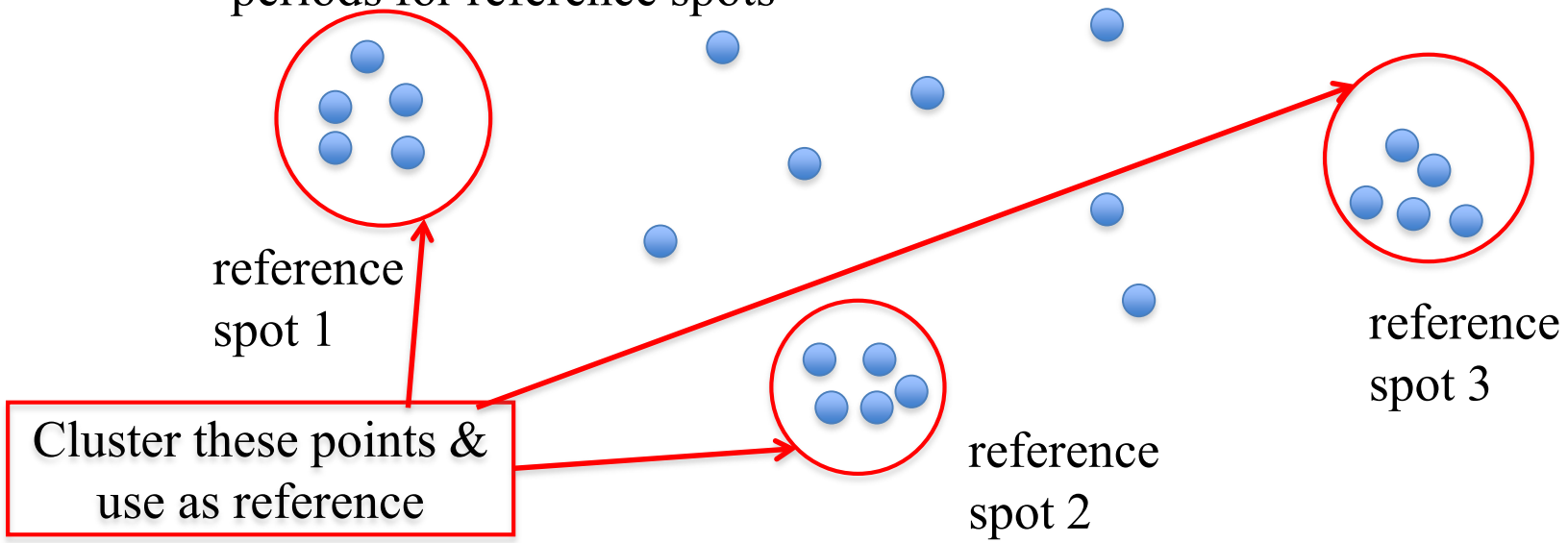
- Fixed (Time) Period Approach
  - To segment the long trajectory into a set of smaller (shorter) sub-trajectories based on a given fixed time period
- Reference Spot Approach
  - Find reference spots using clustering algorithms and then find associated periods for reference spots



Periodic Pattern Mining

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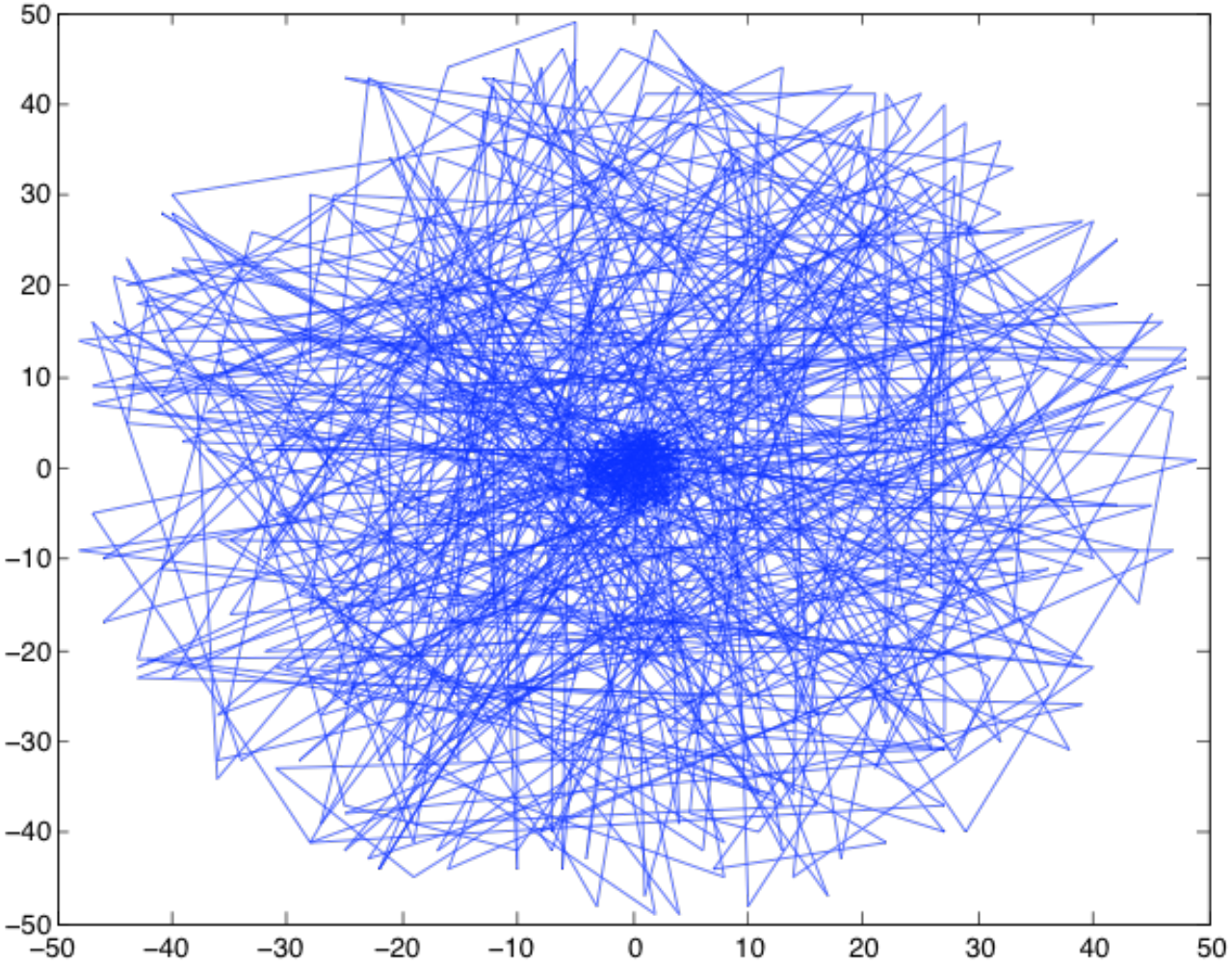

Not easy! Eg. movements of a bee (or bees)

Periodic Pattern Mining

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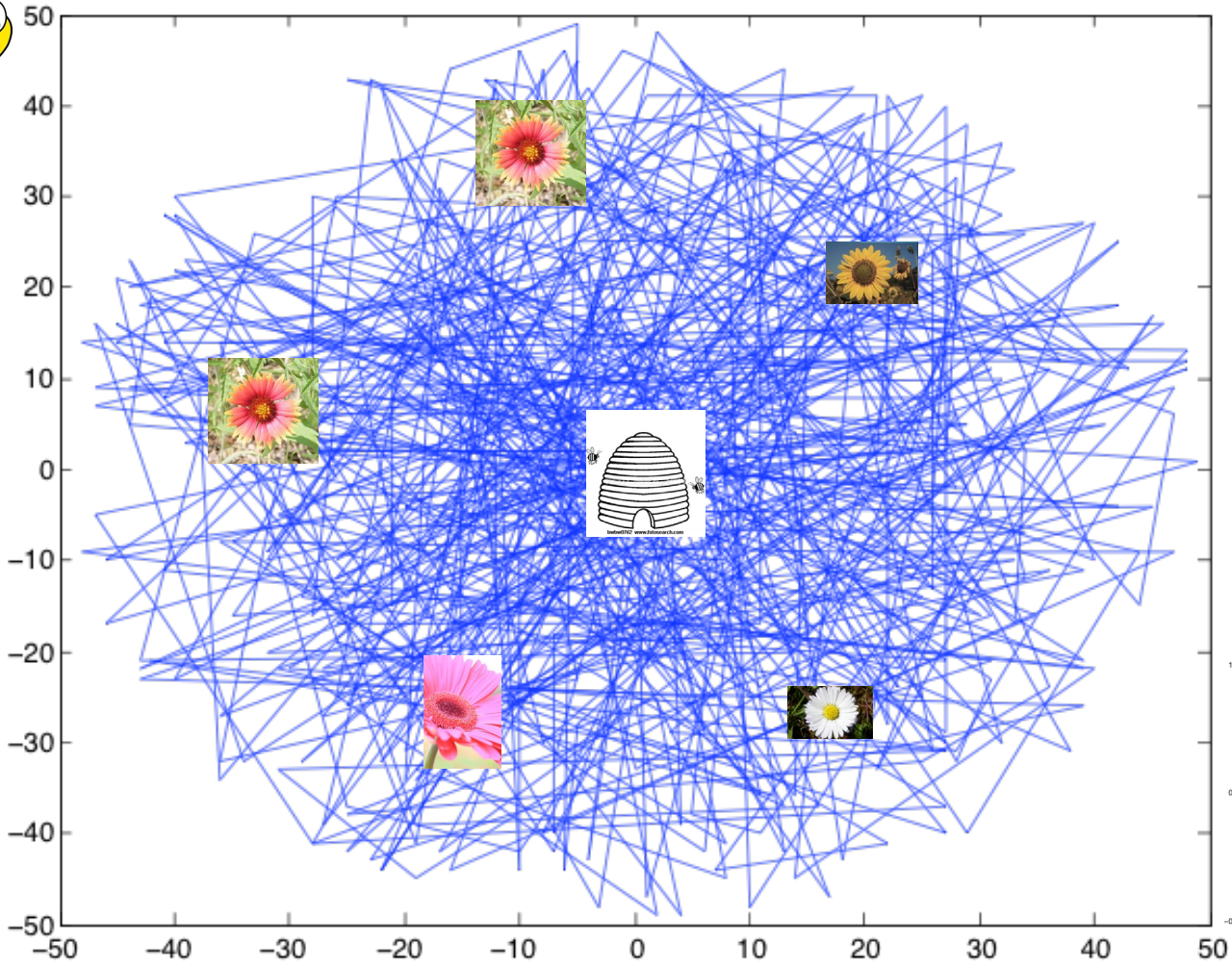

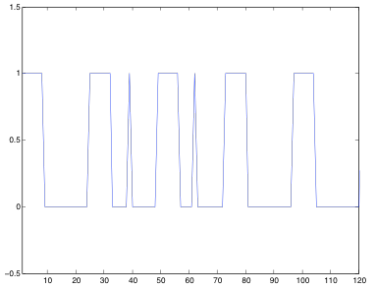

Trajectory Pattern Mining

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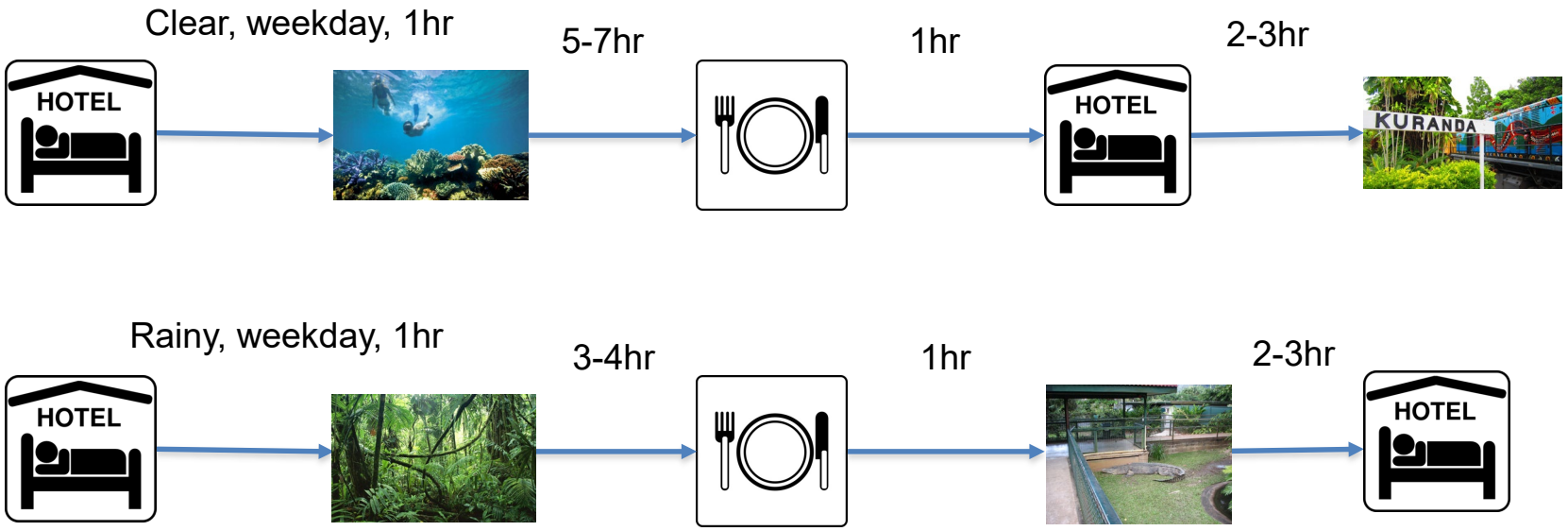
- TPM considers spatio-temporal information
- In addition, add on aspatial *semantic information* to produce richer patterns



Open Challenges

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- Incorporate semantics – semantic trajectory data mining by incorporating aspatial information
- Techniques largely the same:
  - classification is still in its infancy
  - Association mining (more used)
  - Lots of pre-processing with uncertainties and noise handling