



Understanding Individual-Space Relationships to Inform and Enhance Location-Based Applications

Licia Amichi (Ph.D)

Gautam Malviya Thakur (Ph.D)

Carter Christopher (Ph.D)

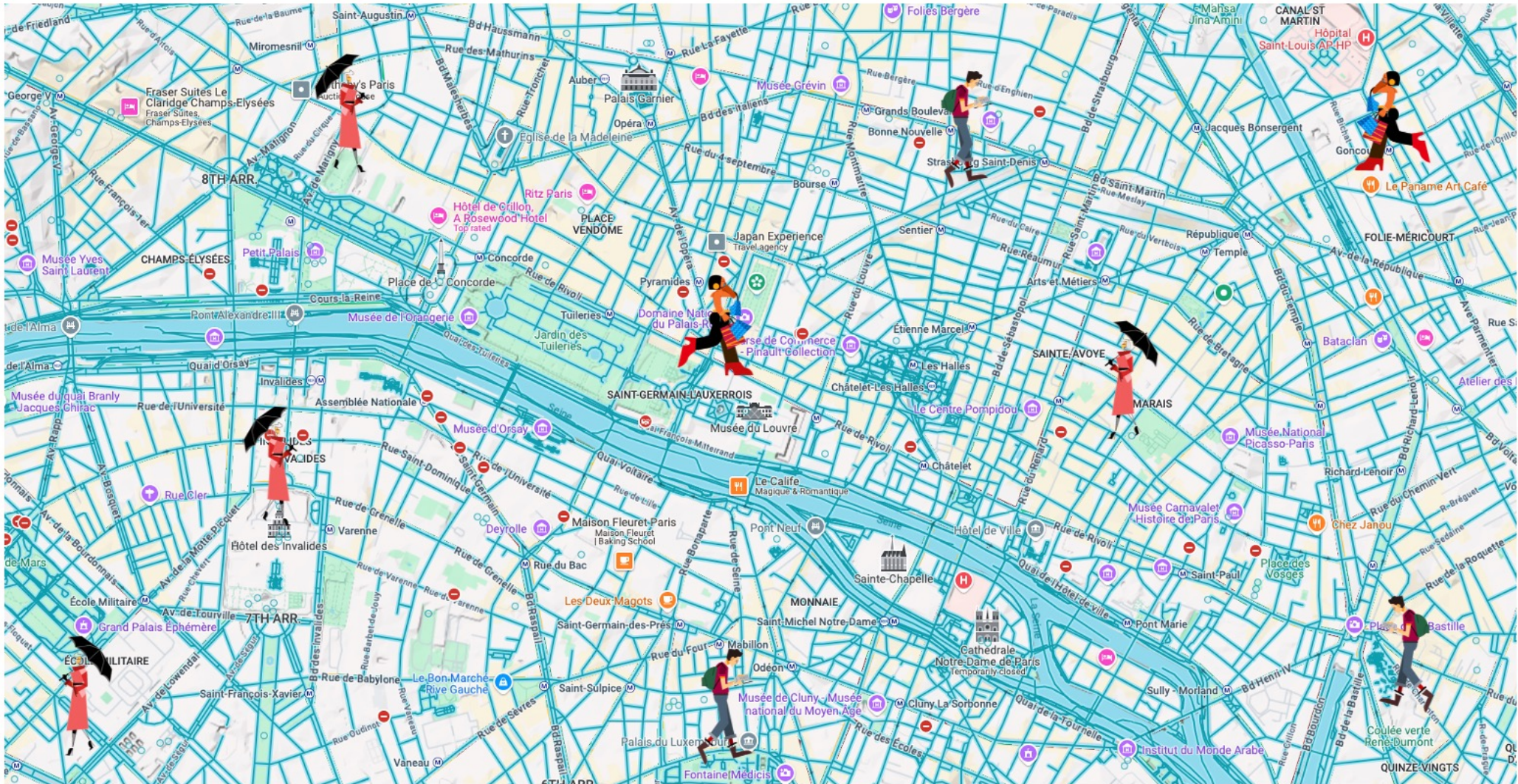


U.S. DEPARTMENT OF
ENERGY

ORNL IS MANAGED BY UT-BATTELLE LLC
FOR THE US DEPARTMENT OF ENERGY

Contact: amichil@ornl.gov

Human-Space Relationships

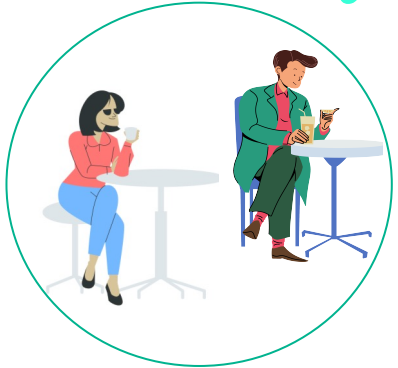


Human-Space Relationships

Work



Discovery



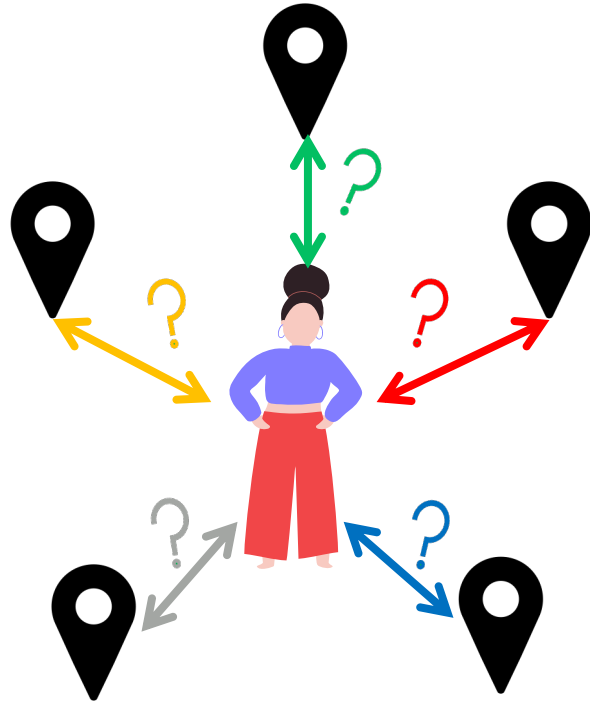
Regular



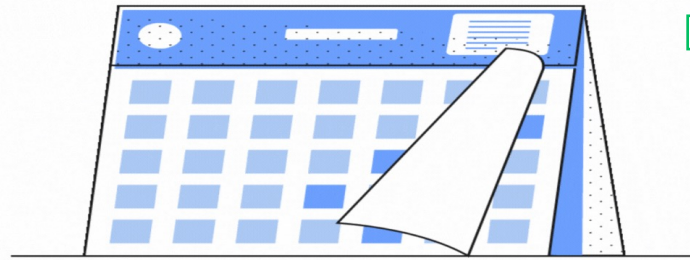
Casual



How to capture Individuals Perceptions of Space?

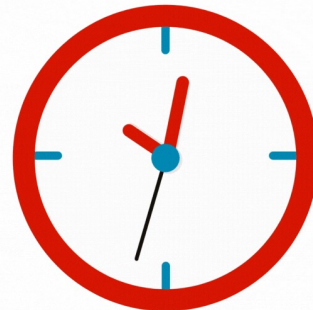


How often?



Frequency

For how long?



Dwell

Mobility and POI Data



Mobility Data

Dataset	#Users	#Records	Time Period	Coverage
Singapore	144,795	264,246,258	December 1 st , 2022 – January 31 st , 2023	Singapore
Beijing (Geolife)	182	17,621	April 2007– August 2012	Beijing mostly

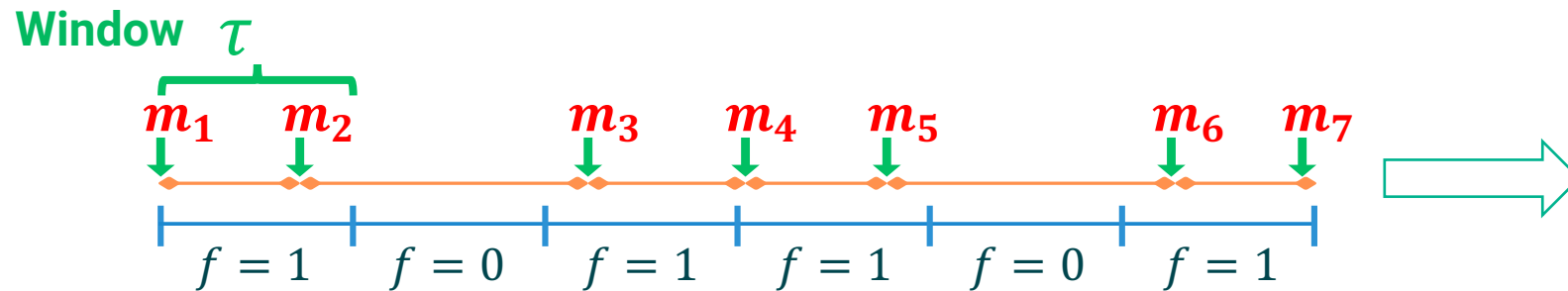
Poi PlanetSense Data

Dataset	#Pols
Singapore	238,690
Beijing	1,677,835

Mobility Data: *Temporal Completeness*

Mobility trace

$$\mathcal{D}_u = \{(\underbrace{m_1}_{(lat_1, lon_1)}, t_1), (m_2, t_2), \dots, (m_n, t_n)\}$$



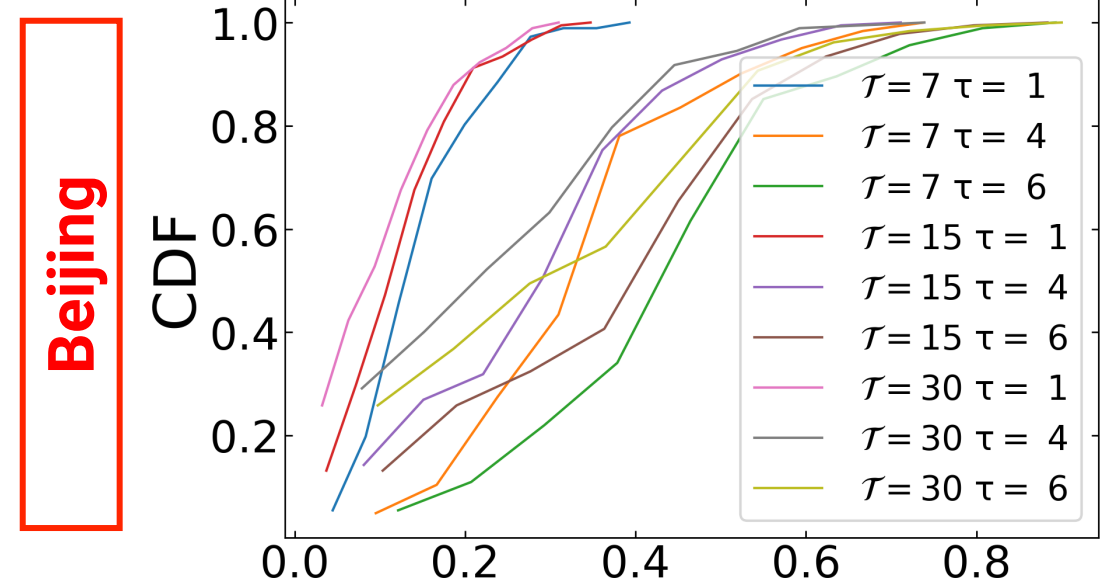
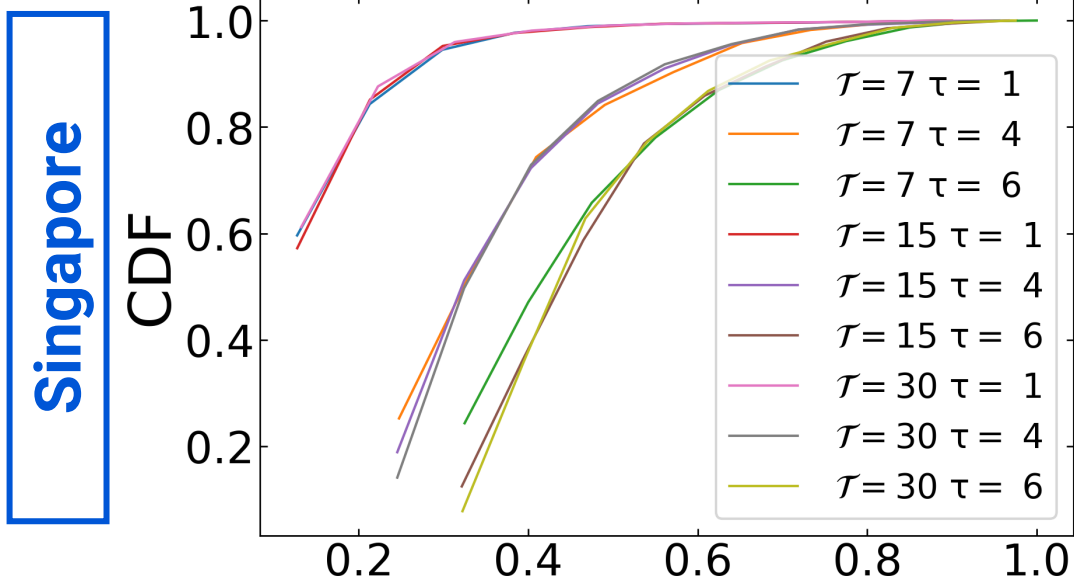
$$\mu_T(\mathcal{D}_u) = \frac{\tau}{P} \sum_{i=0}^{\frac{P}{\tau}} f_\tau(i)$$

Observation Period = 24 hours

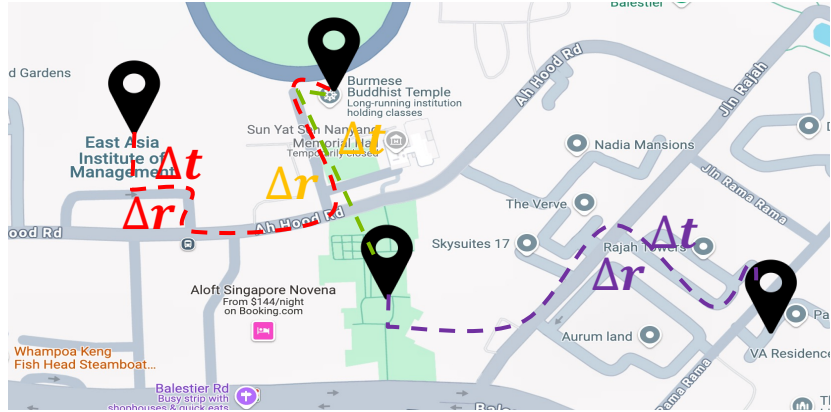
Mobility Data: *Temporal Completeness*

Window: $\tau \in \{1,4,6\}$

Data period: $\mathcal{T} \in \{7,15,30\}$



Mobility Data: Spatial Completeness

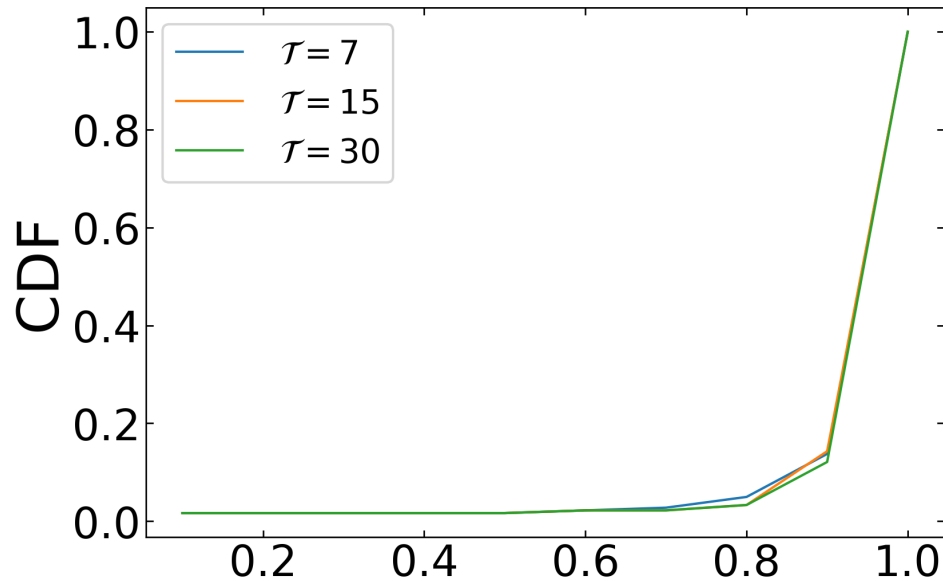


$$\mu_S(\mathcal{D}_u) = \frac{1}{N} \sum_{i=1}^N g(i)$$

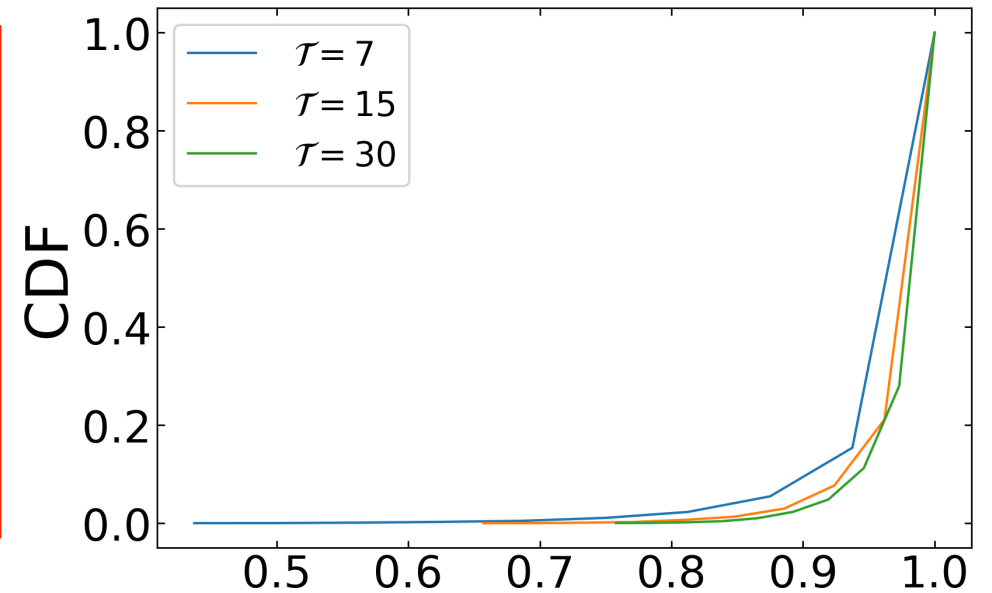
↑
Number of records

$g = 1$ if $\frac{\Delta r}{\Delta t} < \text{MAXSPEED}$
 $g = 0$ else

Singapore



Beijing



Mobility Data: *Spatial Completeness*

Maximize

↑ *#Users*

↑ *#Days*

↑ u_T

↑ u_S

Singapore

$\mathcal{T} = 30 \text{ days}$

$\tau = 1 \text{ hour}$

Beijing

$\mathcal{T} = 15 \text{ days}$

$\tau = 1 \text{ hour}$



Conflate with PoI data

Visitation classification

Enriched mobility trace

$$\mathcal{D}_u = \{(lat_1, lon_1, t_1, Pol_1), (lat_2, lon_2, t_2, Pol_2), \dots, (lat_n, lon_n, t_n, Pol_n)\}$$

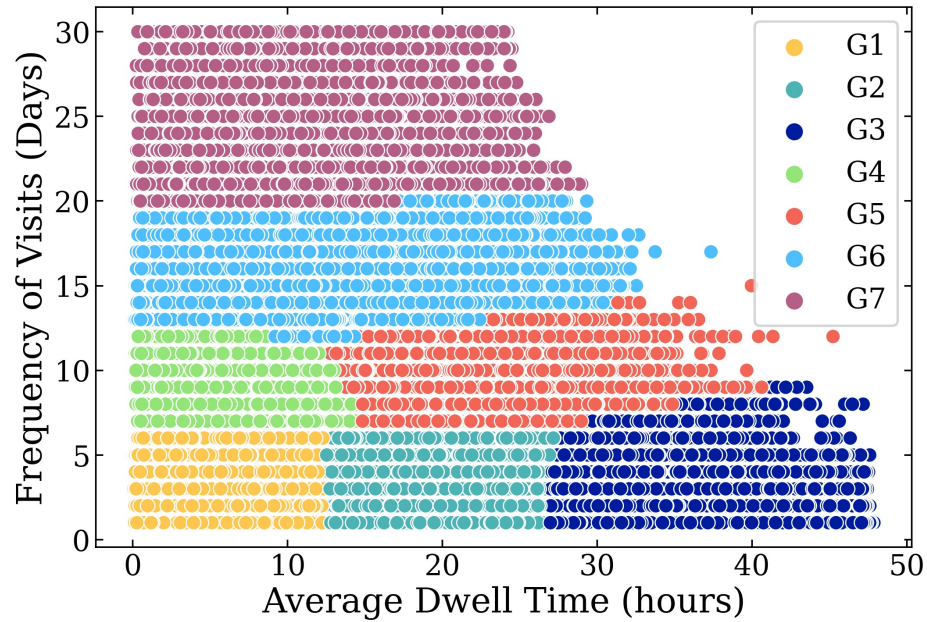
Pols	Frequency of visits	Dwell time
Pol_1	5 days	45 min
Pol_2	35 days	10 min
\vdots	\vdots	\vdots
Pol_n	1 days	5 min



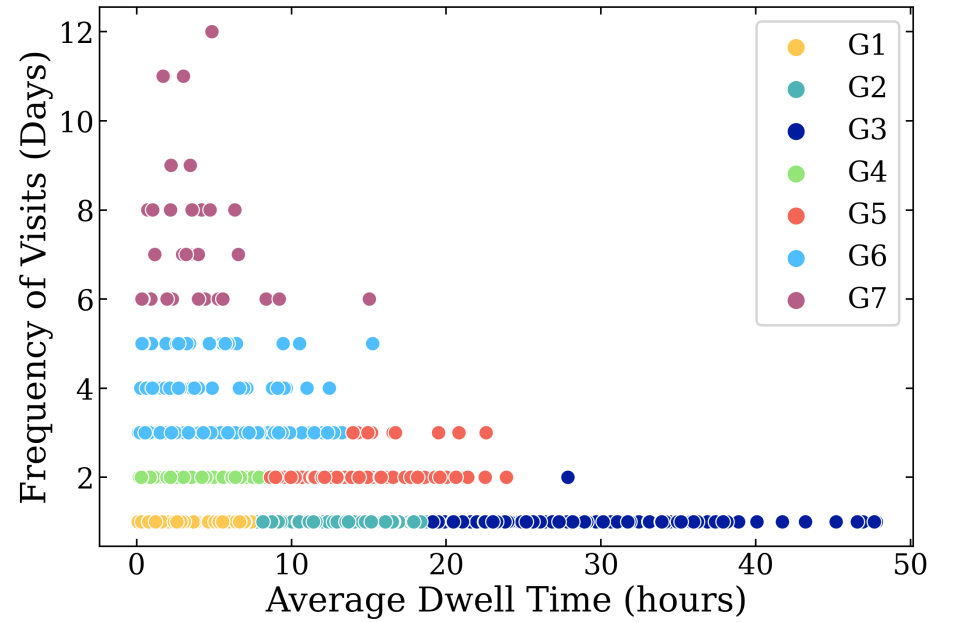
For each individual u and for each Pol

Visitation classification: Clustering

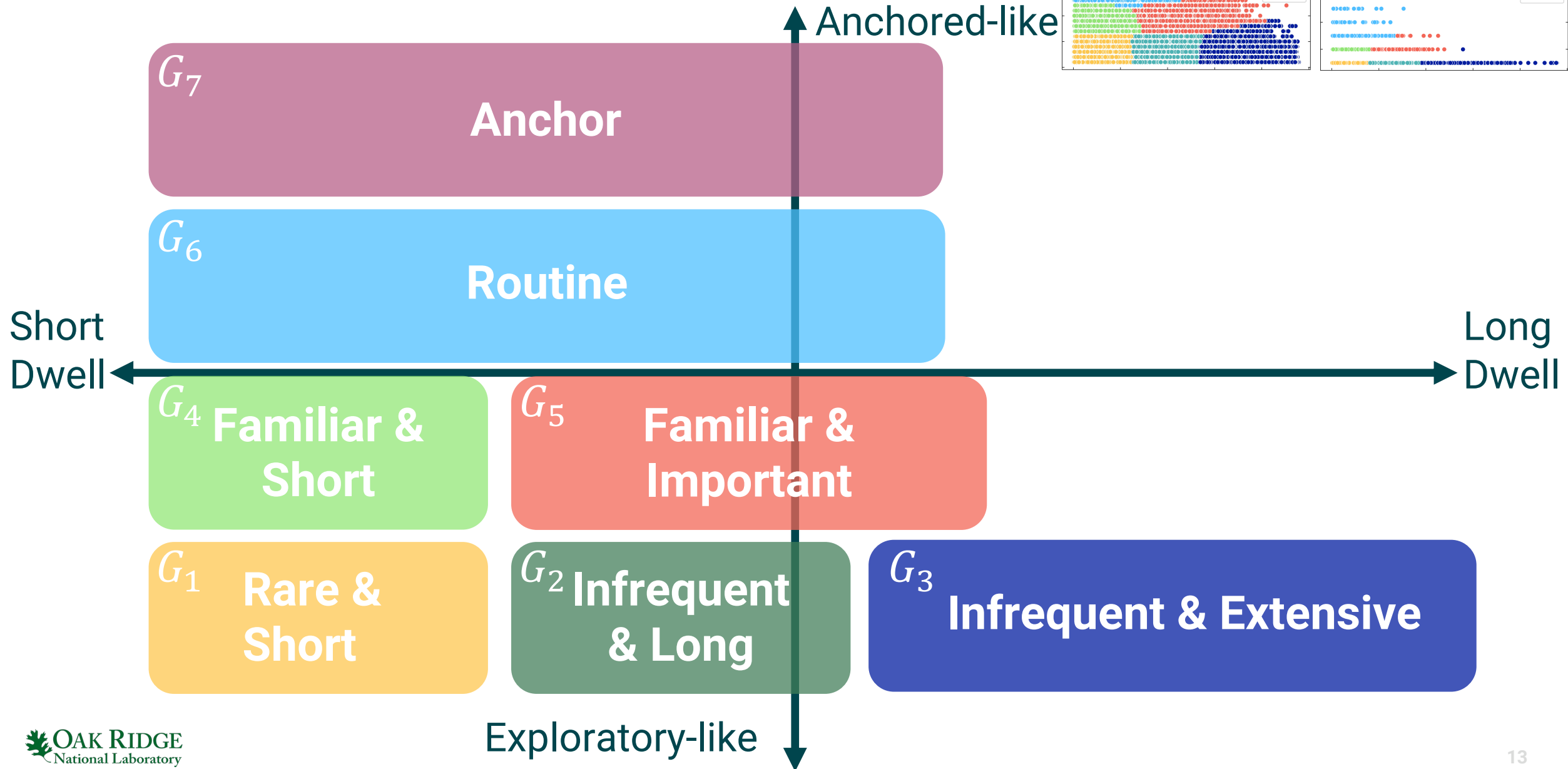
Singapore



Beijing

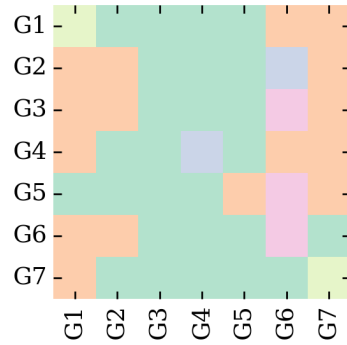


Visitation classification: Clustering

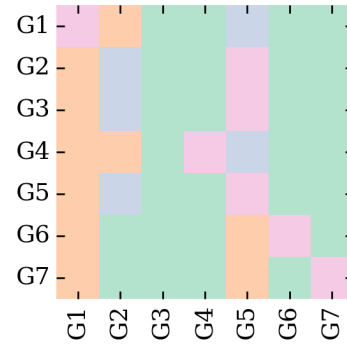


Visitation classification: Visitation Patterns

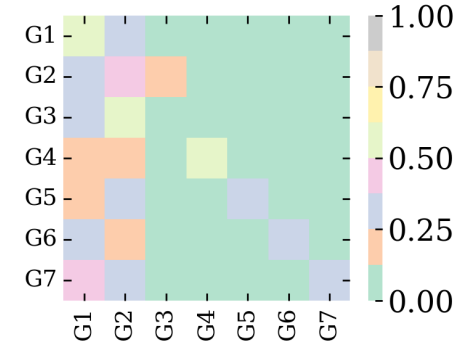
Singapore



- Routine Stability
- Occasional Exploration

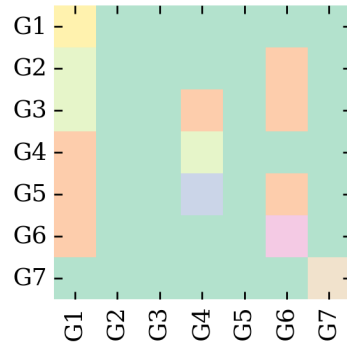


- Exploration
- Routine-Driven Stability

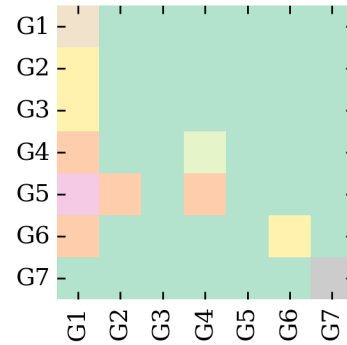


- High Exploration
- Dynamic Mobility

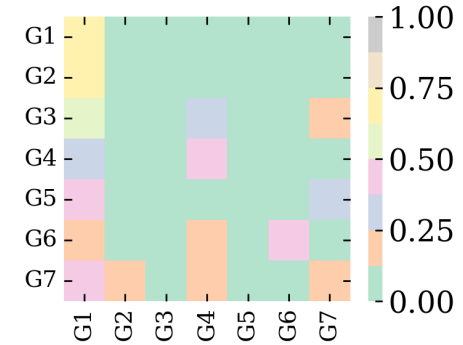
Beijing



- Brief Exploration
- Routine Anchors



- Routine-Breaking
- Anchored Consistency



- Predominantly Exploratory
- Low Routine

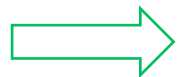
Visitation classification: Visitation Patterns

Singapore

- Dynamic frequency
- Longer novelty-seeking

Beijing

- Strong Routine



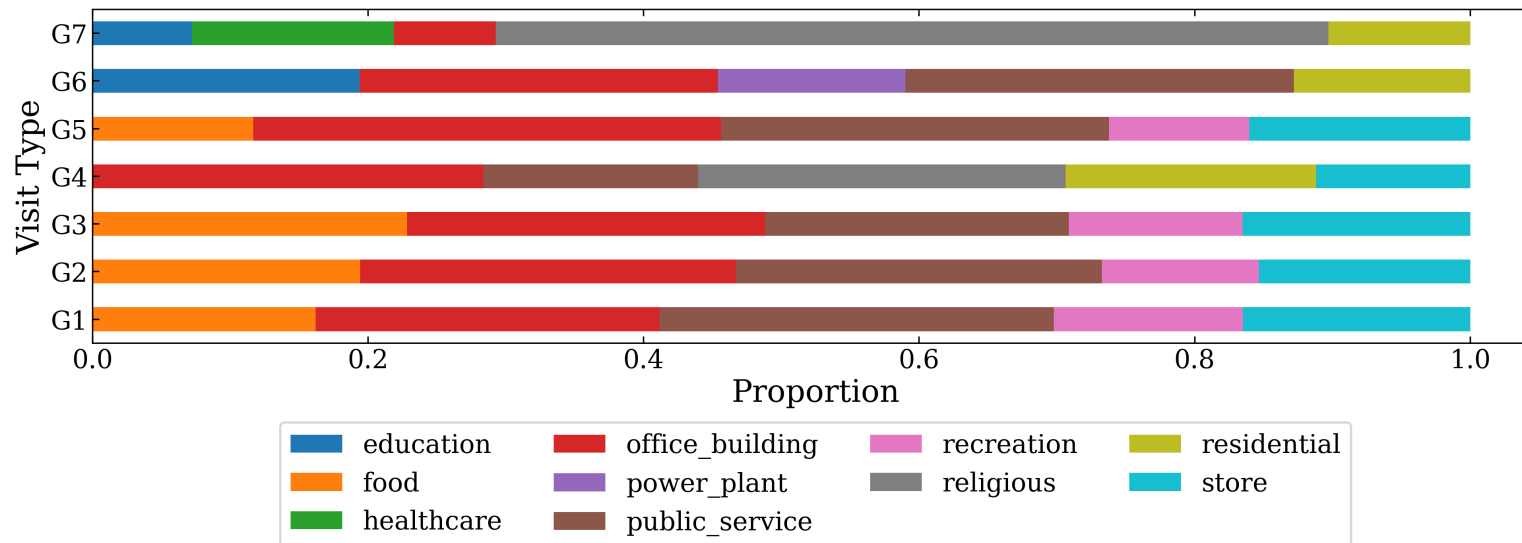
Urban settings shape distinct mobility patterns

Visitation classification: Semantic Patterns

Singapore



Beijing



Visitation classification: Semantic Patterns

Shared Trends

- Public_service, residential, and office_building

City-Specific

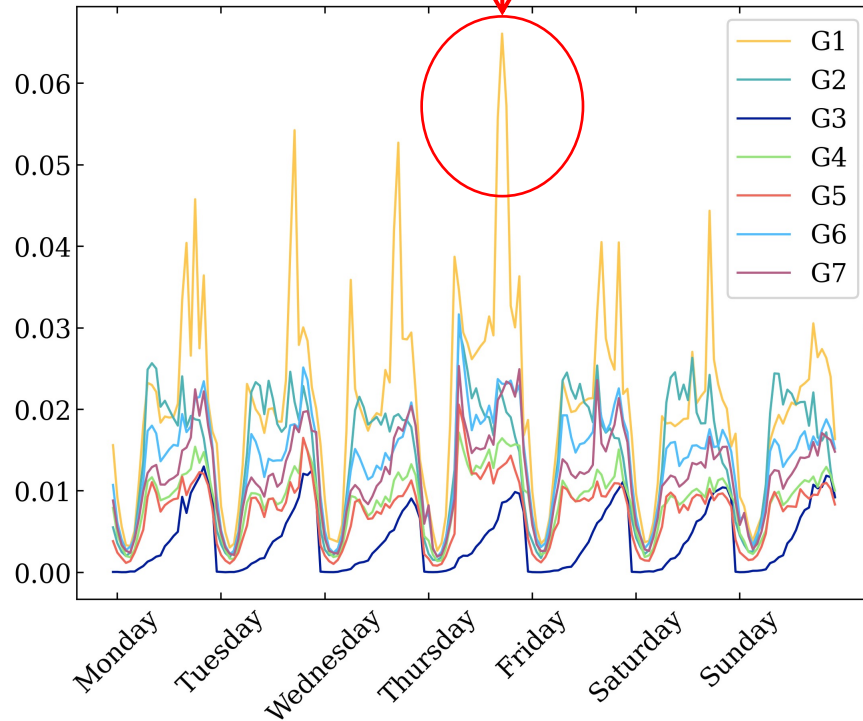
- **Singapore:** Recreation as anchor
- **Beijing:** Diverse semantics food, education, and power-related

Visitation classification: Temporal Patterns

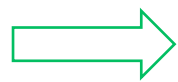
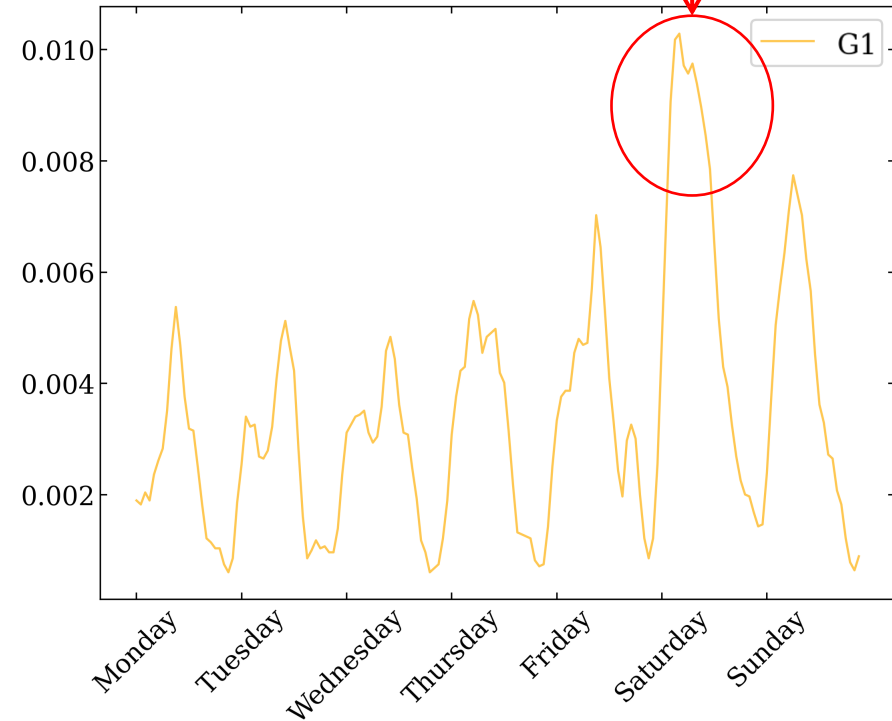
Social gatherings & After-work meetups

Leisure time

Singapore

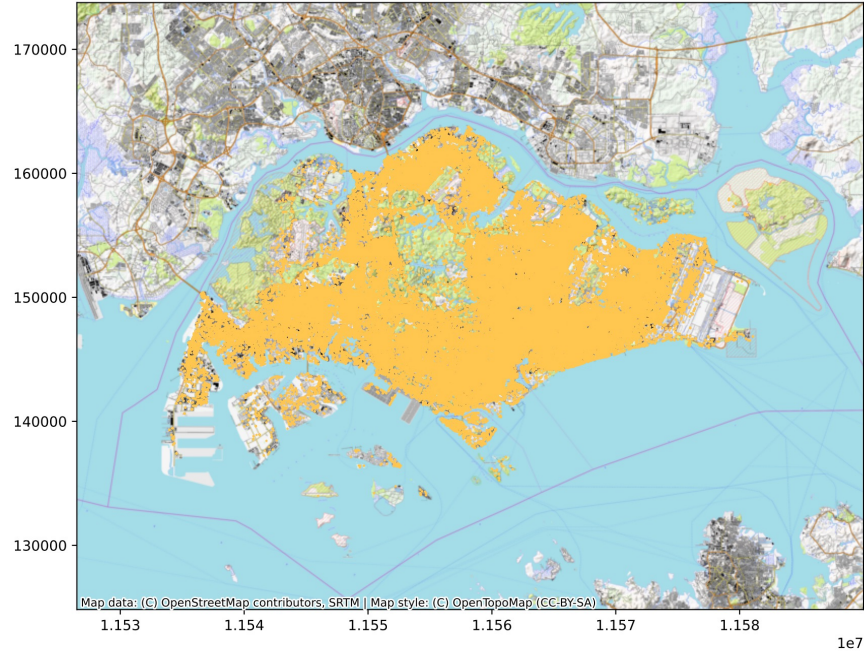


Beijing



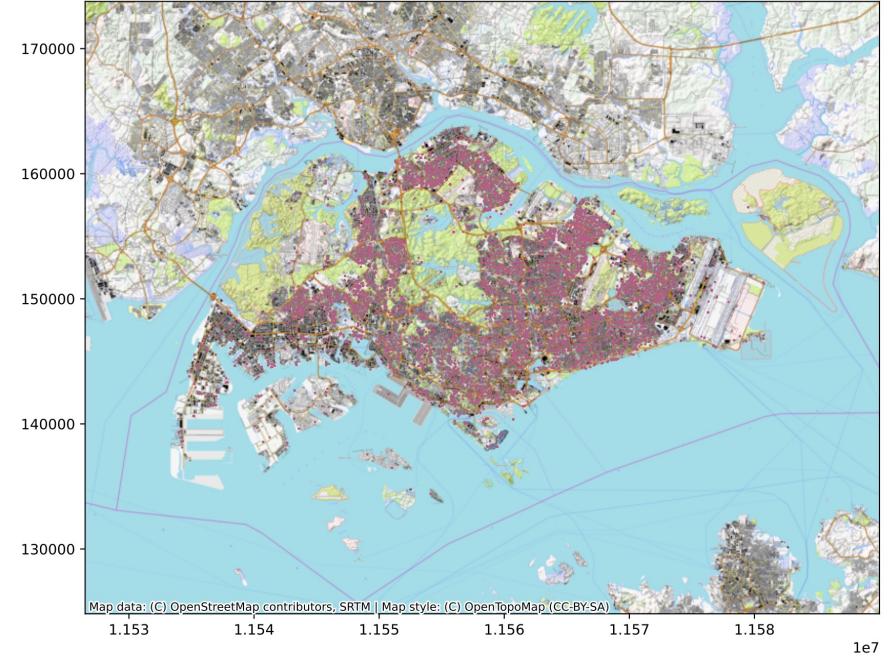
Different Temporal Patterns

Visitation classification: Spatial Exploitation



G1 exploratory-like

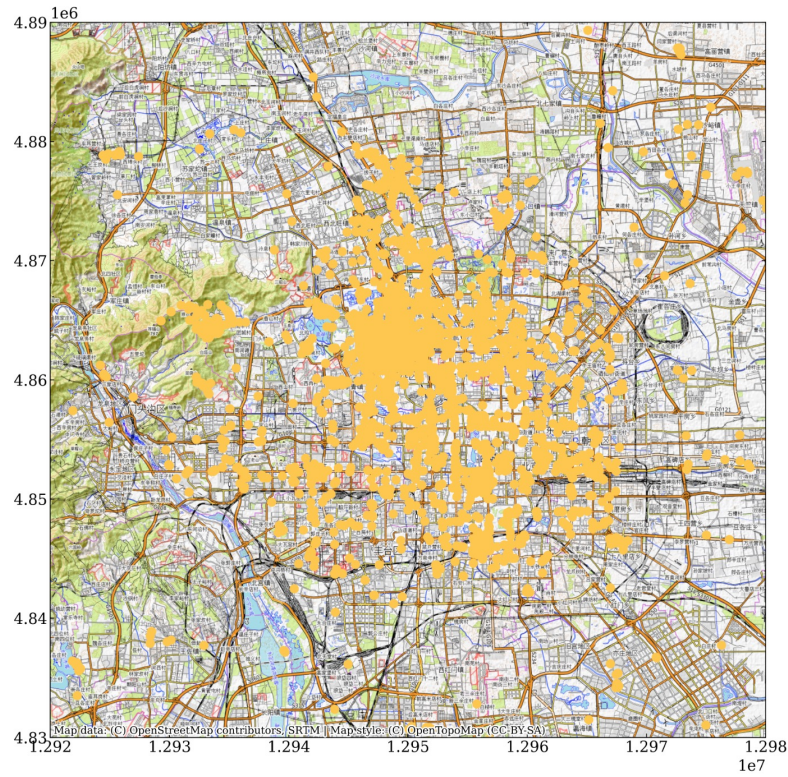
➡ Broadly across the city



G7 anchor-like

➡ Residential Areas

Visitation classification: Spatial Exploitation



G1 exploratory-like

➡ Broadly across the city



G6+G7 anchor-like

➡ Peking University & Haidian Business

Individuals-Space Relationships & Recommendation Systems

Context-Aware Recommendations

Frequent visitors → 

Exploratory visitors → 

Temporal and Spatial Personalization

When?



Where?



Routine and Novelty Balance



Dynamic Adaptation

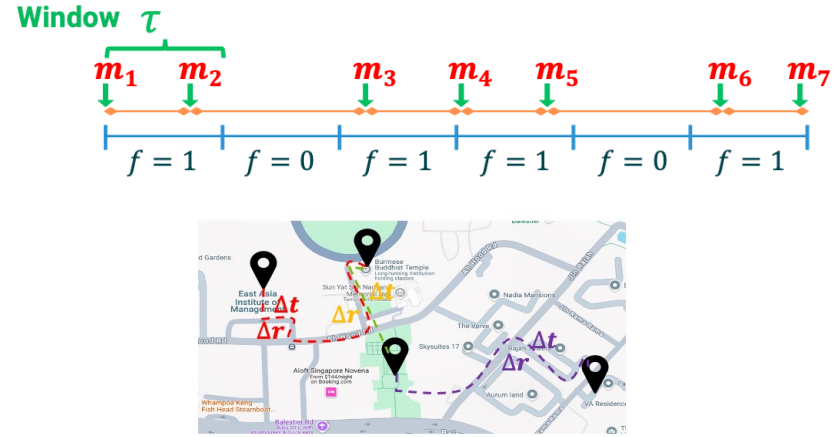


Conclusion

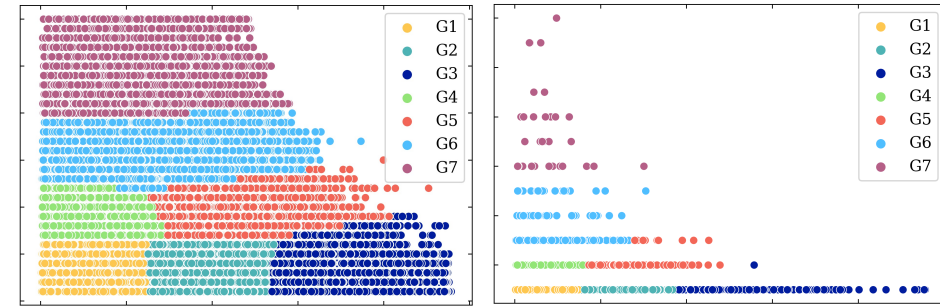
Mobility Data



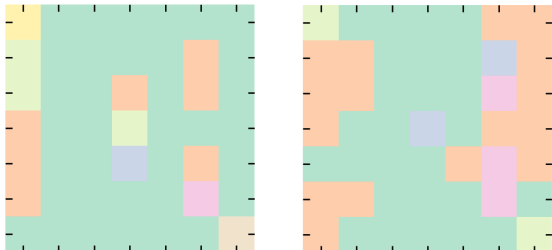
Temporal & Spatial Completeness



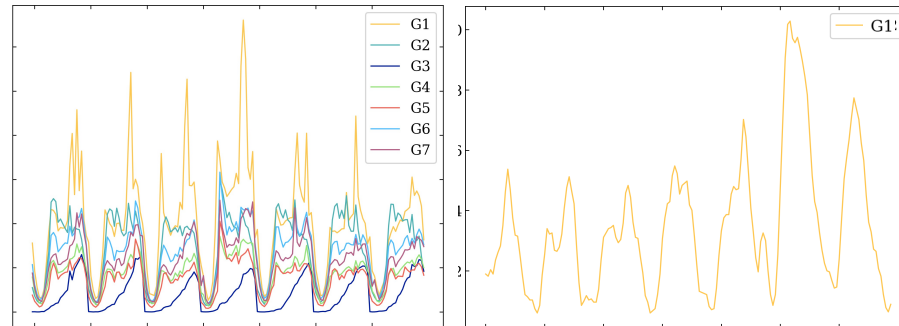
Visits Groups



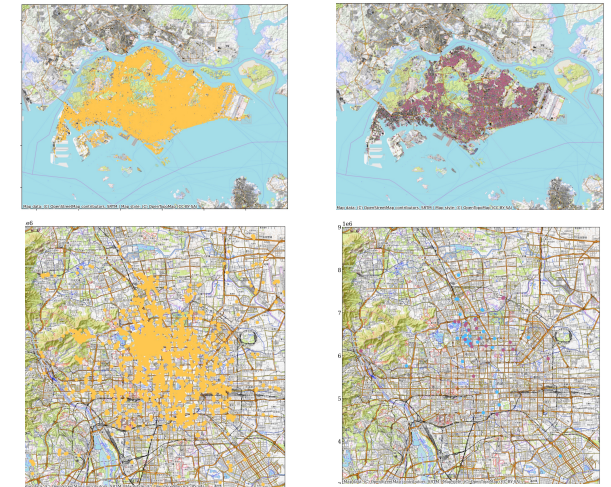
Visits Patterns



Temporal Patterns



Spatial Exploitation





Licia Amichi



Gautam M. Thakur



Carter Christopher

Thank you 😊