Rethinking Prism Anchors: Investigating Spatial-Time Fixity and Flexibility of Activities using Smartphone-Based Activity-Travel Survey Data

Yaxuan Zhang (zhan6322@umn.edu), Ying Song, Yingling Fan

I. Introduction

The space-time prism in Hägerstrand’s space geography delineates all accessible locations and time for individuals given their capability, coupling and authority constraints.

- The prism anchors are defined using fixed activities such as Home, Work and School.
- Other flexible activities such as Shopping, Recreation, and Eating Out are scheduled between fixed activities.

However, different social-economic status of individuals may lead to distinct views on how flexible an activity is in their daily schedules.

- Individuals may have non-routine Home, Work and School activities with changing locations and/or time.
- Individuals may have routine Shopping, Recreation, and Eating Out activities due to specific constraints.

Smartphone-based activity-travel survey allows us to track individuals’ movements in space and collect detailed information about their activities and trips in near real-time.

II. Objective

Investigating the fixity of an activity type with respect to spatial locations and time periods using activity-travel survey data collected by smartphone.

Specific Aims

1. Spatial Stationarity
   - Whether an activity episode is stationary (SA) or non-stationary (NSA) based on its spatial trajectory.

2. Temporal Fragmentation
   - Whether the allocation of time for an activity type is fragmented based on all episodes of that type within a day.

3. Spatial-temporal Recurrence
   - Whether episodes for an activity type occur recurrently at a location during similar time.

4. Individual Variation
   - Whether these findings vary across different individuals or groups.

III. Data Collection

- Daynamica Application
  - Activity Episodes ($e_{ij}$)
    - User ID ($u_i$)
    - Episode Seq ($e_{ij}$)
    - Activity Type ($a_j$)
    - Start Time ($t_{si}$)
    - End Time ($t_{ei}$)
    - Trajectory ($d_{ij} = (x_{ij}, y_{ij})$)
  - Activity Types ($a_j$)
    - Home (H)
    - Work (W)
    - Education (E)
    - Personal business (P)
    - Shop (S)
    - Eat out (O)
    - Leisure/Recreation (L)
    - Other/Unknown (U)

- Twin Cities Metro Areas
  - 372 participants
  - 6 neighborhoods
  - 7-day survey period

IV. Methods

1. Spatial Stationarity
   - (1) Spatial region: Convex hull; square root of area (SRA)
   - (2) Dispersion: standard deviational ellipse (SDE); maximum distance to mean center (MDM)
   - (3) Change in status: start and end locations

   Calibrate threshold value for “SMALL”: Box-Cox $t$ distribution

   Categorize activities into stationary and non-stationary

   Get locations for SAs:
   - Episode-level: center of SDE
   - Individual-level: list of SDE centers

   Get stationary part for NSA:
   - Episode-level: density-based cluster(s)
   - Individual-level: compare cluster(s) to SAs’ list

2. Temporal Fragmentation

   (1) Time range: first starts till last ends $t_{sij} - t_{eij}$
   (2) Total duration within the range $\sum_{ij} t_{eij} - t_{sij}$

3. Spatial-temporal Recurrence
   - (1) Cluster(s) of SA locations
   - (2) Temporal profiles of each cluster

V. Preliminary Results

- Spatial stationarity: Home-based tours and trips are sometimes considered as home activities

<table>
<thead>
<tr>
<th>Region</th>
<th>Criteria</th>
<th>Start-end</th>
<th>Number of Home</th>
<th>Number of Users</th>
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</tbody>
</table>

- Temporal Fragmentation: Working time may scatter within a day, especially during weekends

- Recurrence: Eat-out at the same locations during similar time across multiple days

VI. Conclusion

- Intuitively fixed activities such as home and work may be non-stationary or occur at fragmented time.
- Intuitively flexible activities such as eat out may reoccur at the same locations during similar time.
- The prism anchors could be personalized by learning from individuals’ previous schedules.