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# Extracting dynamic urban mobility patterns from mobile phone data

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# Motivation

- Various mobility patterns in urban area
  - How to explore?

**CBD, Beijing**

**Suburb, Beijing**

# Background

- Information and communication technologies (ICTs)
  - Greater mobility flexibility
  - A wide range of spatio-temporal data sources
    - i.e., georeferenced mobile phone data

# Background (Cont.)

- Modeling Urban Mobility Patterns
  - Data source
    - Travel diary ?
    - ICT data
  - Urban patterns
    - Spatial clustering
    - Spatial interaction
    - Rhythm of a city
      - Cities are dynamic…
      - Mobile phone datasets to model dynamic patterns

# Objective

- Interpret and model the dynamic mobility pattern of a city
  - Pattern similarity measure based on Dynamic Time Warping
    - e.g., pattern of high crime rate area

  - Outlier detection
    - e.g., traffic congestion

# Example dataset

- Mobile Phone Connections in a large city in Northeast China
  - Time, duration, and locations of mobile phone connections over 9 days

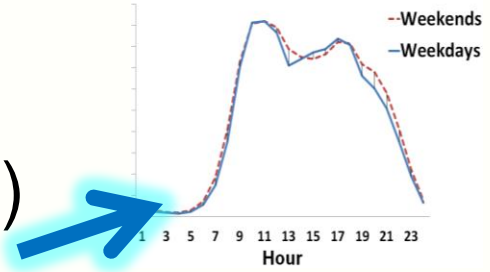
| User ID | Longitude | Latitude | Time | Duration |
|---|---|---|---|---|
| 13********* | 126.***** | 45.***** | 12:06:12 | 5mins |

# Methodology

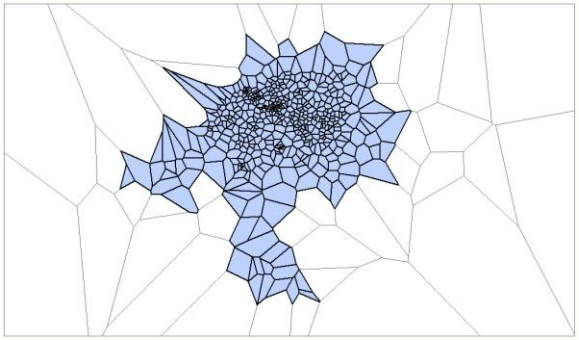
- Data Preprocessing
- Analysis 1: Use Dynamic Time Warping to measure similarity of time series
  - Distance matrix
- Analysis 2: Outlier detection

# Data Preprocessing

- Divide study area
  - Voronoi polygon (based on towers)
  - **What to compare**: 24-hour series for each polygon based on mobility count
    - Normalized series between [0,1]

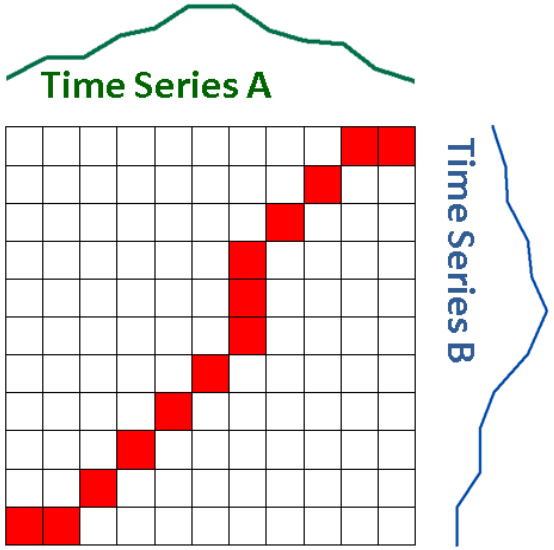



- Eliminate outliers
  - Remove polygons > 10km$^2$
  - Remove polygons with mobility count = 0



# 1. Measure similarity of time series

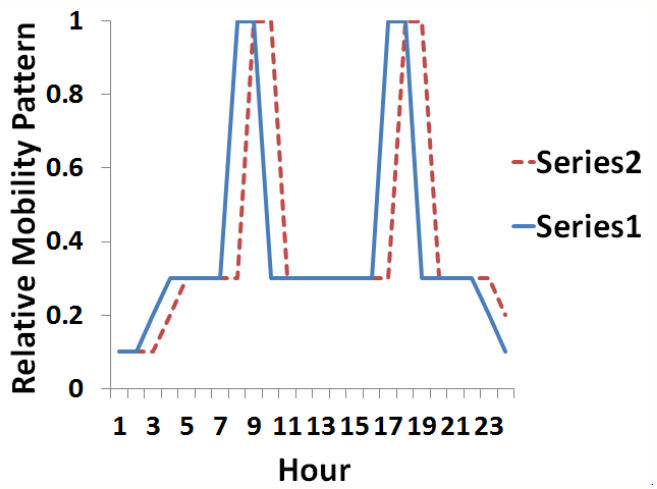
- Dynamic time warping
  - Construct a DTW grid
  - Calculate a distance measure of for each grid cell (here we use absolute differences).
  - Find a path through the grid which minimizes the total distance
    → DTW distance
  - Robust (displacement)

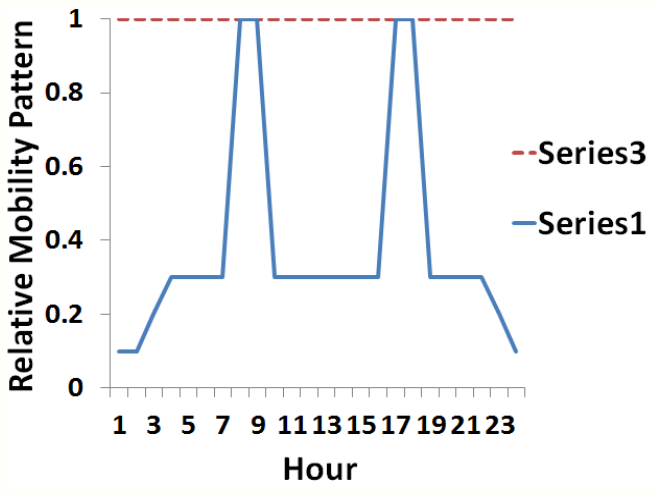


# 1. Measure similarity of time series (Cont.)

- A comparison between DTW and other distance measures

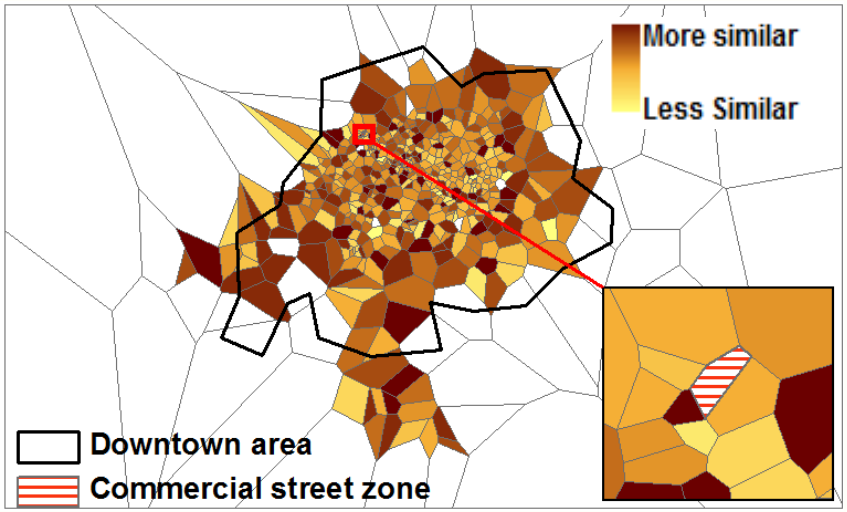
| | Dis1 (Series 1 vs Series 2) | Dis2 (Series 1 vs Series 3) | Distance Ratio (Dis2/Dis1) |
|---|---|---|---|
| DTW | 0.00208 | 0.31 | 149.04 |
| Euclidean | 1.41 | 3.33 | 2.36 |
| Fréchet | 0.70 | 0.90 | 1.29 |



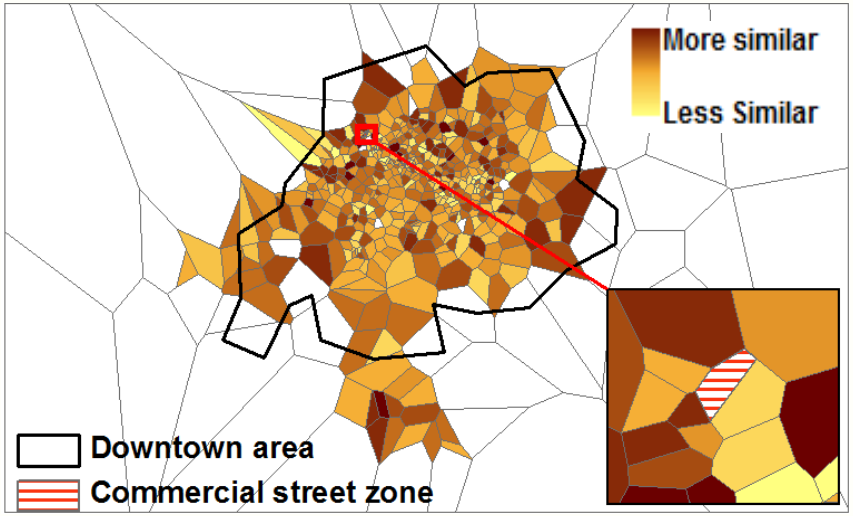



# Data Analysis

- Mapping the similarity to reference areas
  - Commercial street zone




**Weekdays**



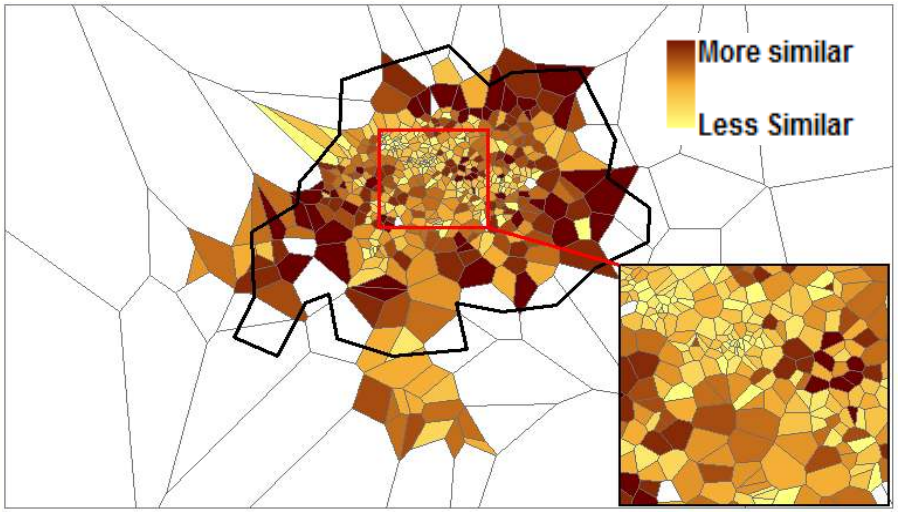

**Weekends**

# Data Analysis (Cont.)

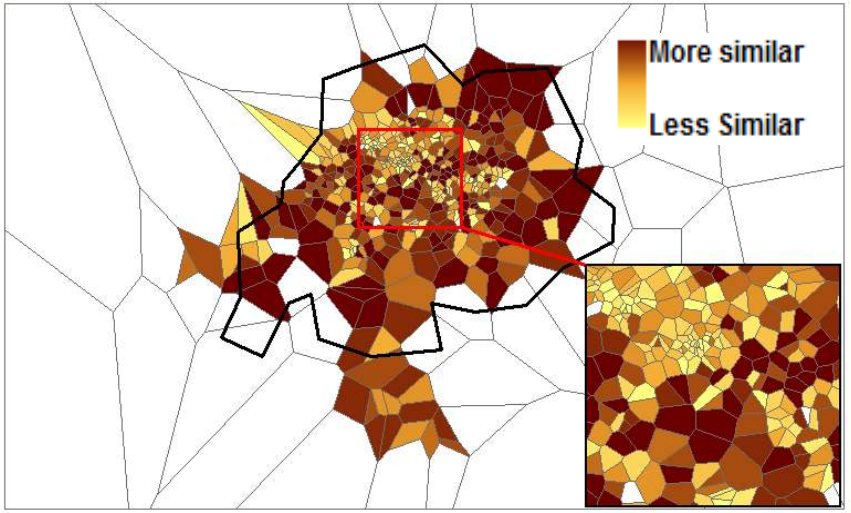
- Mobility patterns on weekdays are closer to the pattern in the reference area
- Irregular patterns during weekends
  - More random (off-schedule) activities

# Data Analysis (Cont.)

- Mapping the similarity to reference areas
  - Benchmark series:
    [1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]



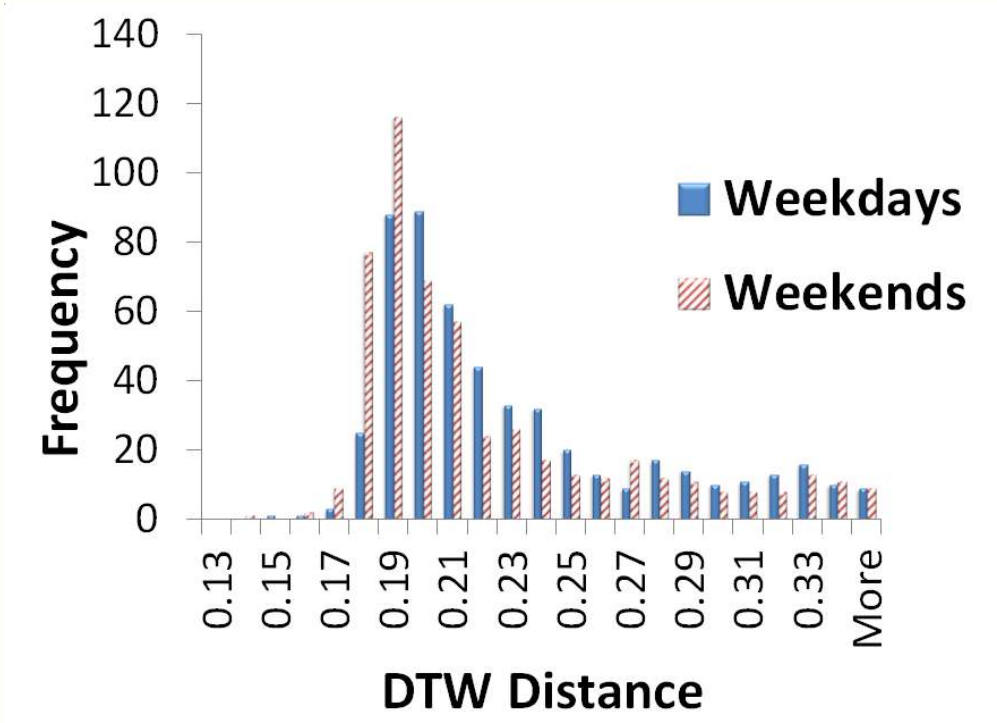

**Weekdays**




**Weekends**

# Data Analysis (Cont.)

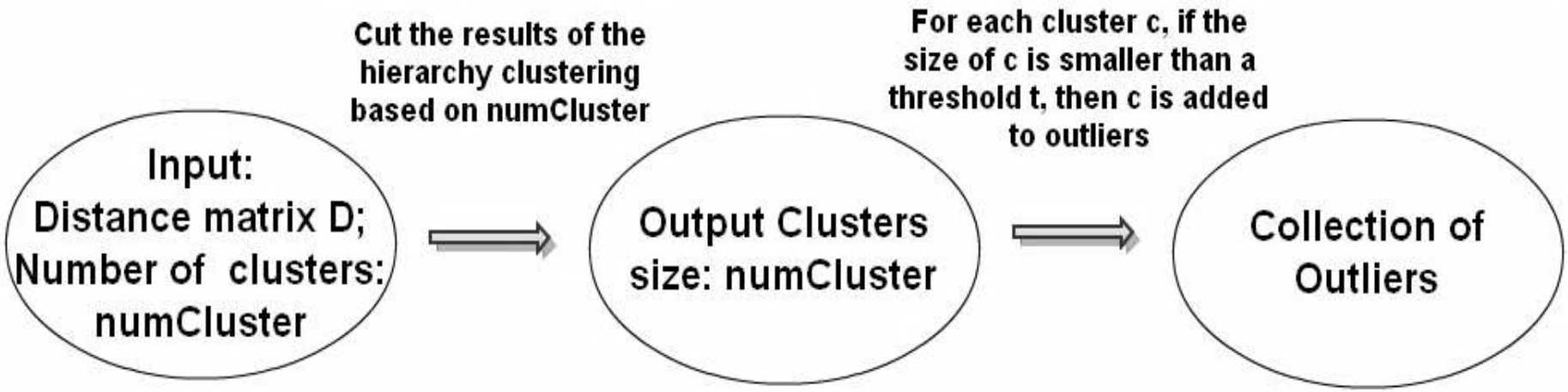
- Series on weekends are “flatter” (even distribution)



# 2. Outlier detection

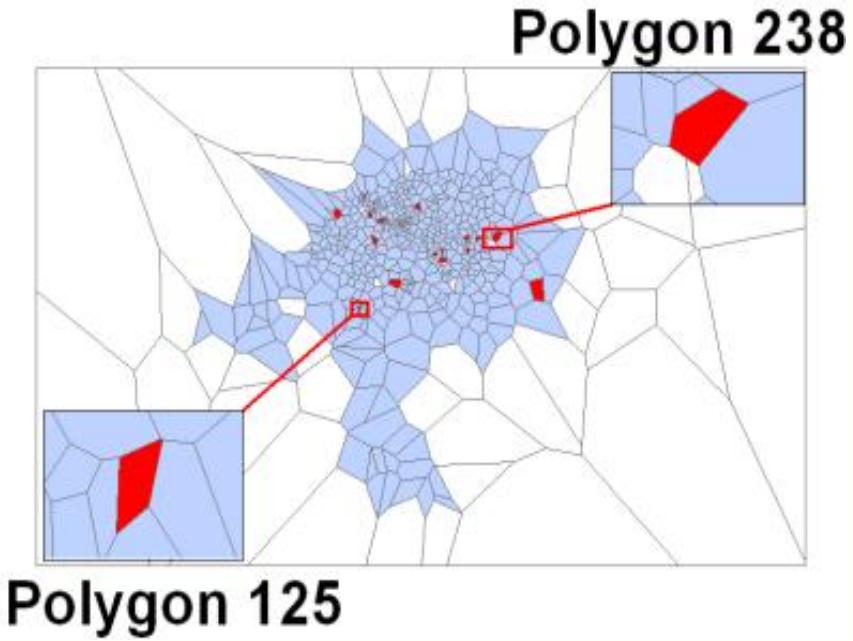
- Detect ‘abnormal’ activities based on similarity measure
- Hierarchical classification

  numCluster = max(2; sqrt(n/2)) (Lee et al. 2008)

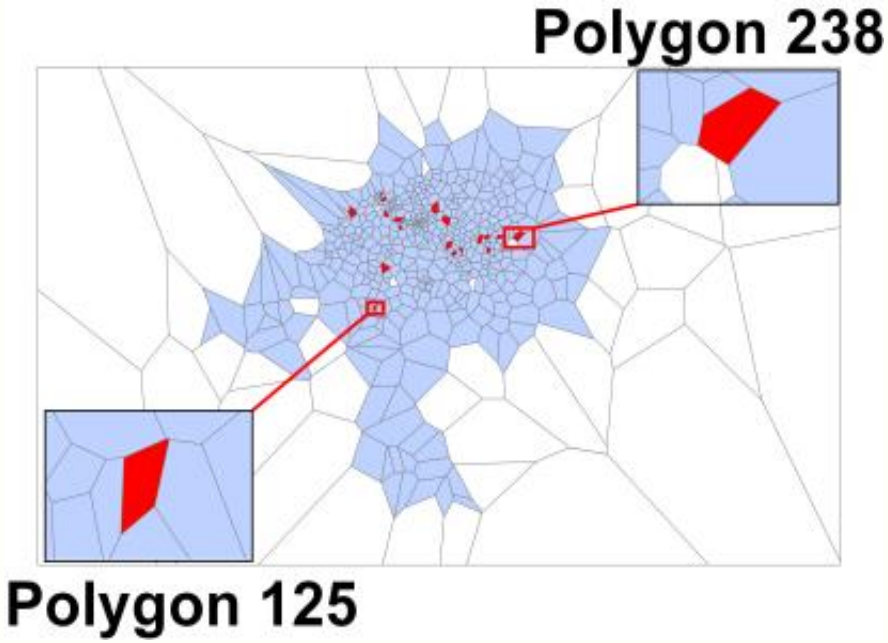


# Outlier polygons

- 15 outliers for weekdays and 18 for weekends



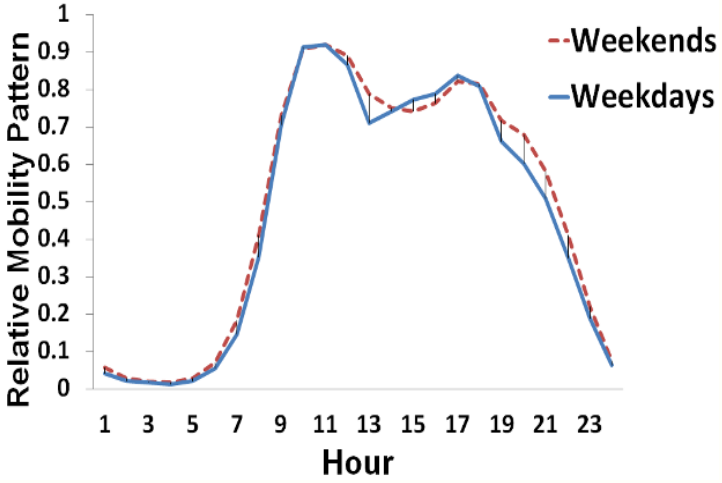

**Weekday**




**Weekends**

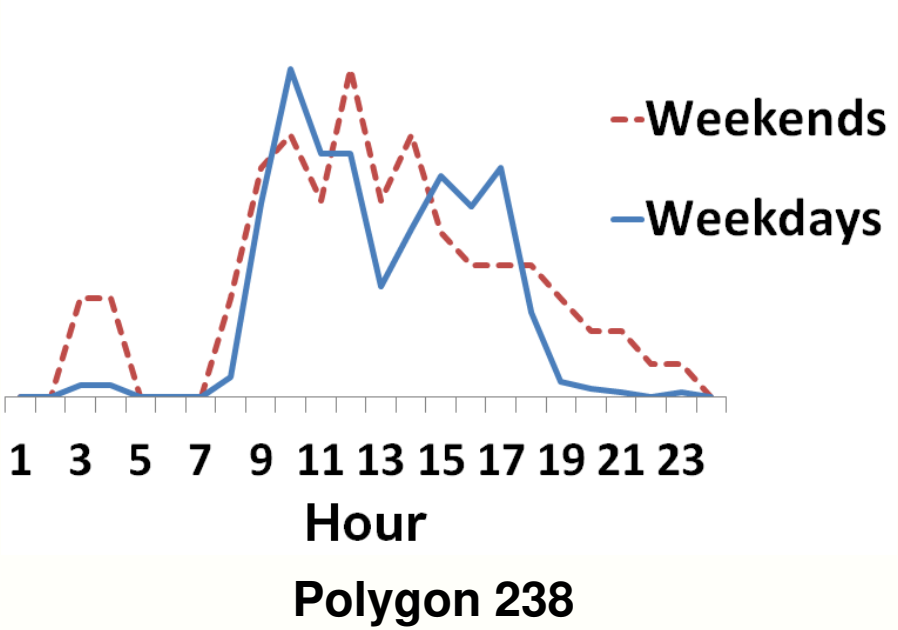
# Data Analysis

- Define a typical normal mobility series
  - Average mobility after removing outliers
    - Two mobility peaks each day: 9am and 6pm
    - lowest point between 2-4am
    - consistent with common sense



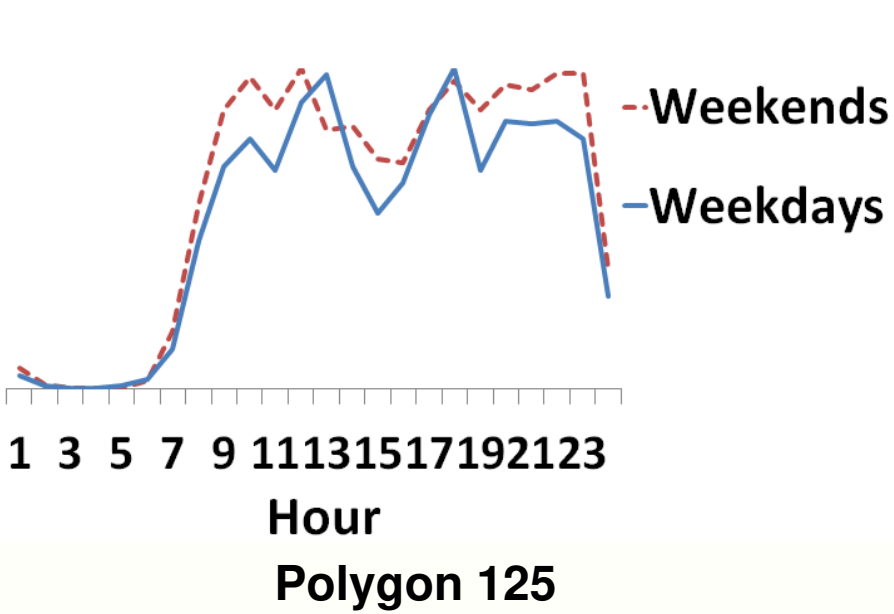
# Mobility patterns in outlier areas

- Outlier Polygon 238
  - Night clubs and other leisure facilities
  - International trading center



# Mobility patterns in outlier areas

- Outlier Polygon 125
  - Several community colleges
  - Not many night clubs, bars, etc.



# Summary

- DTW is an effective method for exploring similarity / dissimilarity of urban mobility patterns.
- The study area has the highest mobility density around 9am and 6pm.
- Identification of ‘abnormal’ mobility patterns
  - Providing reference for transportation and urban planning

# Future Work

- Identify the influence of spatio-temporal granularity
  - Grid cells / 1 hour granularity
- Examine individual mobility patterns
  - Characterizing user trajectories based on the abnormality of visited areas
- Apply to other cities

# Acknowledgement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  - Swiss National Science Foundation, Grant No. 141284

# Questions and Comments?