

Extracting dynamic urban mobility patterns from mobile phone data

Yihong Yuan^{1,2} and Martin Raubal¹

¹Institute of Cartography and Geoinformation, ETH Zurich

²Department of Geography, University of California, Santa Barbara

yyuan@ethz.ch, mraubal@ethz.ch

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

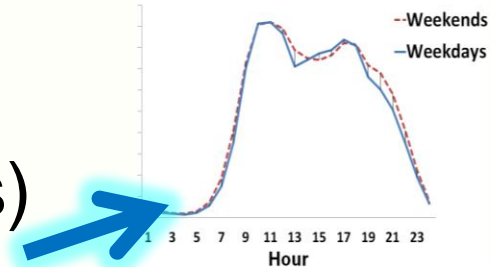
User ID	Longitude	Latitude	Time	Duration
13*****	126.*****	45.*****	12:06:12	5mins

Methodology

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

Data Preprocessing

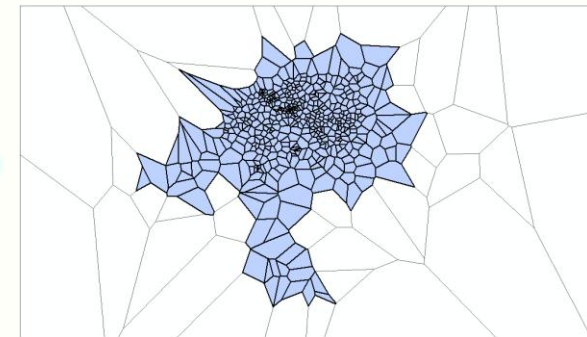
- Divide study area
 - Voronoi polygon (based on towers)
 - **What to compare:** 24-hour series for each polygon based on mobility count



- Normalized series between [0,1]

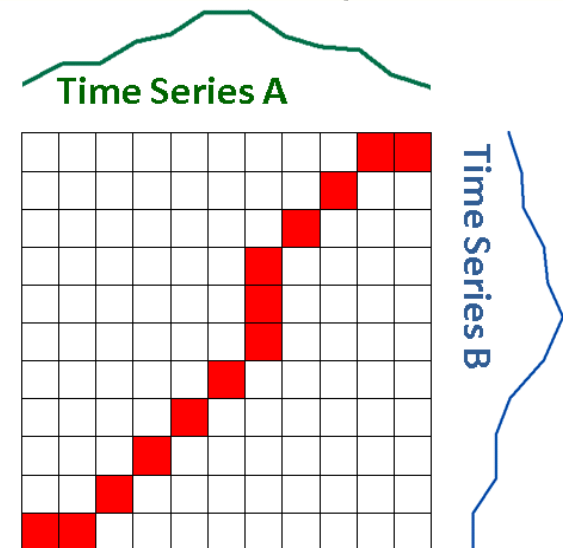
- Eliminate outliers

- Remove polygons $> 10\text{km}^2$
- Remove polygons with mobility count = 0



1. Measure similarity of time series

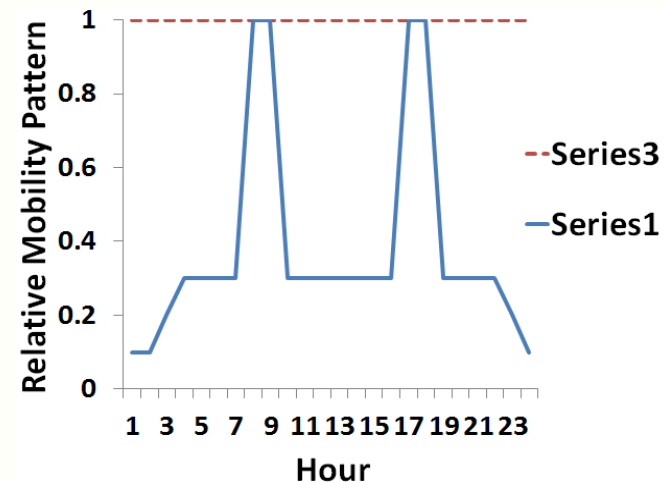
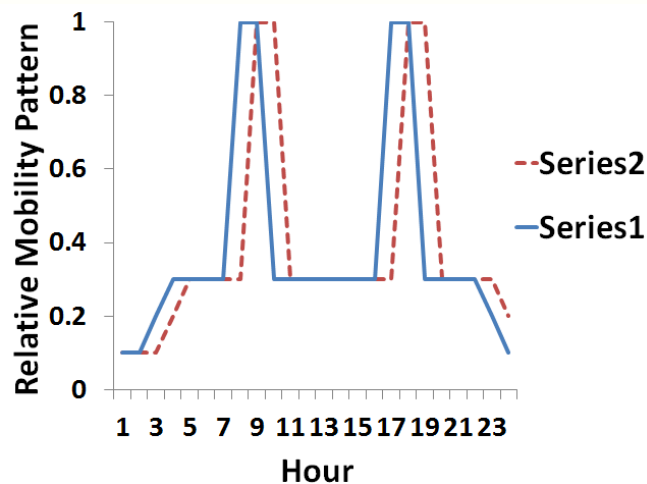
- Dynamic time warping
 - Construct a DTW grid
 - Calculate a distance measure of for each grid cell (here we use absolute differences).
 - Find a path through the grid which minimizes the total distance
 - ➔ DTW distance
 - Robust (displacement)



1. Measure similarity of time series (Cont.)

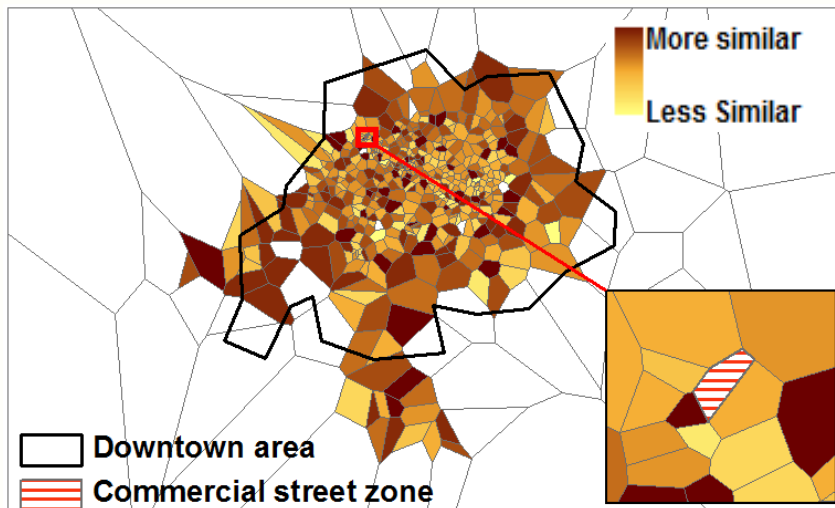
- A comparison between DTW and other distance measures

	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

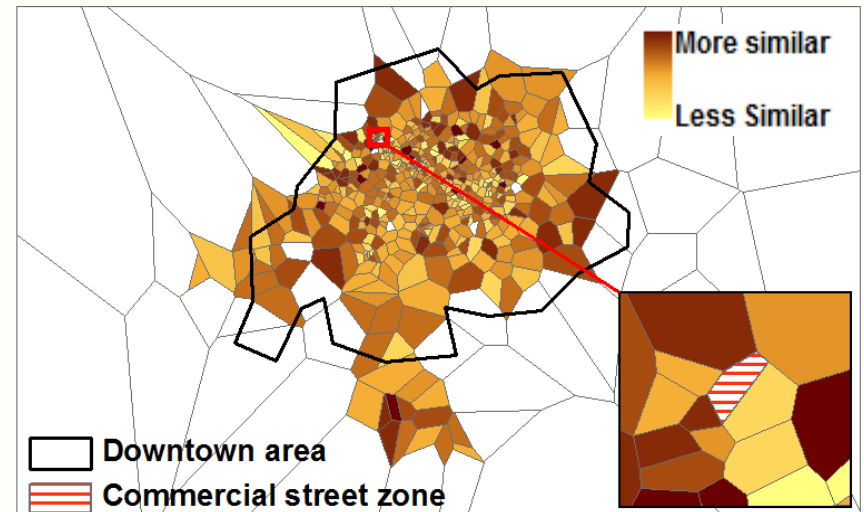


Data Analysis

- Mapping the similarity to reference areas
 - Commercial street zone



Weekdays



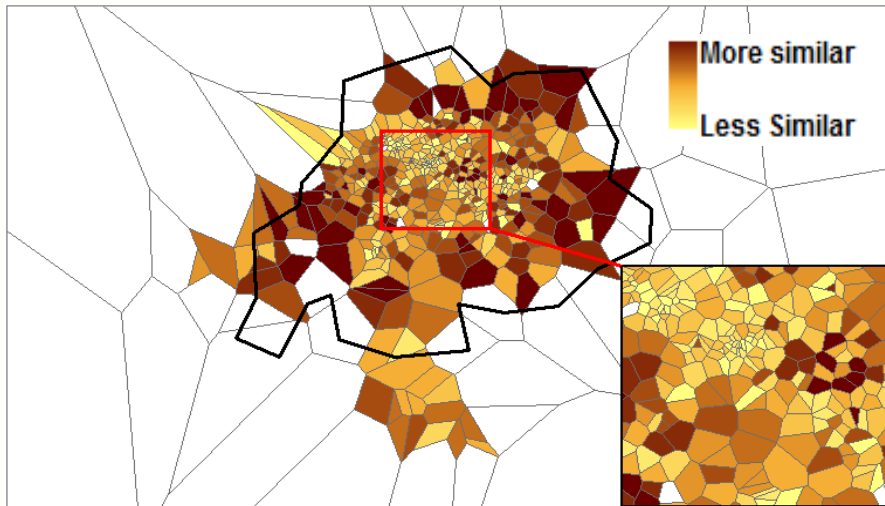
Weekends

Data Analysis (Cont.)

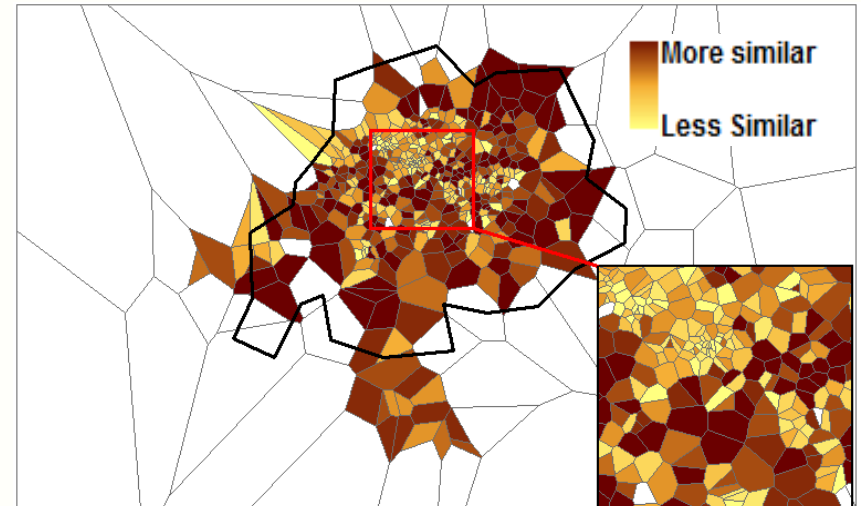
- Mobility patterns on weekdays are closer to the pattern in the reference area
- Irregular patterns during weekends
 - More random (off-schedule) activities

Data Analysis (Cont.)

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



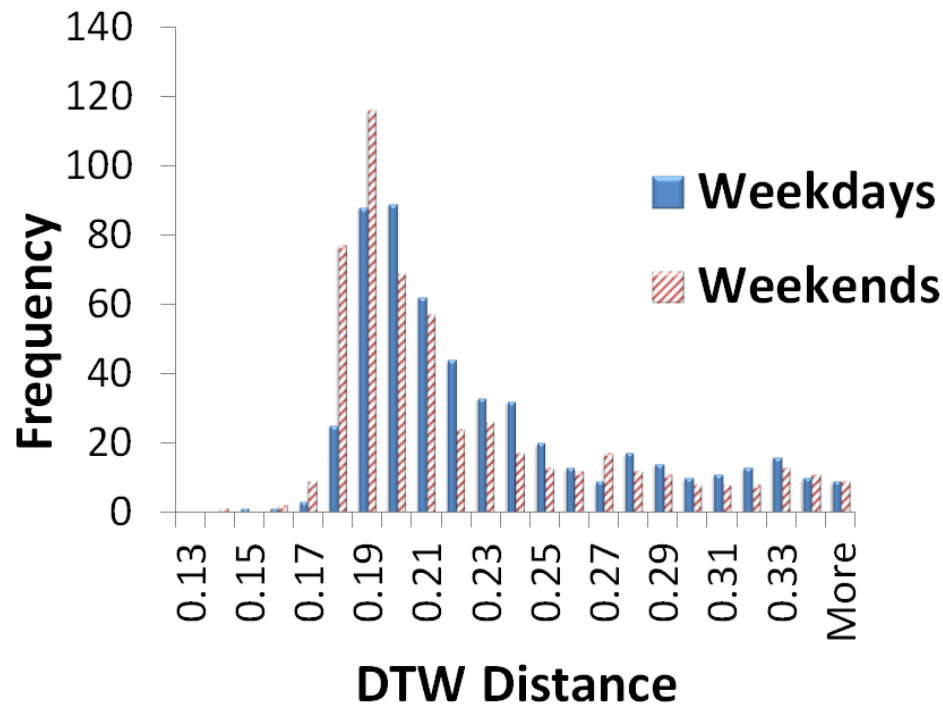
Weekdays



Weekends

Data Analysis (Cont.)

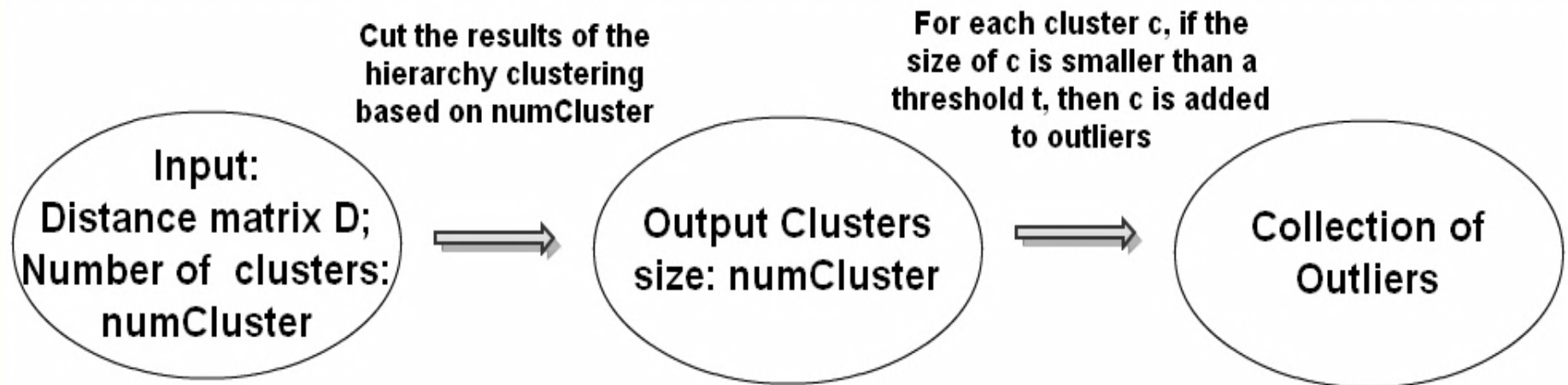
- Series on weekends are “flatter” (even distribution)



2. Outlier detection

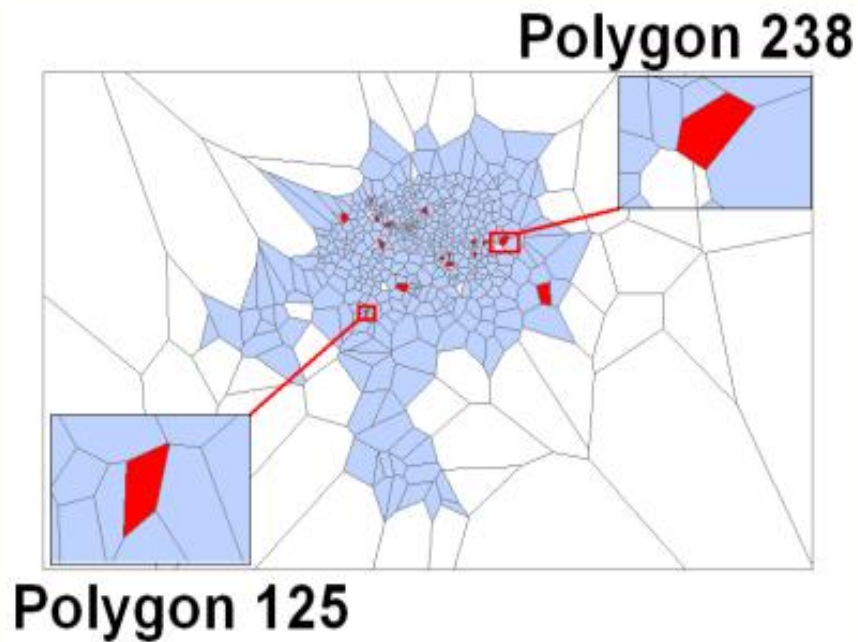
- Detect 'abnormal' activities based on similarity measure
- Hierarchical classification

$\text{numCluster} = \max(2; \text{sqrt}(n/2))$ (Lee et al. 2008)

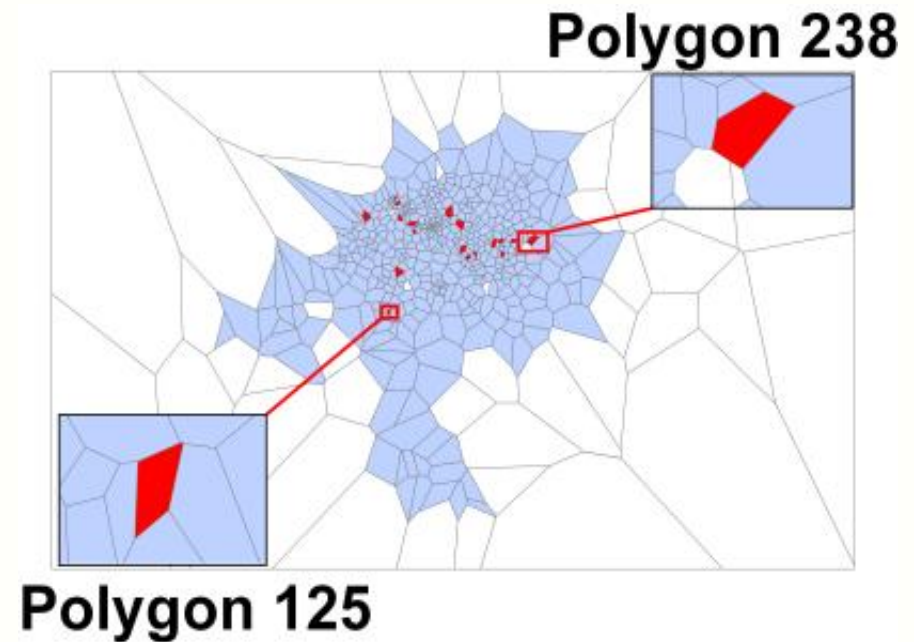


Outlier polygons

- 15 outliers for weekdays and 18 for weekends



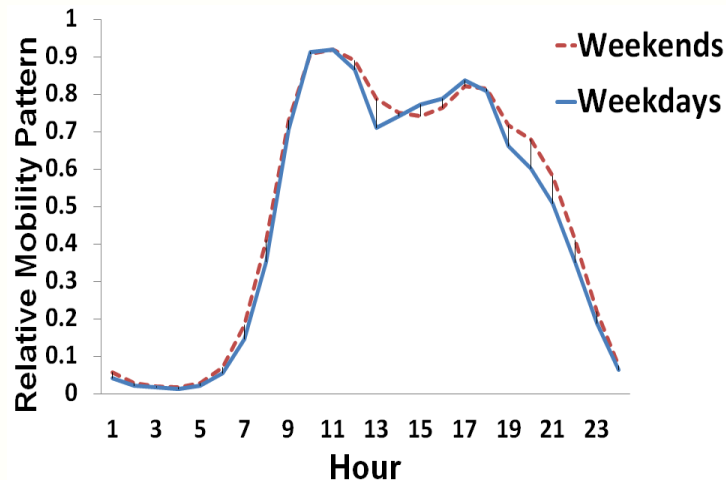
Weekday



Weekends

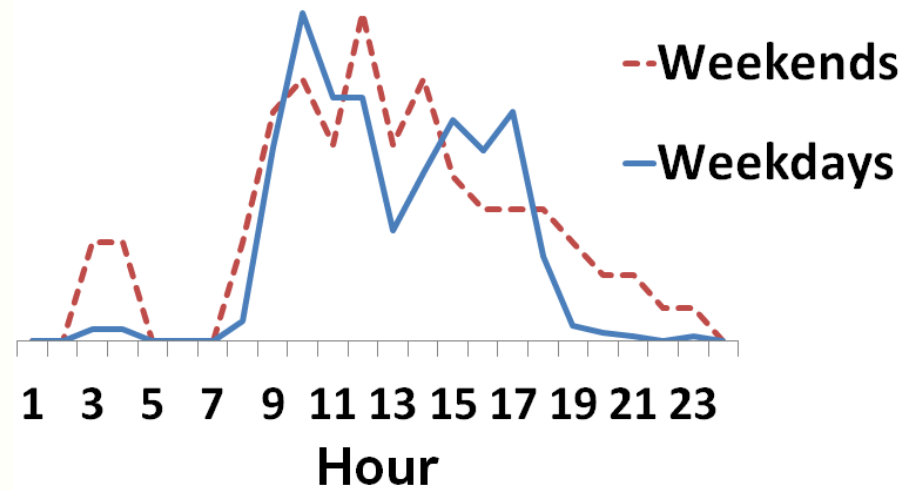
Data Analysis

- 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

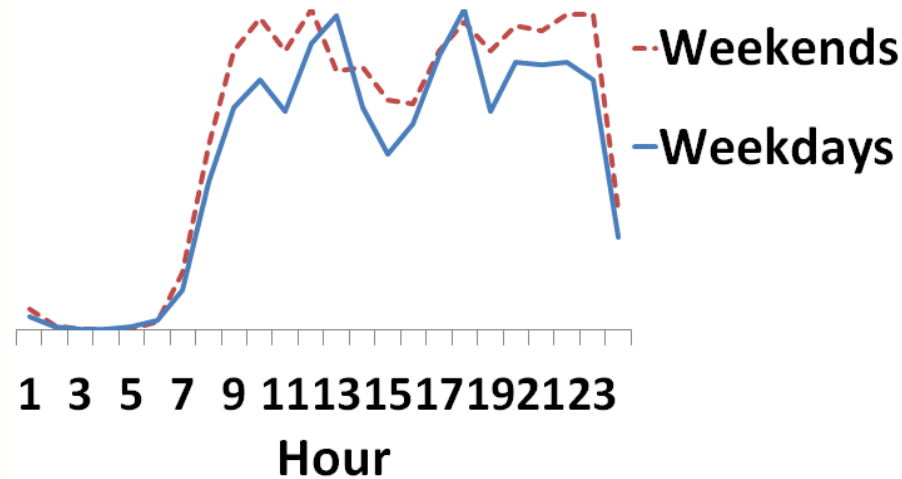
- Outlier Polygon 238
 - Night clubs and other leisure facilities
 - International trading center



Polygon 238

Mobility patterns in outlier areas

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



Polygon 125

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

- This research is funded by:
 - Swiss National Science Foundation, Grant No. 141284

Questions and Comments?