User Clustering with GPS Trajectories

Yan Wang

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Overview

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Problem definition

- User clustering with GPS trajectories

Problem definition

- User clustering with GPS trajectories
- It's important
  - Spatial-temporal data: general
  - Applications
- It's challenging
  - Spatial-temporal data: complex
  - Geographical data: rich context

Dataset

- GeoLife from Microsoft Research Asia
  - Latitude, Longitude, Timestamp, UserID
  - Large-scale
    - 167 users, 2 years, 17K+ trajectories, 1M+ km, 48K hours
- Subset in urban area of Beijing
- Why choosing GeoLife?
  - Suitable for the problem
  - Large enough

Approach

- Framework
  - Preprocessing
  - Feature extraction
  - Clustering
- Why?

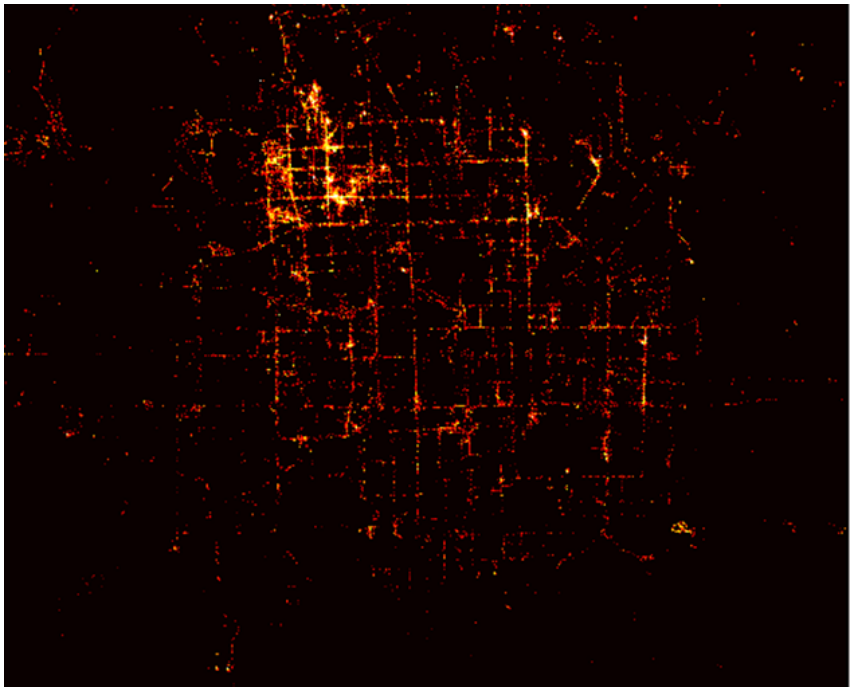
Visualization and analysis

- What does the overall data look like?

- Problems?
  - Not informative enough!
  - More interested in *intentionally* visit

Preprocessing

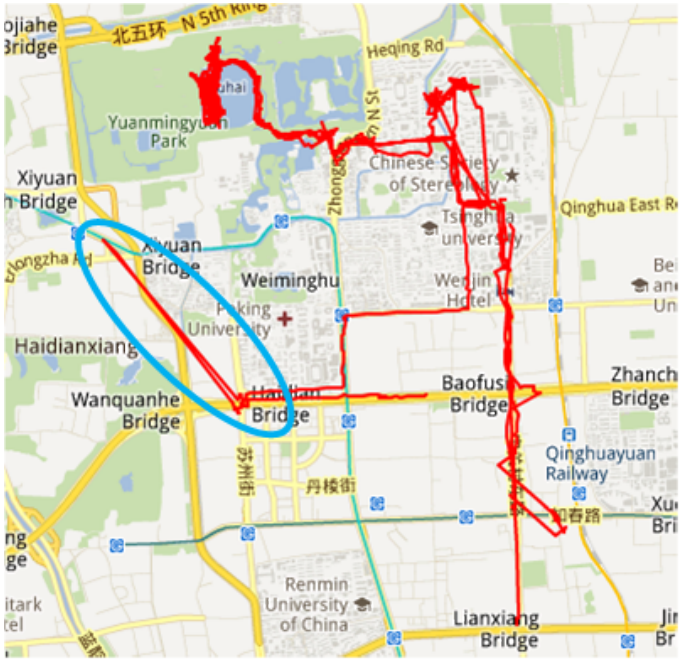
- Filter high-speed points



- Solution!
  - Noise filtered
  - Enough points preserved (4M+)

Visualization and analysis

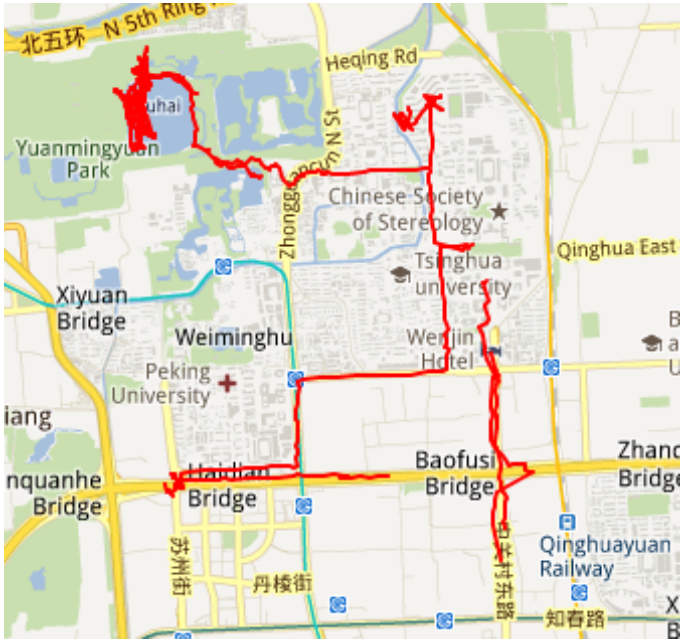
- What does one user look like?



- Problems?
  - Outliers!

Preprocessing

- Discard points inconsistent with local average



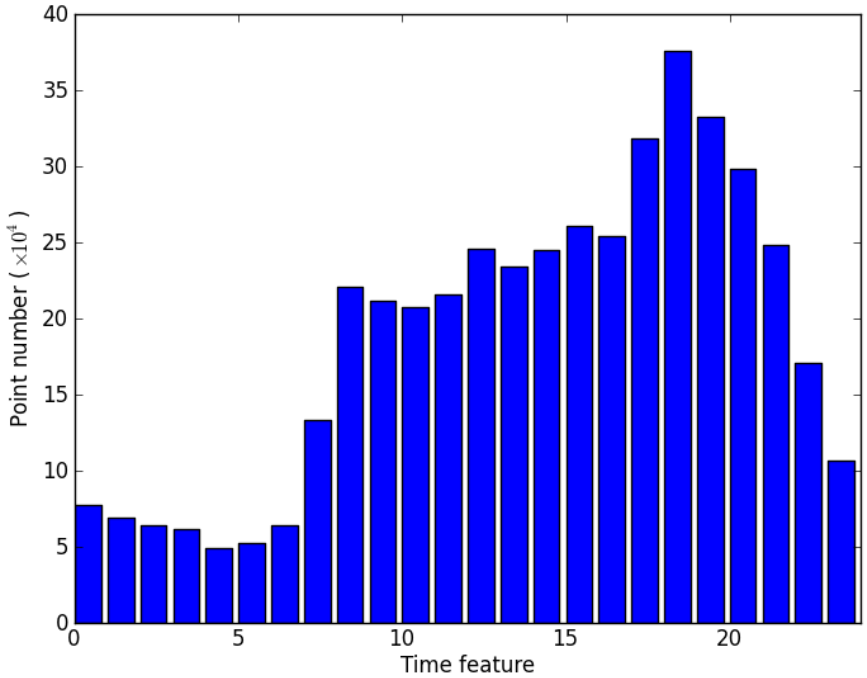
- Solution!
  - Smooth and reasonable trajectories

Feature extraction

- Intuition
  - Traveling time
    - Morning? Afternoon? Evening?
    - Hour in timestamp
  - Traveling area
    - Northwest? Central?
    - 1 from 100 regions in Beijing
  - Category
    - Restaurants? Bookstores? Shopping malls? Parks?

Visualization and analysis

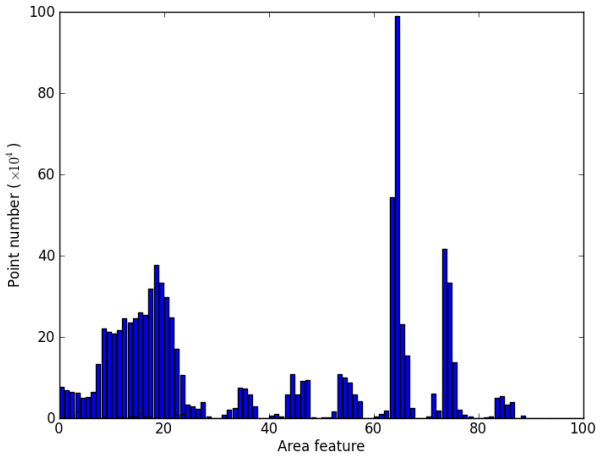
- Traveling time

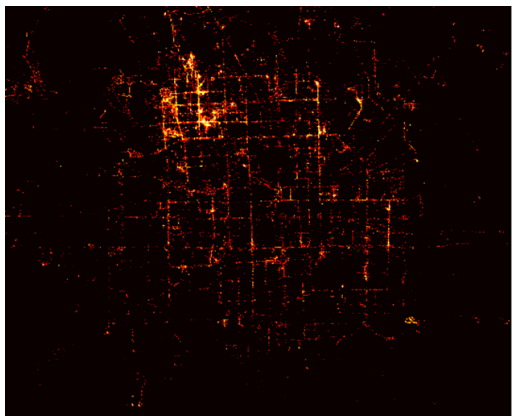


- Good
  - Reasonable
  - Balanced

Visualization and analysis

- Traveling area
  - Right figure
- Very unbalanced
  - Why?
- Periodical
  - Why?
  - Problem of distance





Visualization and analysis

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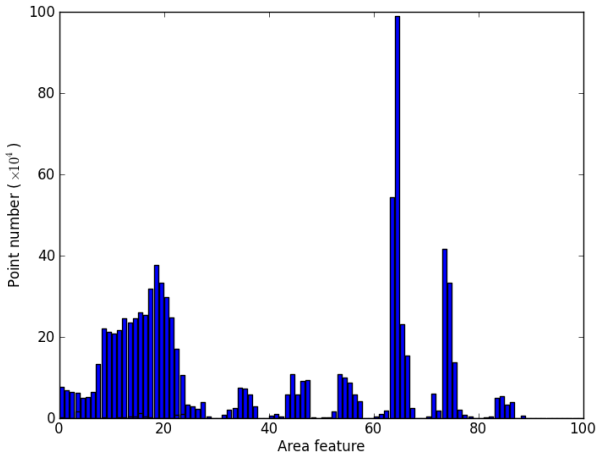
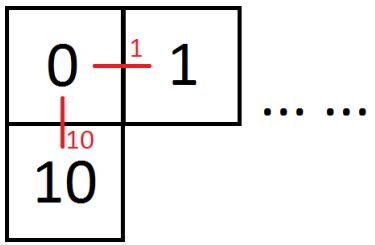
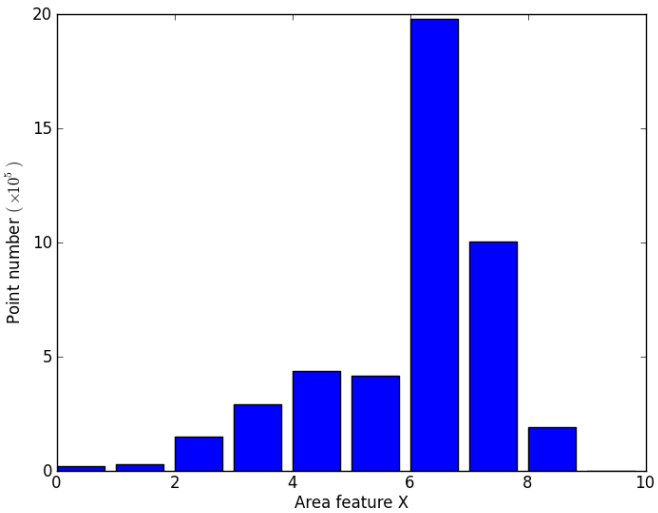
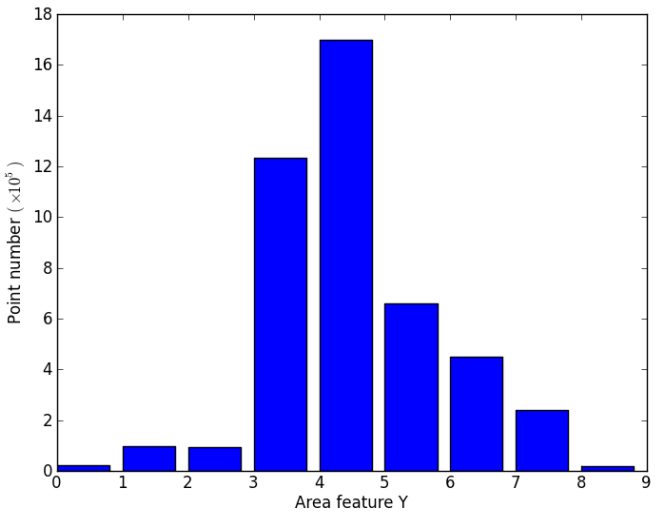




Refined feature design

- 1D $\Rightarrow$ 2D





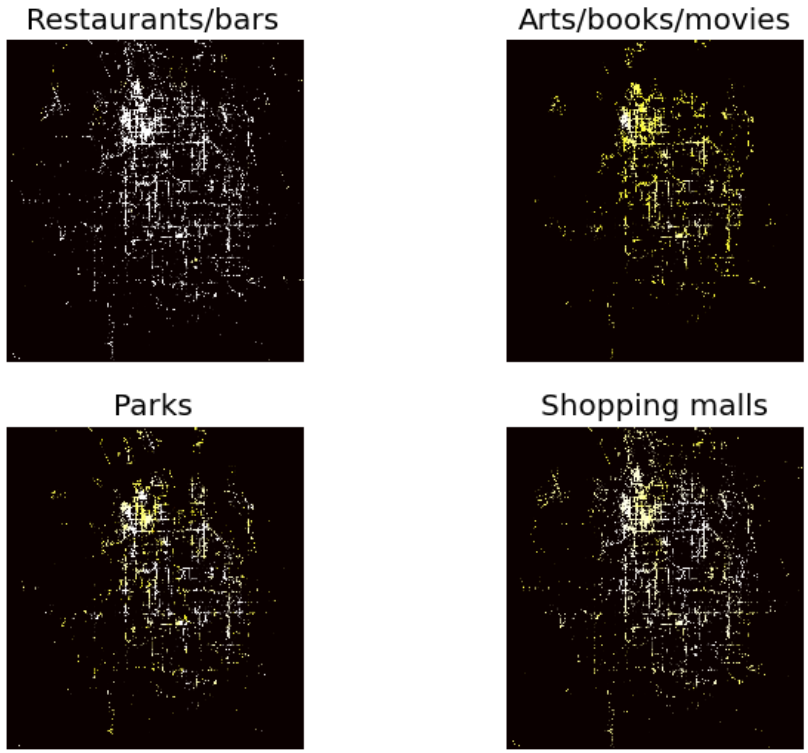
- Solution!

Incorporate geographical contexts

- A sample scenario
- What we need
  - Describe the "category" of a place
- What we have
  - Google Place API
  - (Lat, Lon, Type, Search range) $\Rightarrow$ Detailed info about local business
- What to do
  - # Restaurants, # Bookstores, # Shopping malls, # Parks

Visualization and analysis

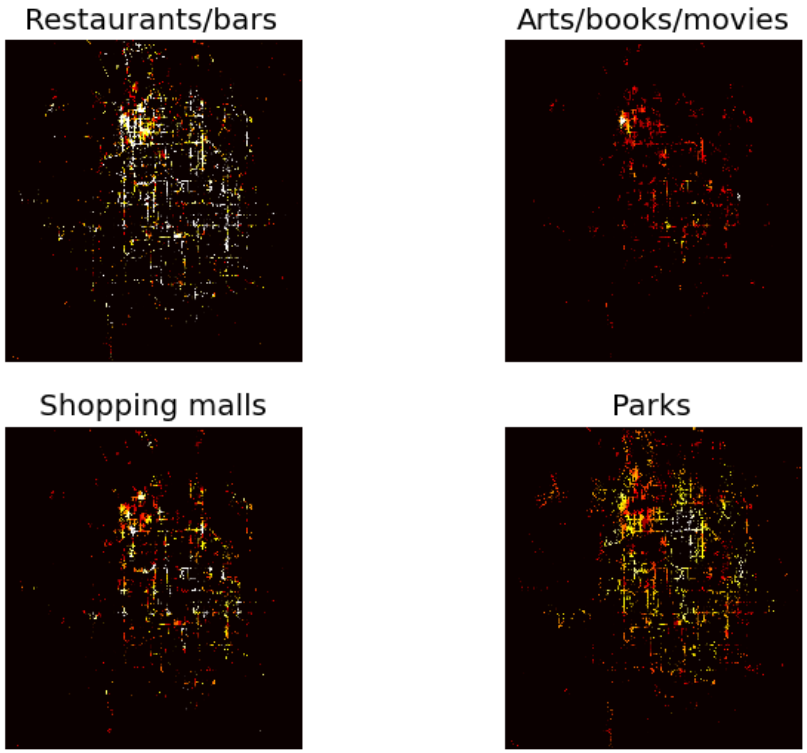
- Geographical distribution



- Homogeneous
  - Why?
  - Google Place API returns 20 results at most.

Refined feature design

- Decrease search range



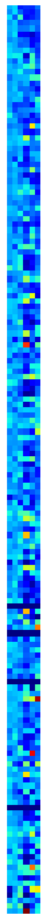
- Solution!
  - More discriminative

Refined feature design

- Feature
  - Mean of traveling time
  - Mean of traveling area
  - Mean of "category" feature
- Build Bag-of-Words feature
- Normalization
  - 0-mean, 1-standard-deviation

Visualization and analysis

- Problems?
  - Missing values
- Solution
  - Fill them with mean



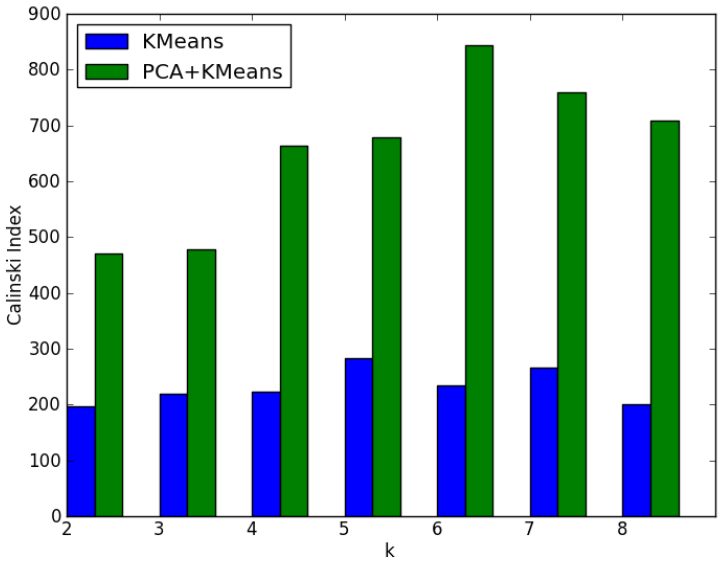
Clustering

- Approaches
  - K-Means
  - Spectral Clustering
  - Affinity Propagation: no cluster # required ahead
- Feature selection with PCA

Experiments

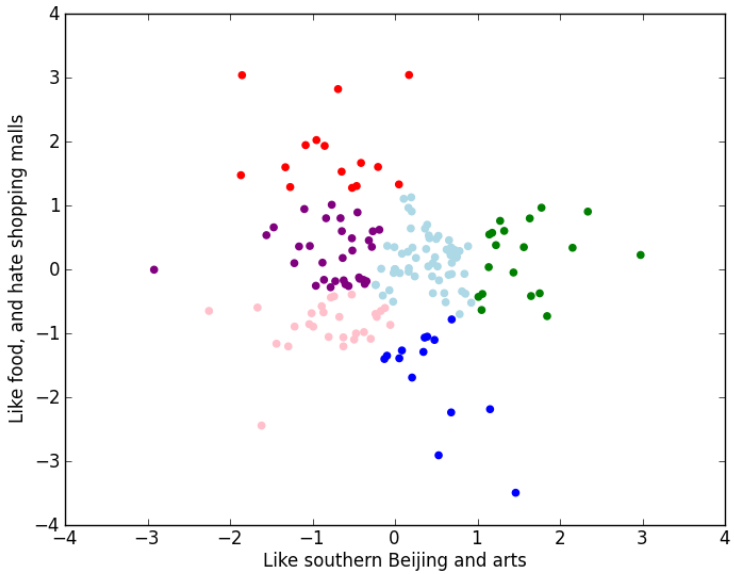
- KMeans

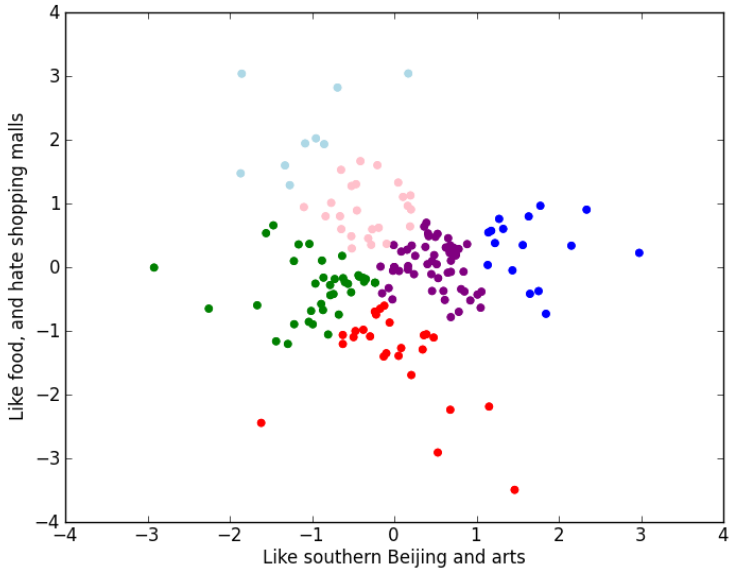
- Calinski Index
  - $\frac{\text{Between Cluster SS}/(K-1)}{\text{Within Cluster SS}/(N-K)}$
- The larger, the better
- No need to normalize



Visualization and analysis

- k = 6, PCA + KMeans

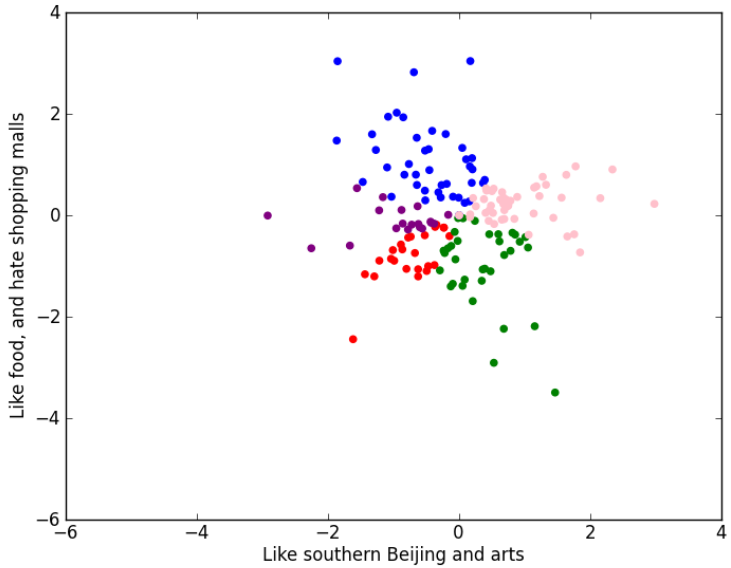




- KMeans cannot give stable results
- The data is not really suitable for clustering

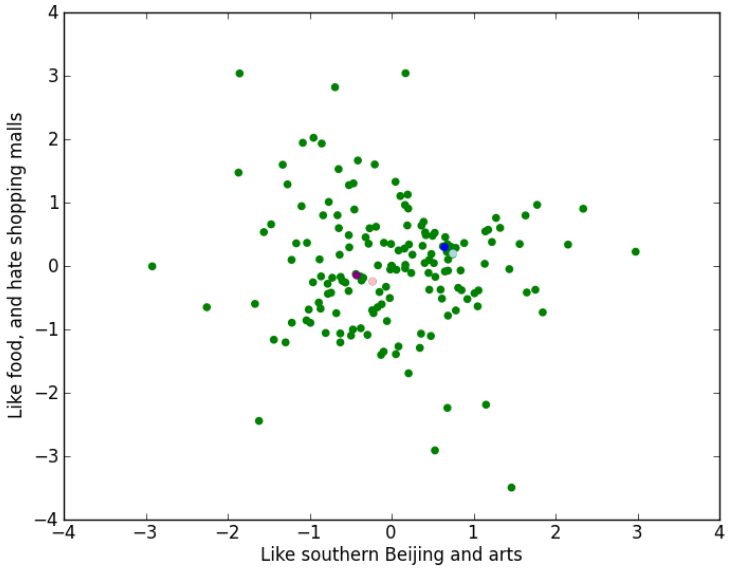
Visualization and analysis

- Affinity Propagation thinks there should be 5 clusters
- It can provide a stable result



Visualization and analysis

- Spectral Clustering provide non-sense results: one huge cluster with tiny "outlier" clusters.



- Actually a good method!

Conclusion

- What I did
  - Iterative feature design
    - For spatial-temporal data
    - Incorporate rich context of geographical data
  - Feature selection
    - Improve clustering performance
  - Clustering approaches comparison
- What I learned
  - *LOOK INTO THE DATA! IN EVERY STEP!*
    - Discover and solve problem efficiently
    - Solid practice
  - Ask why
    - Dig internal insights
    - Detect bugs

Thank you

- Slides and more demos available at
  - `http://lab.grapeot.me/`
- Discuss and contact
  - `https://www.facebook.com/grapeot/`