# PGT: Measuring Mobility Relationship using Personal, Global and Temporal Factors

Hongjian Wang, Zhenhui Jessie Li, Wang-Chien Lee
Penn State University

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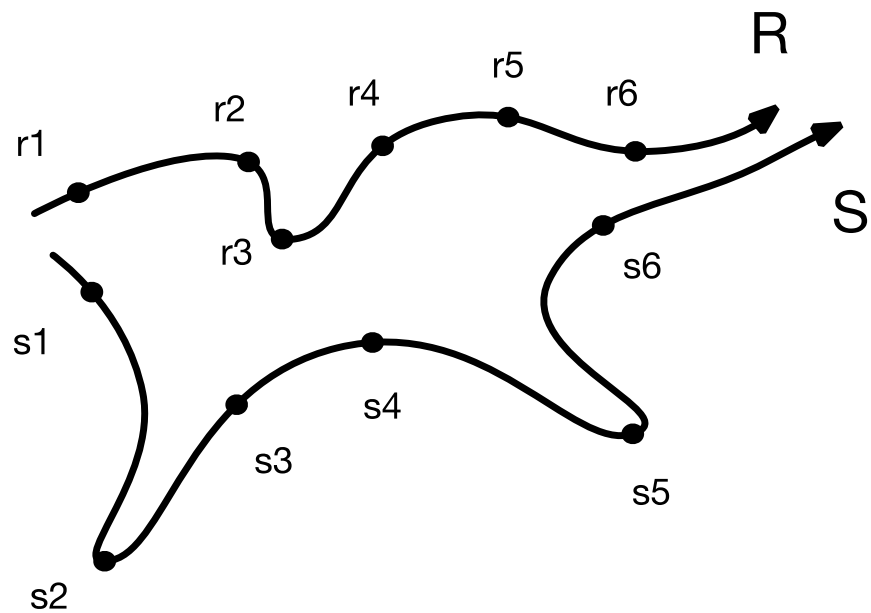
# Measure the Mobility Relationship Strength

- Given trajectories of two users, measure their relationship strength

| ID | Location | Time-stamp |
|---|---|---|
| R | 40.812, -77.856 | 2014-11-22 13:00:00 |
| R | 40.770, -77.855 | 2014-11-22 13:30:40 |
| R | 40.774, -73.975 | 2014-12-27 10:00:00 |
| … | … | … |




- Applications
  - Recommendation
  - Crime investigation

# Baseline Method -- Meeting Frequency

the more frequently you co-locate with another person,

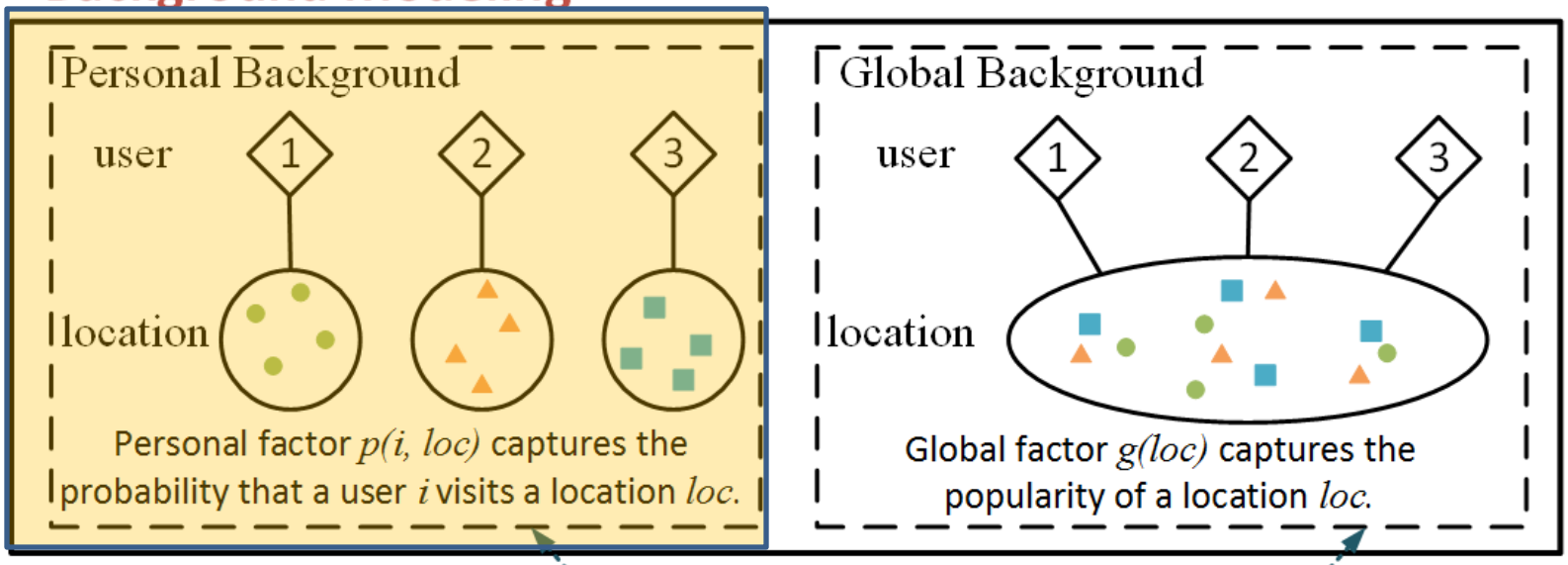
less frequently

the stronger the mobility relationship is.

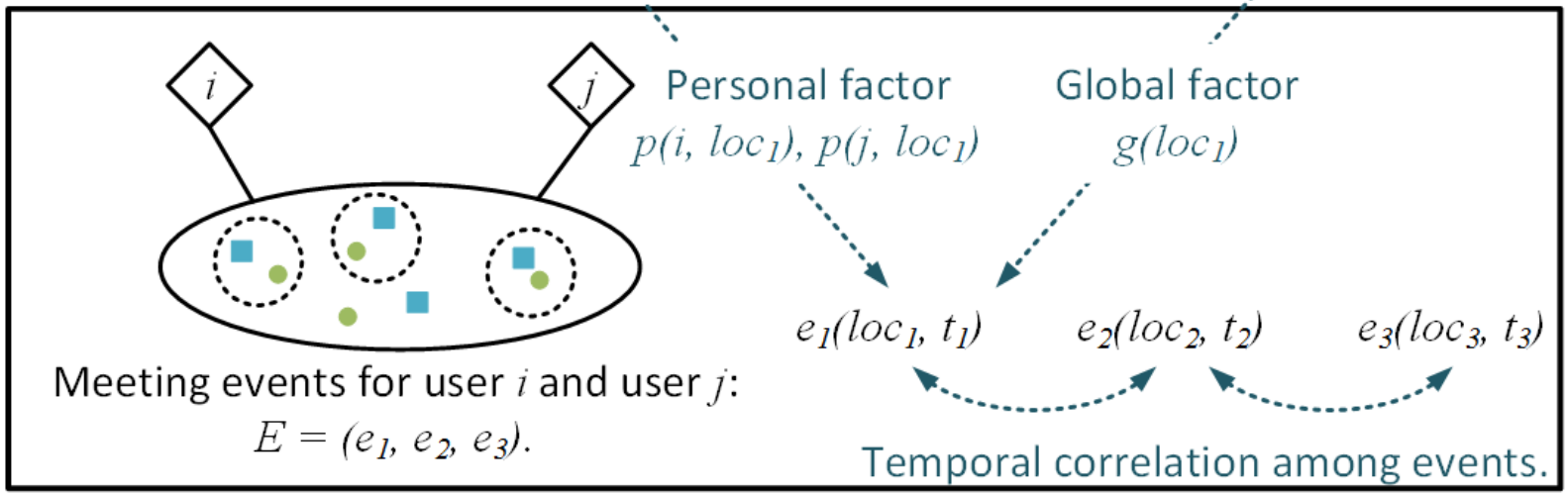
weaker

***Is this always true?***

## Background Modeling




## Mobility Relationship Mining



# Personal Background is Important

Meeting 3 times in Shanghai is less likely to happen.
It is happening, because of user's intention.

Co-location event in Shanghai should carry higher weight.

# Personal Background Formulation

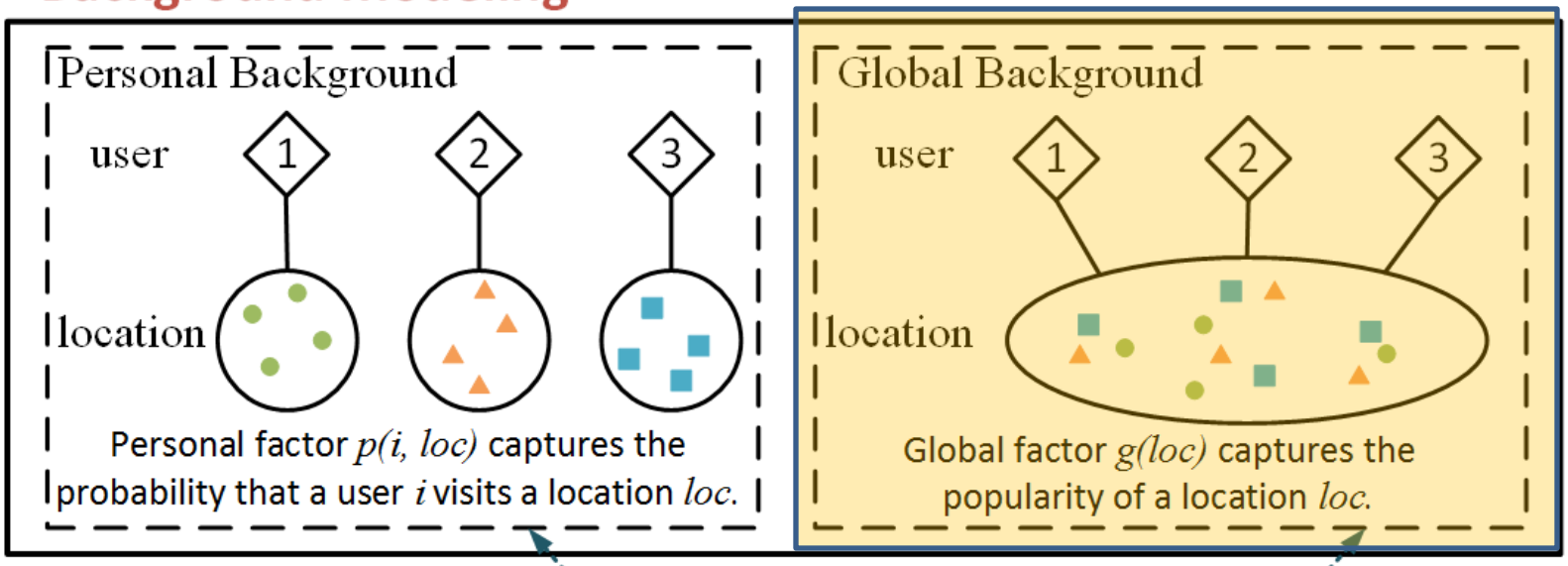
- For given user $i$, the probability of visiting location $loc_k$ is

$$\rho(i, loc_k) = \sum_{loc_q^i \in S_i} e^{-c \cdot \frac{dist(loc_k, loc_q^i)}{|S_i|}}$$

The visited location is far from others, the probability is low.

Distance Function

## Background Modeling

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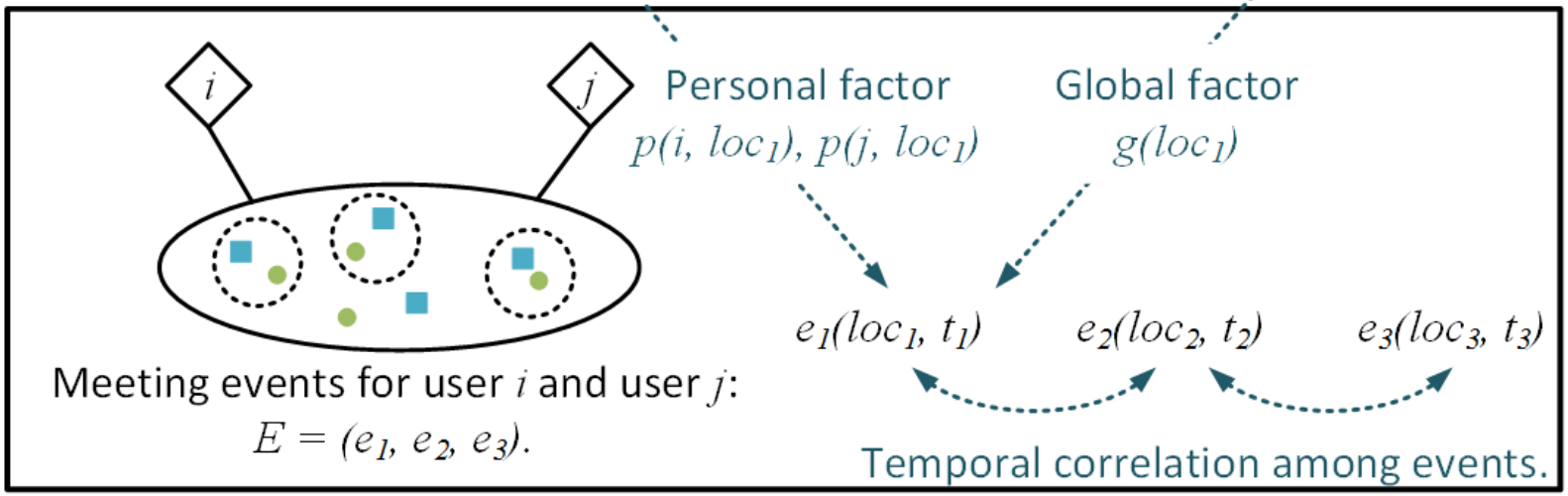


# Global Background Matters

- A and B meet in downtown for 10 times.
- C and D meet in D's house for 10 times.

Relationship(A,B) = Relationship(C,D) ?

# Global Background Formulation

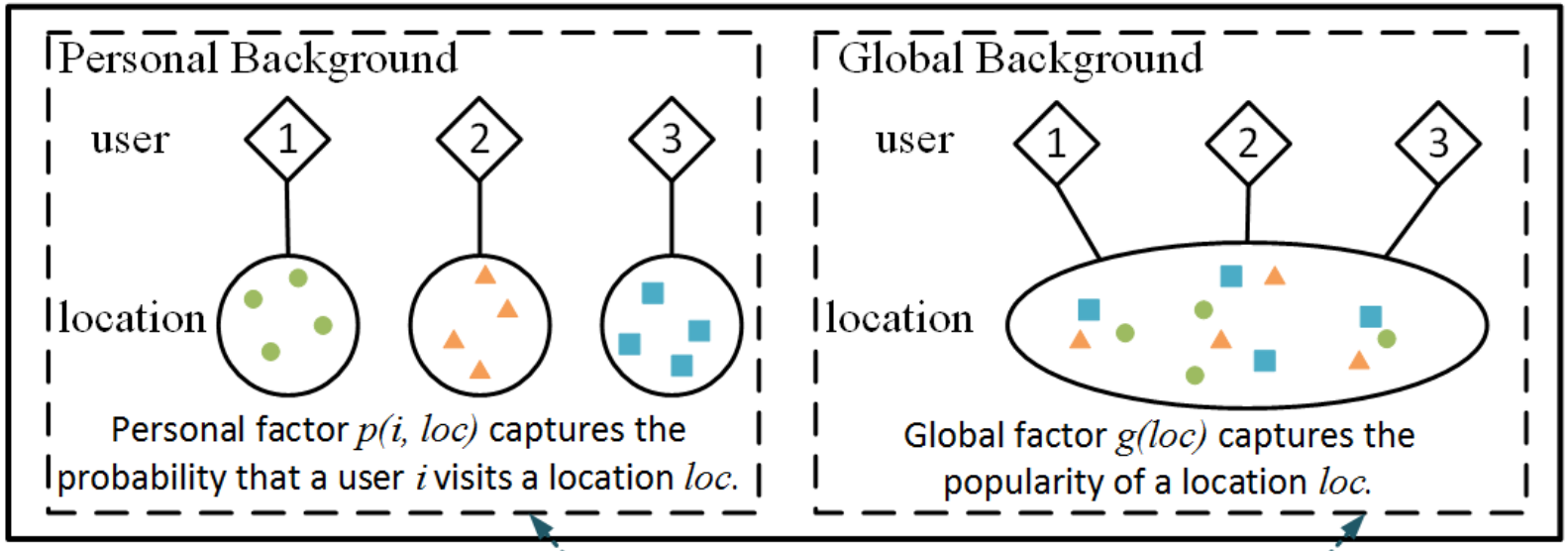
$$P(i, loc_k) = \frac{|S_i(loc_k)|}{\sum_i |S_i(loc_k)|}$$

At $loc_k$, the probability of observing different use *i*.

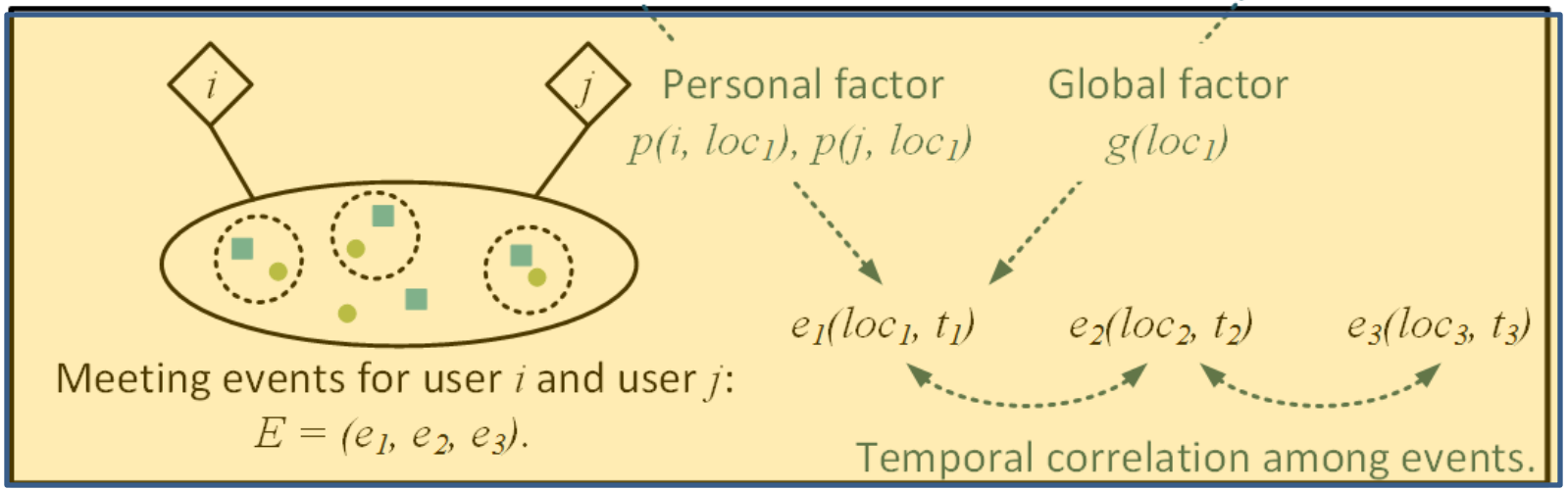
$$g(loc_k) = \sum_{i:P(i,loc_k)\neq 0} -P(i, loc_k) \cdot \log P(i, loc_k)$$

Entropy of $loc_k$.
Fewer users visited -> lower entropy -> more private location

## Background Modeling




## Mobility Relationship Mining



# Temporal Correlation Between Events

| | | | | |
|---|---|---|---|---|
| 03-26 10:00 | 03-26 11:20 | 03-26 14:30 | 03-26 15:36 | 03-26 15:37 |

Continuous meeting events → probably one-time trip?

| | | | | |
|---|---|---|---|---|
| 03-01 10:00 | 04-23 09:20 | 05-01 11:30 | 06-21 10:46 | 06-26 08:37 |

Sporadic meeting events → a stronger relationship indication

# Related Work

- Co-location frequency as measure (without considering background):
  - ***Kalnis et al. SSTD, 2005***
  - ***Jeung et al. VLDB, 2008***
  - ***Li et al. VLDB, 2010***
  - ***Cranshaw et al. Ubicomp, 2010.***
  - ***Zheng et al. ICDE, 2013***
- Global factors: ***Pham et al. SIGMOD, 2013.***
- Personal factors: ***None***
- Temporal factors: ***None***

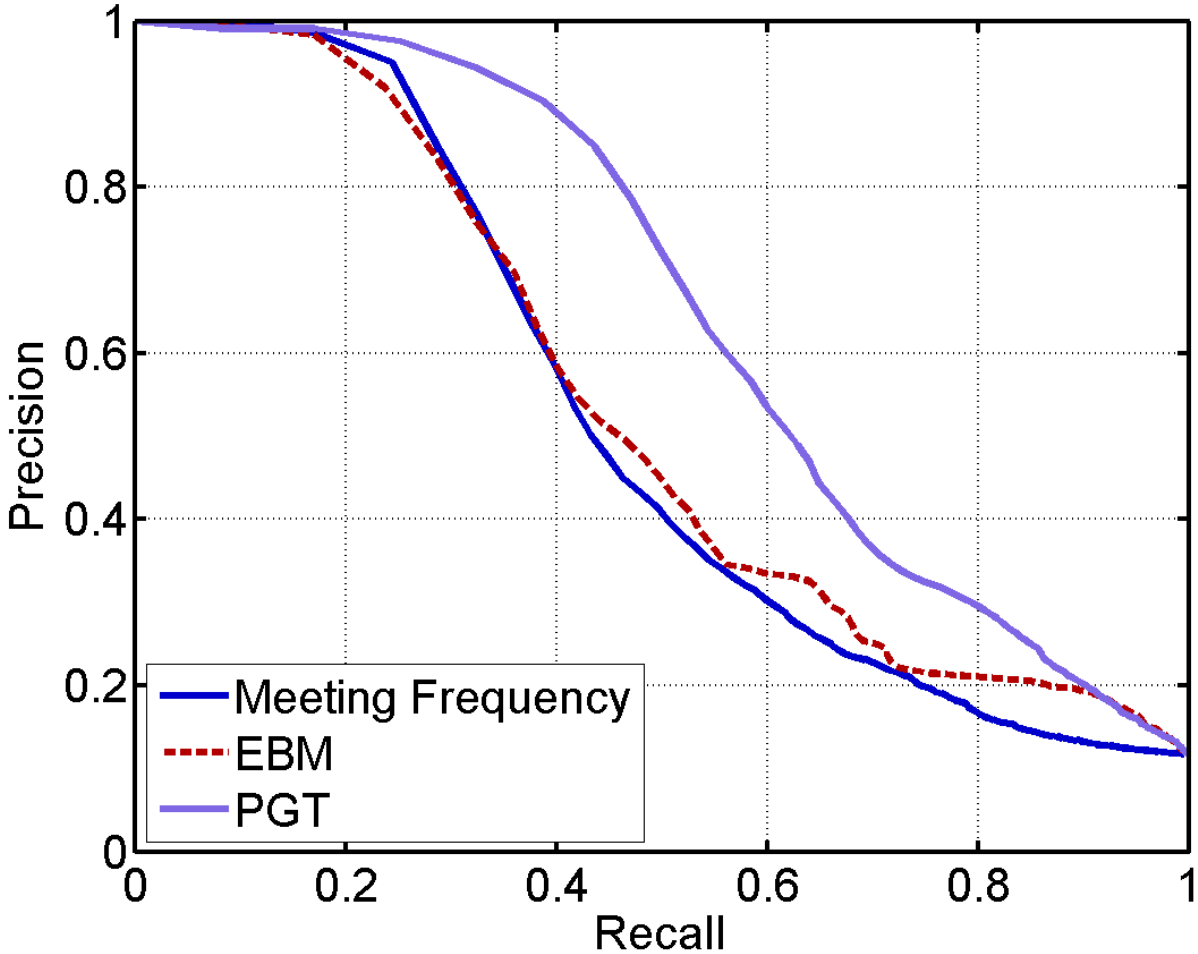
# Experiments

- Dataset – location-based social networks check-in data*
  - Gowalla (Feb, 2009 – Oct, 2010)

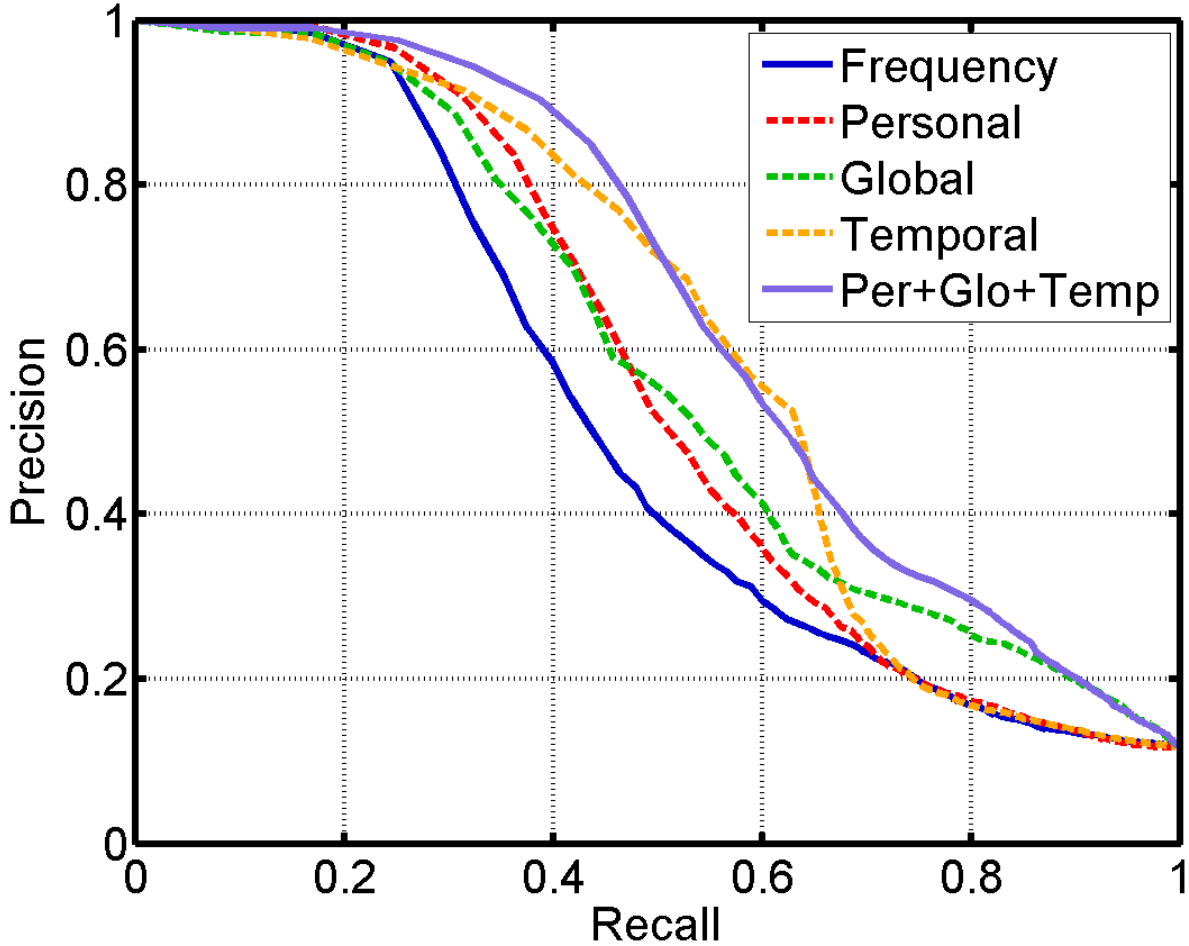
| | Gowalla |
|---|---|
| No. of users | 107,092 |
| No. of friend pairs | 950,327 |
| No. of check-ins | 6,442,890 |
| Average check-ins per user | 60 |

**** E. Cho, S. A. Myers, and J. Leskovec, "Friendship and mobility: user movement in location-based social networks," in Proc. KDD, 2011.***

# Experiments: Compare with the State of the Art on Gowalla

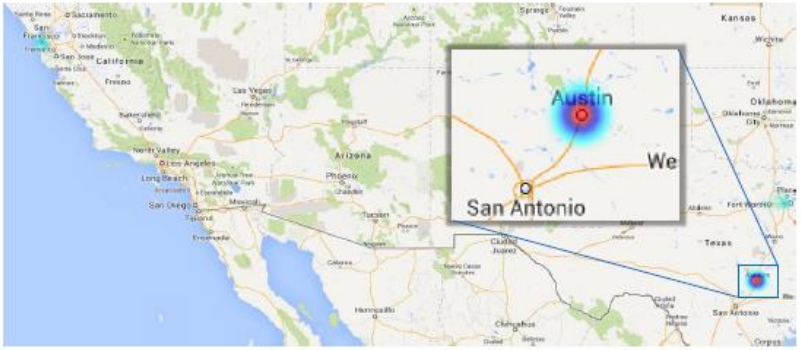


# Experiments: Compare Various Factors




**The precision-recall curves on top 5000 users from Gowalla.**

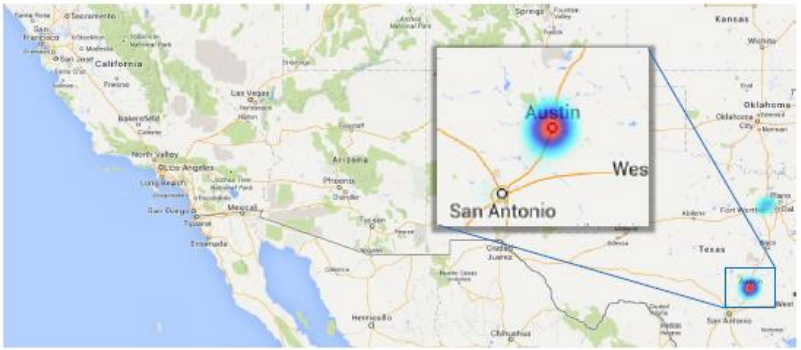
# Case Study: Personal Factor Works




(a) User #267

(b) User #510

***Friend***




(c) User #350

(d) User #6138

***Not***

# Summary

- We propose a unified framework to measure the strength of relationship based on two users' mobility.
- Our model is simple and deterministic, which considers:
  - Personal probability visiting a location
  - Location popularity from general public
  - Temporal correlation among co-locations

# Future Work

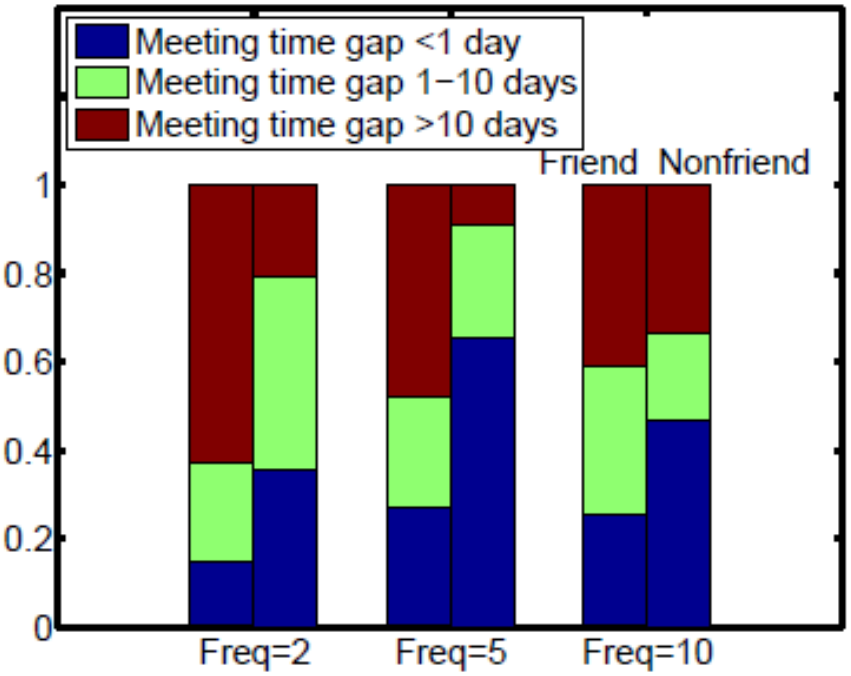
- Extend this work from identifying pairwise relationships to discovering common interest groups.
- Further combine the semantic context at each location, such as the Point of Interest (POI) at that location.

***Thank you!***

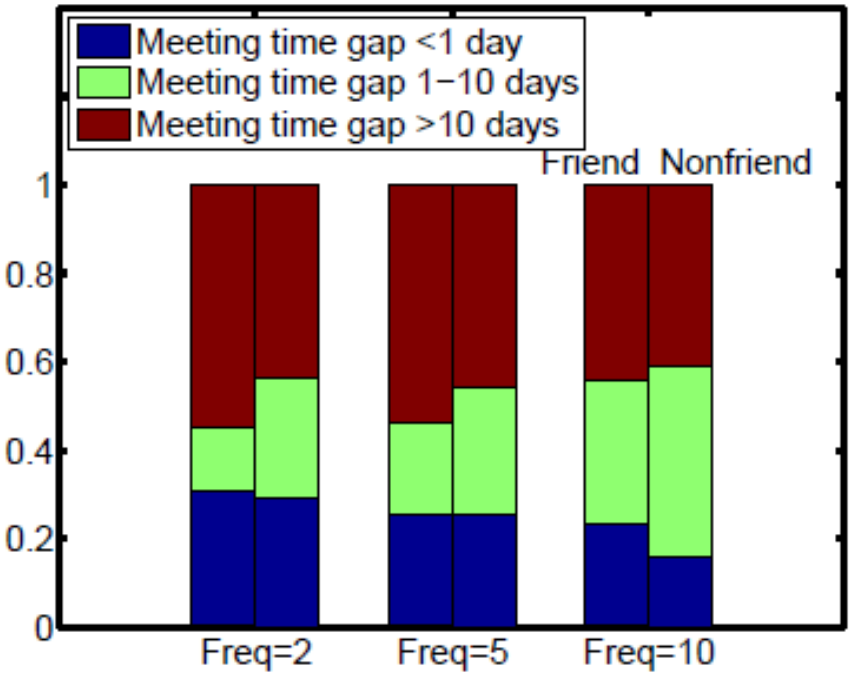
# Dataset Properties

- The Gowalla users tend to check-in at featured spots, and recommend places and trips for others.
- The Brightkite users tend to check-in with acquaintance to maintain personal social circle.
- As a result, check-ins in Gowalla are mostly made on popular places.

# Datasets Have Different Properties




(a) Gowalla




(b) Brightkite

**The distribution of time gaps between consecutive meeting events for three representative groups (meeting frequency = 2; 5; 10).**

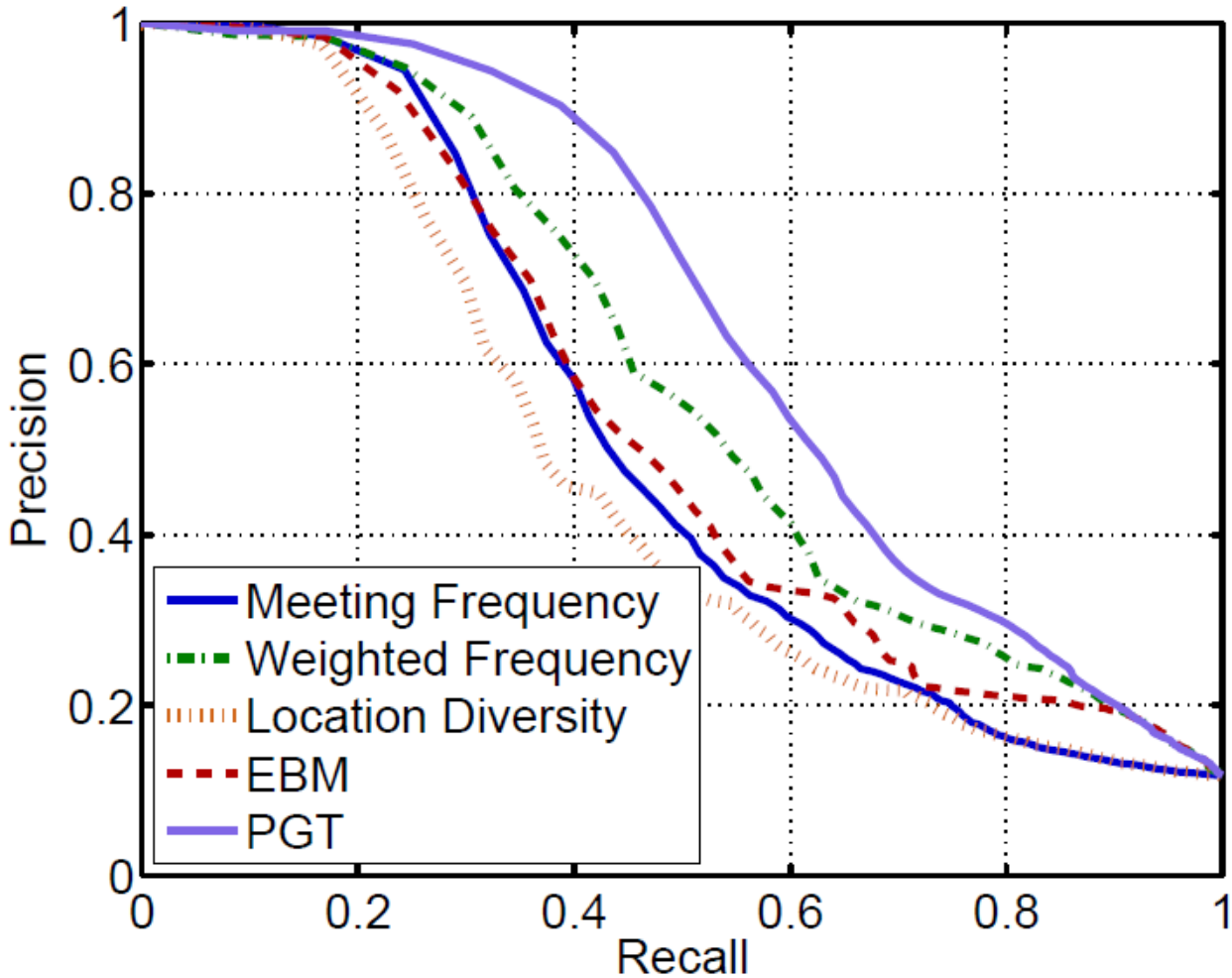
# Social Relation From Geospatial Data

- Diversity of co-locations

**Table 1: Example of Diversities**

| Co-occurrence Vector | Shannon Entropy | $D_{ij}$ Value | Diversity | Likelihood of Coincidences | Prob. of a Friendship |
|---|---|---|---|---|---|
| $C_{12} = (1, 1, 1, 1, 1, 0, 0, 0, 0, 0)$ | 1.609 | 5.000 | High | Low | High |
| $C_{23} = (1, 2, 1, 1, 0, 0, 0, 0, 0, 0)$ | 1.332 | 3.789 | Medium | Medium | Medium |
| $C_{13} = (0, 0, 4, 0, 0, 0, 0, 0, 0, 0)$ | 0.000 | 1.000 | Low | High | Low |

High diversity -> high probability of friendship

***H. Pham, C. Shahabi, and Y. Liu, "Ebm: An entropy-based model to infer social strength from spatiotemporal data," in Proc. SIGMOD, 2013.***

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