

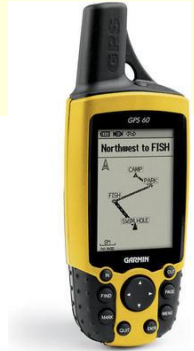


# Location Recommendation & Route Planning

H.P. Hsieh  
NCKU EE

# Sources of Geo-Social Location Data

- GPS Devices
  - In-car GPS
  - Personal GPS logger
- Location-based services + mobile phone
  - Check-in actions and records
  - E.g. Facebook, Foursquare, Twitter
- Digital Camera
  - Geo-tagged photos
  - E.g. Flickr, Instagram, Panoramio



Such user mobility records reveal how people travel around an area!

# User-Generated Geo-Locations

## ■ Geographical Footprints

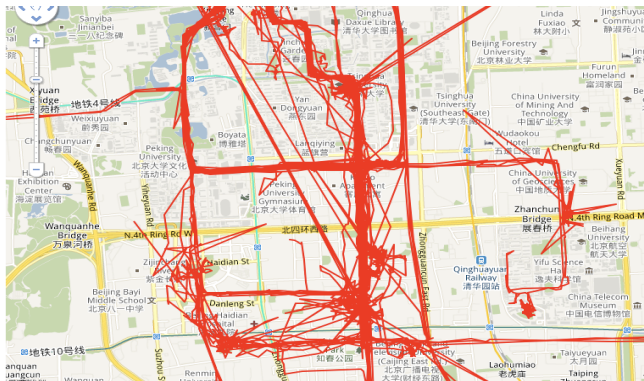
- A sequence/set of location data points with

- Latitude-longitude records
- Time stamps

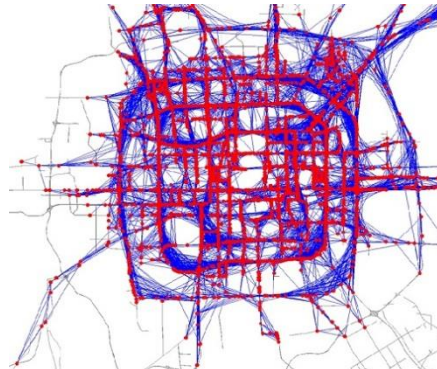
- Represent the spatial-temporal human activities

ID	Timestamp	Location
"Peter"	2010-04-02 13:12	37.5, -122.5
"Peter"	2010-04-02 15:22	37.2, -123.5
...	...	...

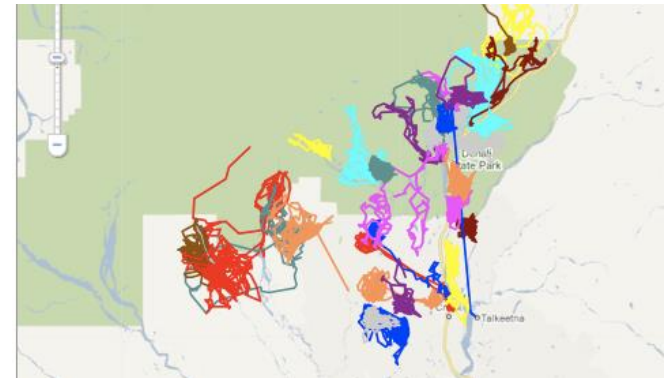
Human movement



Taxi movement



Animal movement





# Location Recommendation

- This is my first time visiting Florence, where are the best to go?



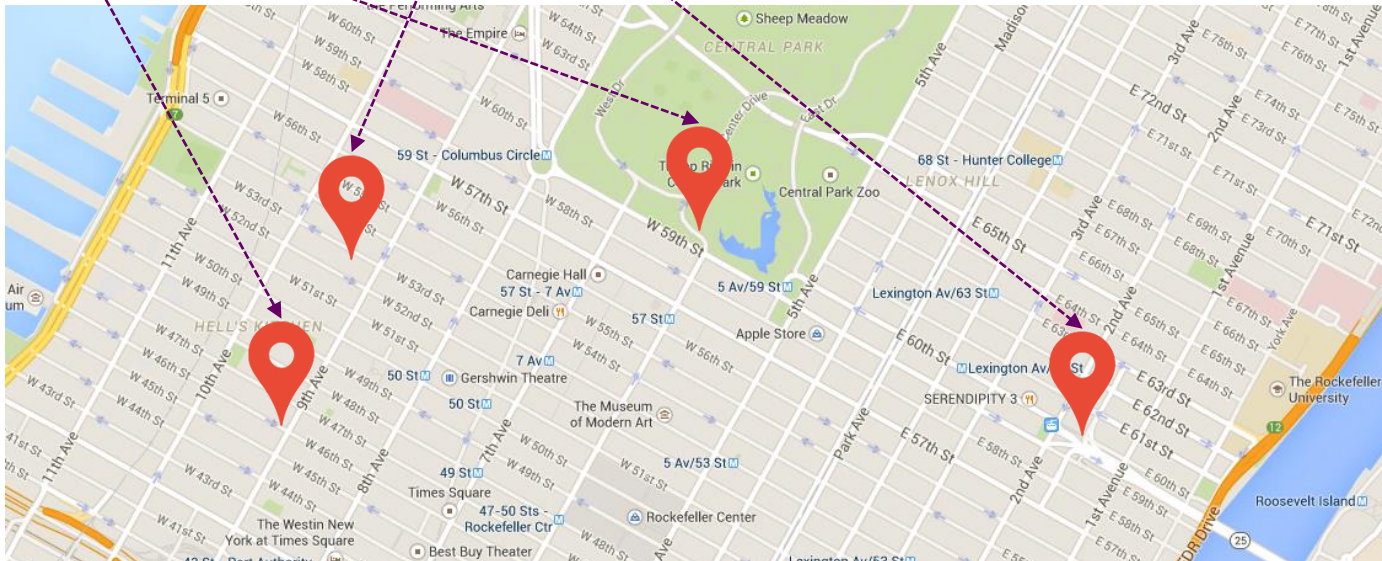
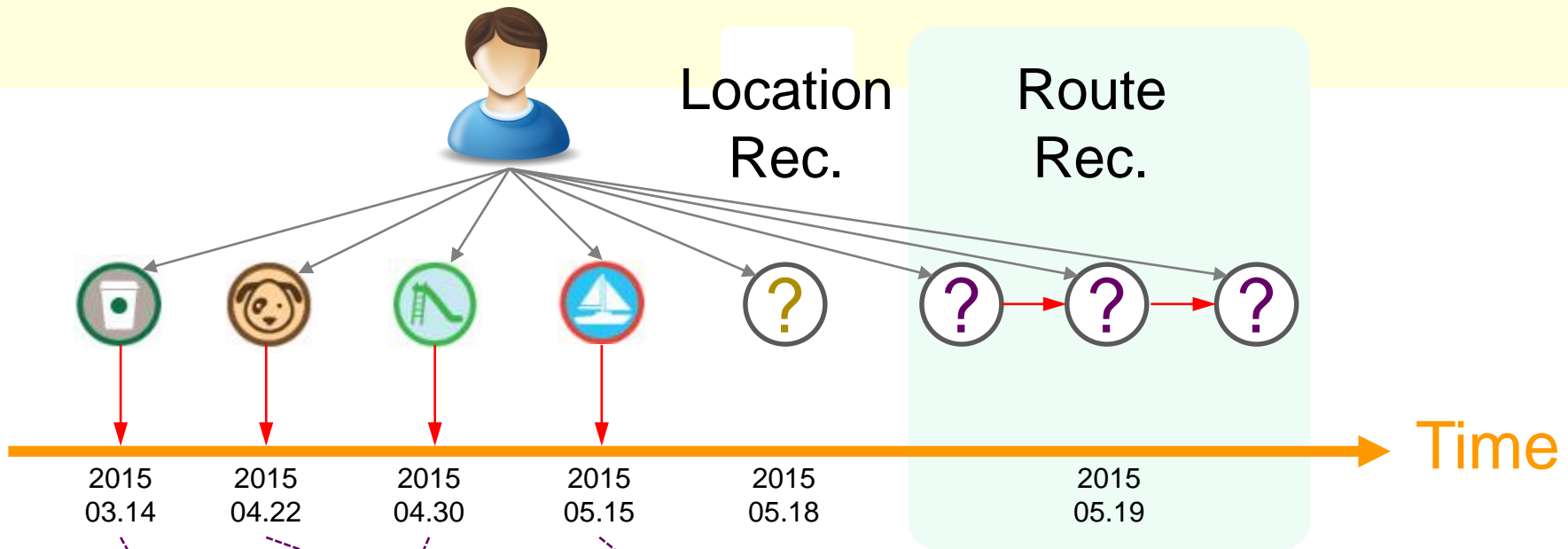
- It's dinner time now. Which one should I choose among thousands of restaurants?



# Location & Route Recommendation

- Location, Point-of-Interest (POI), Venue
  - A geographical point with specific function that users may find useful or interesting
    - E.g. restaurant, store, landmark
- Given
  - A set of historical user-generated location data
  - Query/Requirement: depict the user needs
    - Information about the desired places → Location Rec.
- Recommend → Route Rec.
  - A set of locations/venues/POI
  - A sequence of locations/venues/POI
    - Satisfy the query requirements as much as possible

# Location & Route Recommendation



# Location Recommendation vs. Location Prediction

- Location Recommendation
  - Recommend **NEW** locations (**never visited before**)
- Location Prediction
  - Predict the next **existing** locations (**had ever visited**)
- General considered factors
  - Current location info
  - Current time
  - User history/preference
  - Social interaction

Route Planning can be viewed as the **successive** applications of location recommendation.



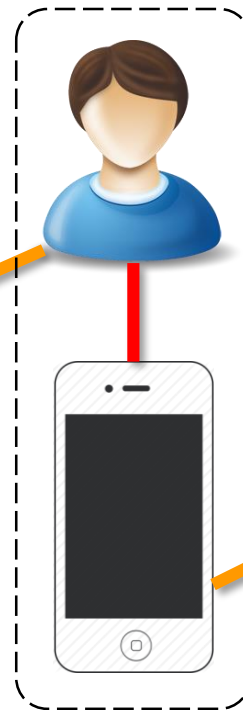
# Location/Route Rec on Geo-Social Media

- User **check-in** actions bridge the **geo-social gap** between real world and online social network

Real World



Check In

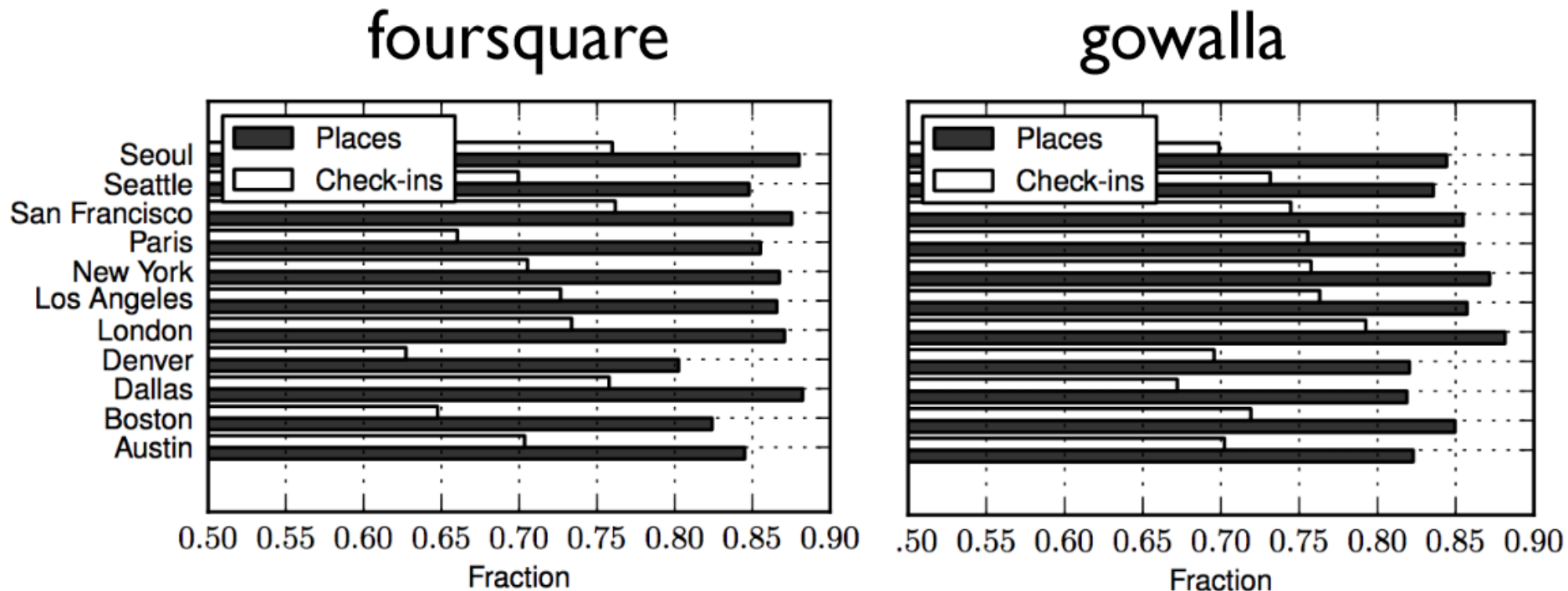


Online Social Network





# Check-in at New Venues

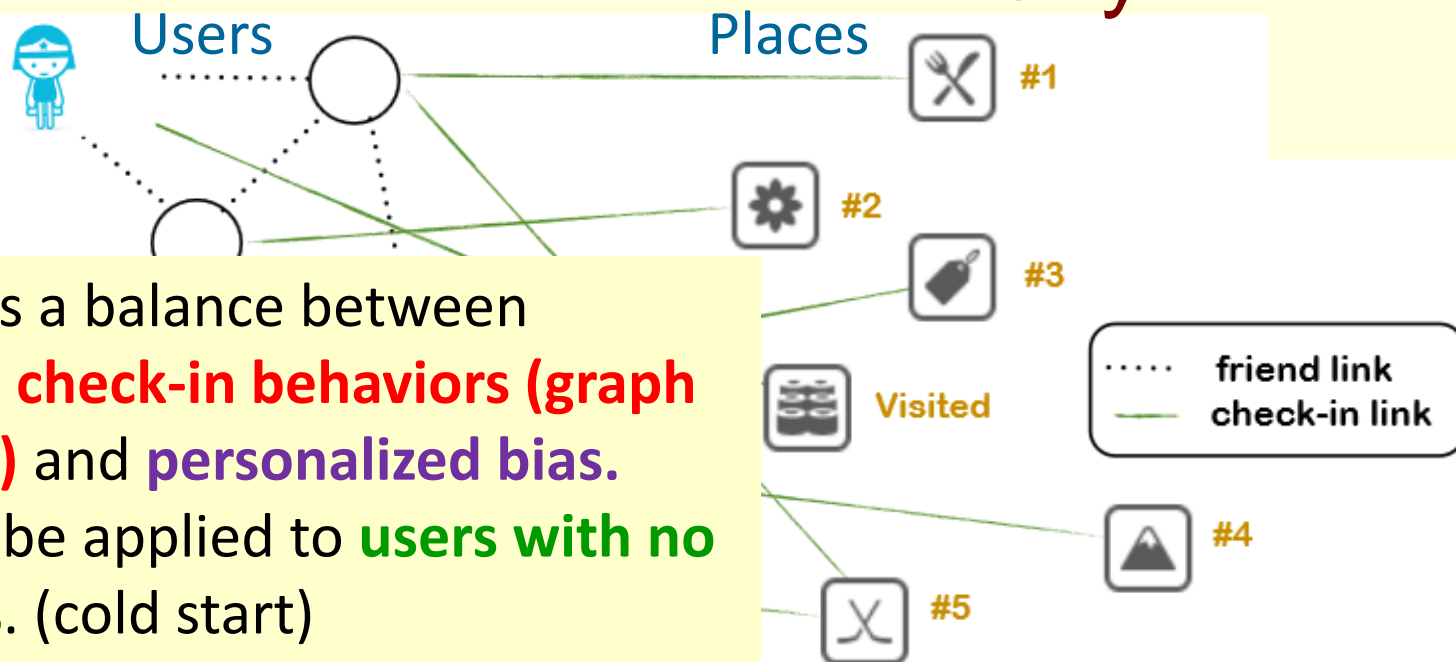


- People seek to discover new locations
  - 80%-90% of visited places are new
  - 60%-80% of check-ins occur at new places

# General Location Rec Strategies

- **Popularity**: rank locations using # of check-ins
- **Content Filtering**: using venue type preference
- **Social Filtering**: rank locations using # of check-ins by friends
- **Home Distance**: geo-distance from home
- **K-NN User Similarity** (CF)
- **Place Network** (Item Similarity)
- **Matrix Factorization**

# A Random Walk Around The City



1. RWR finds a balance between collective **check-in behaviors (graph structure)** and **personalized bias**.
2. RWR can be applied to **users with no check-ins**. (cold start)

Method	APR	Precision@10	Recall@10	Foursquare			Gowalla	
				City	popularity	rwr	popularity	rwr
Random	0.500	0.000	0.003	Austin	0.235	0.222	0.175	0.144
Popular	0.228	0.026	0.089	Boston	0.204	0.196	0.313	0.258
Activity	0.228	0.025	0.087	Dallas	0.247	0.232	0.248	0.197
Home	0.383	0.008	0.026	Denver	0.233	0.200	0.285	0.236
Social	0.392	0.015	0.049	London	0.264	0.262	0.311	0.244
kNN	0.443	0.003	0.011	Los Angeles	0.212	0.196	0.281	0.242
PlaceNet	0.337	0.026	0.077	New York	0.192	0.185	0.280	0.242
MF	0.281	0.004	0.014	Paris	0.265	0.256	0.271	0.204
RW	0.217	0.028	0.094	San Francisco	0.208	0.200	0.220	0.183
				Seattle	0.238	0.218	0.264	0.226
				Seoul	0.210	0.226	0.410	0.381
				Average	0.228	0.217	0.278	0.232

# Tutorials on Location Recommendation

- Jiliang Tang, Jie Tang, Huan Liu.  
Recommendation in Social Media. @ ACM KDD 2014.
- Huiji Gao, Jiliang Tang, and Huan Liu.  
Personalized Location Recommendation on Location-based Social Networks. @ ACM RecSys 2014.
- Yu Zheng.  
Location-based Social Networks. @ WWW 2012.

## Survey Papers:

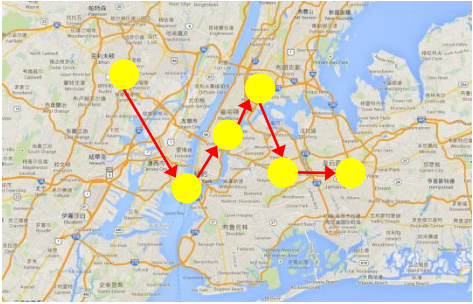
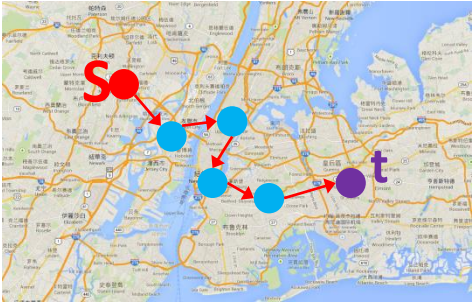

A. Noulas, S. Scellato, N. Lathia, C. Mascolo: A Random Walk around the City: New Venue Recommendation in Location-Based Social Networks. SocialCom 2012.

Jie Bao, Yu Zheng, David Wilkie, and Mohamed F. Mokbel. A Survey on Recommendations in Location-based Social Networks. Geoinformatica 2014.

Yonghong Yu and Xingguo Chen. A Survey of Point-of-Interest Recommendation in Location-Based Social Networks. AAAI Trajectory-based Behavior Analytics Workshop 2015.



# Route Recommendation: Examples

Query	Preferable Routes	Illustration
<ol style="list-style-type: none"> <li>1) A set of locations</li> <li>2) Time span of route</li> </ol>	<p>A route pass through these locations within time span</p>	
<ol style="list-style-type: none"> <li>1) A source loc.</li> <li>2) A destination loc.</li> <li>3) A number of route length</li> </ol>	<p>A route starting from source and arrive at the destination, with length satisfied</p>	
<ol style="list-style-type: none"> <li>1) A city or an area</li> <li>2) A set of labels of interests</li> </ol>	<p>A route in such area, which contains locations possessing such labels</p>	<p>Query: ▲ ◆ ★</p> 

# Category of Geo-Social Trajectory Data

	GPS Trajectory	Uncertain Trajectory
<b>Data Source</b>	GPS recorders, in-car GPS tracer	Check-in actions in LBS Meta info in Geo-tagged Photos
<b>Data Points</b>	Simply Geographical Coordinates Points	Point of Interests (POI) e.g. landmark, restaurant
<b>Property</b>	Smoothly and continuously record every fixed distance/time period	Discretely and sparsely performed by users in LBS and taken by cameras
<b>Sample Rate</b>	<b>High</b>	<b>Low</b>

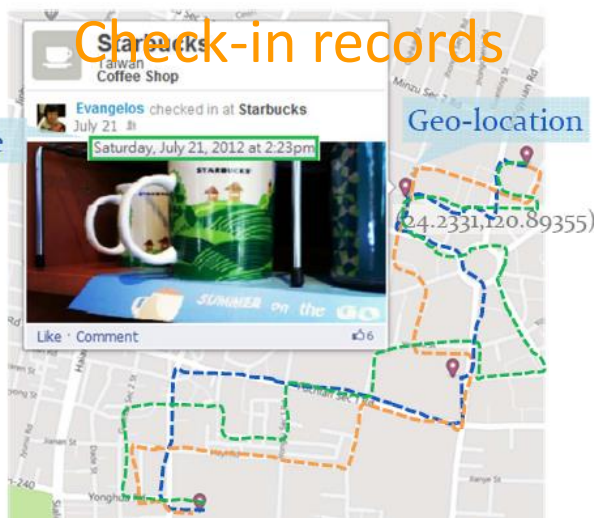
# Challenges on Route Recommendation

## ■ GPS Trajectory

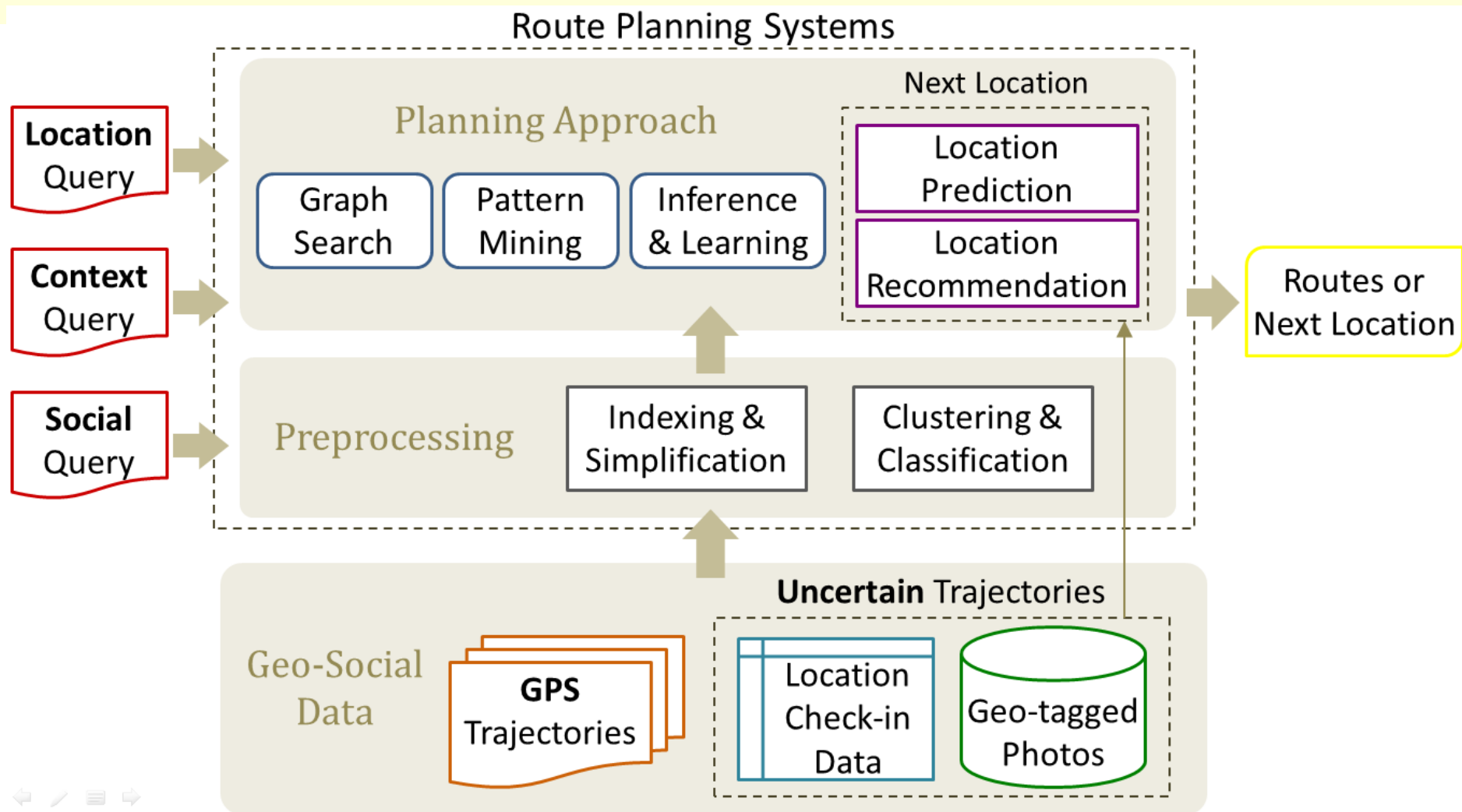
- How to find meaningful and/or popular places?
- How to tackle efficiently million-scale geo-data points for query processing?

## ■ Uncertain Trajectory

- Do not detail the sequences of movement
- Raise **uncertainty** between consecutive points



# Route Planning: Overview

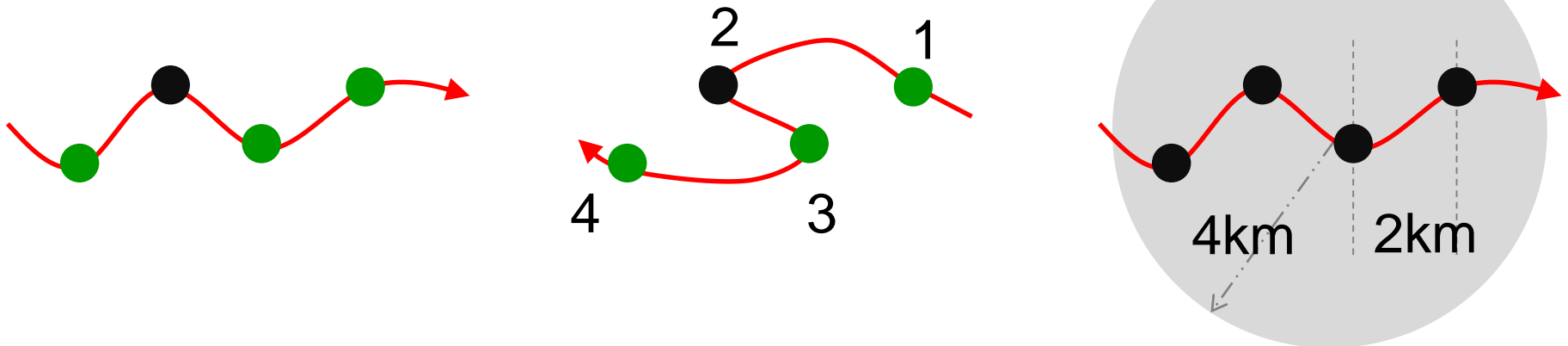




# Route Query: Location Query

## ■ Location Query

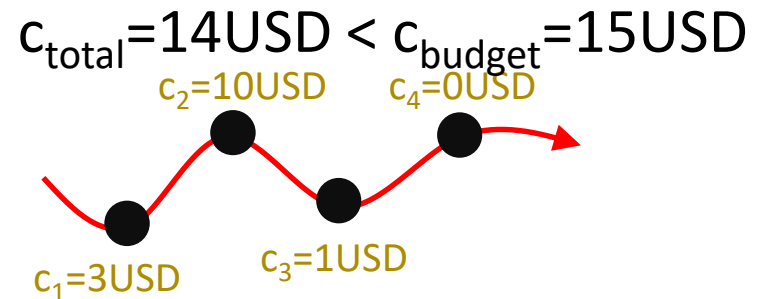
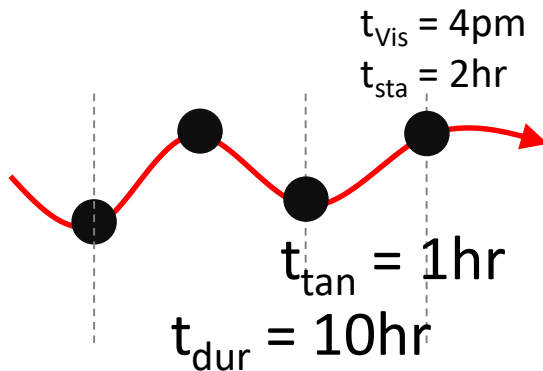
- **Required Locations**: needed to be pass thru
- **Visiting Order**: order of required locations
- **Geo-Distance**: geographical range or the tolerable distance between locations



# Route Query: Context Query

## ■ Context Query

- **Visiting/Stay Time**: whether the visiting time of a location is **proper** or the staying time of a location
- **Transit Time**: the time for transiting between locations
- **Travel Duration**: the total traveling duration in the route

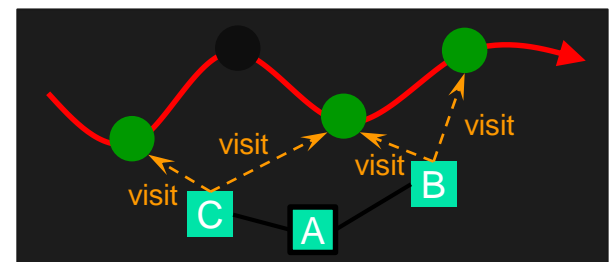
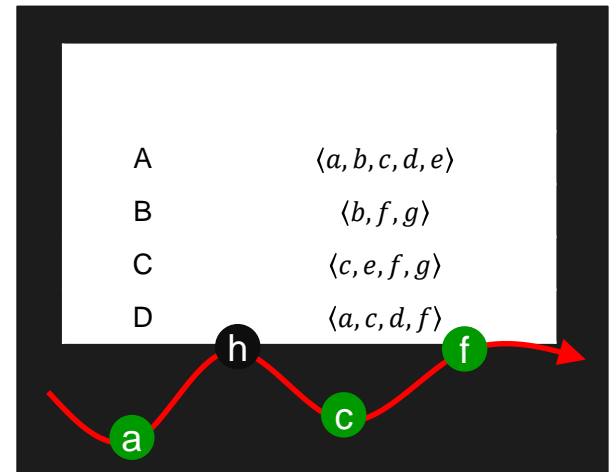
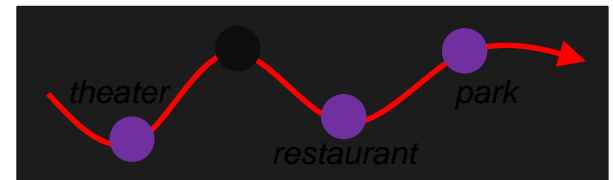
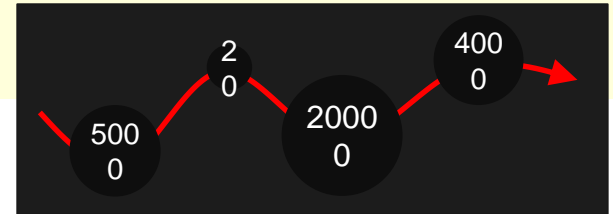
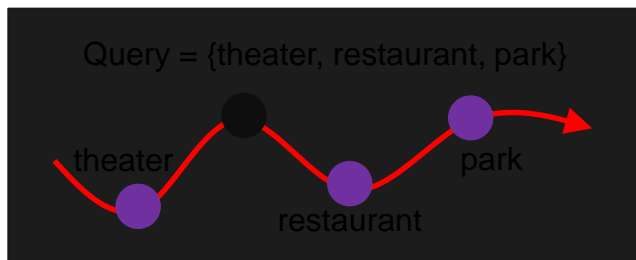


- **Financial Cost**: the budget of a route
- **Top-K retrieval**: whether or not to return top-k preferable routes

# Route Query: Social Query

## ■ Social Query

- **Popularity** of locations
- **User Preference:**  
whether or not to consider user's past visiting history
- **Group or Social factor:**  
group trips or the locations that friends had ever visited
- **Activity Labels:**  
specifying the labels or types of locations in the route



# Approaches & Advanced Tasks

## Approaches

### Graph Search

[Chen'11], [Zheng'11], [Wei'12]

### Pattern Mining

[Tang'11], [Zheng'12], [Tang'13]

### Prediction/Inference

[Jeung'08], [Xue'13], [Hsieh'14]

## Advanced Tasks

### Tackling Uncertainty

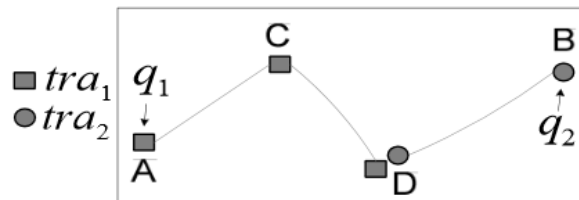
[Zheng'12], [Wei'12]

### Internal Routes

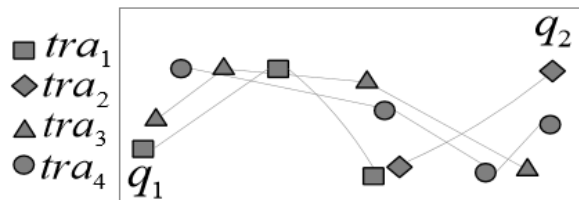
[Lu'11], [Tseng'12]

### Route with auxiliary info

[Cheng'11], [Cao'12]



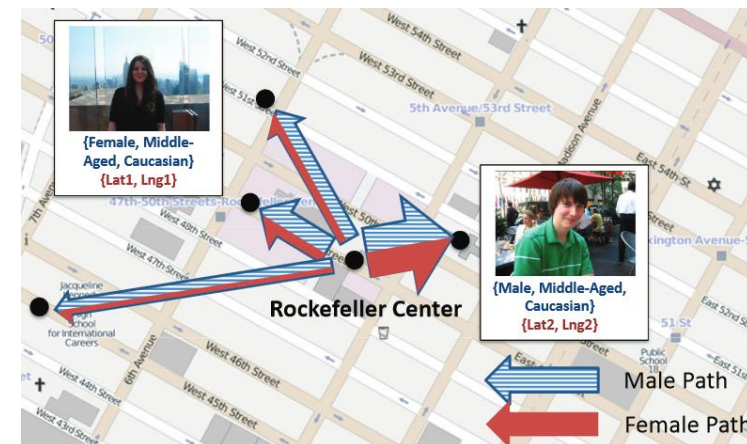
(a) Uncertain trajectories



(c) Uncertain trajectories



(b) A 3.5-hour path.





# Route Queries of Targeted Studies

		Location Query				Context Query				Social Query			
		QL	VO	DI	VT	TT	TD	CO	TK	PO	UP	GS	AL
GSP Trajectory Data	[Tang'13]	■		■			■				■	■	
	[Chen'11]	■		■			■						
	[Zheng'11]	■		■			■			■	■		
	[Tang'11]	■	■								■		
	[Jeung'08]	■			■								
	[Xue'13]	■					■						
Uncertain Trajectory Data	[Wei'12]	■		■			■				■		
	[Hsieh'14]	■		■	■	■	■	■					
	[Zheng'12]	■	■						■	■			■
	[Cao'12]	■				■	■			■	■		■
	[Lu'10]	■		■	■		■	■		■			

# Approach Overview: Graph Search

- Graph Construction G

Trajectory Data		Road Net
Nodes	Locations	Road Segments
Edges	Traversal	Intersection
Node Weights	Popularity / Satisfaction / Traffic	
Edge Weight	Transition Probability / Frequency	

- Design an **objective function**  $f(r)$  based on query, e.g.
  - E.g. visiting/transition popularity, label cover
  - With some **constraints**, e.g. travel time, financial cost
- Find a route/path  $r$  in  $G$  such that  $f(r)$  is optimized

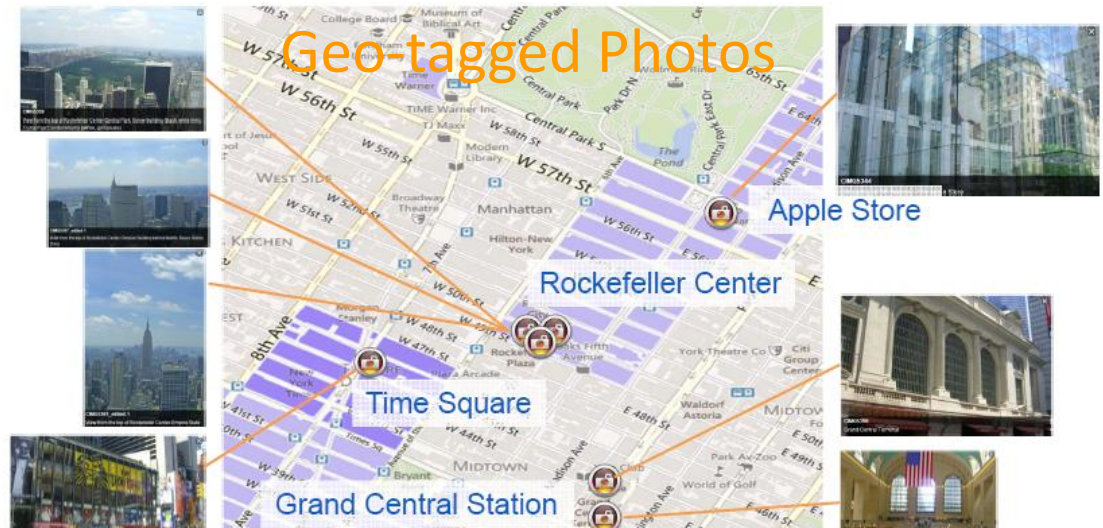
# Challenges on Route Recommendation

## ■ GPS Trajectory

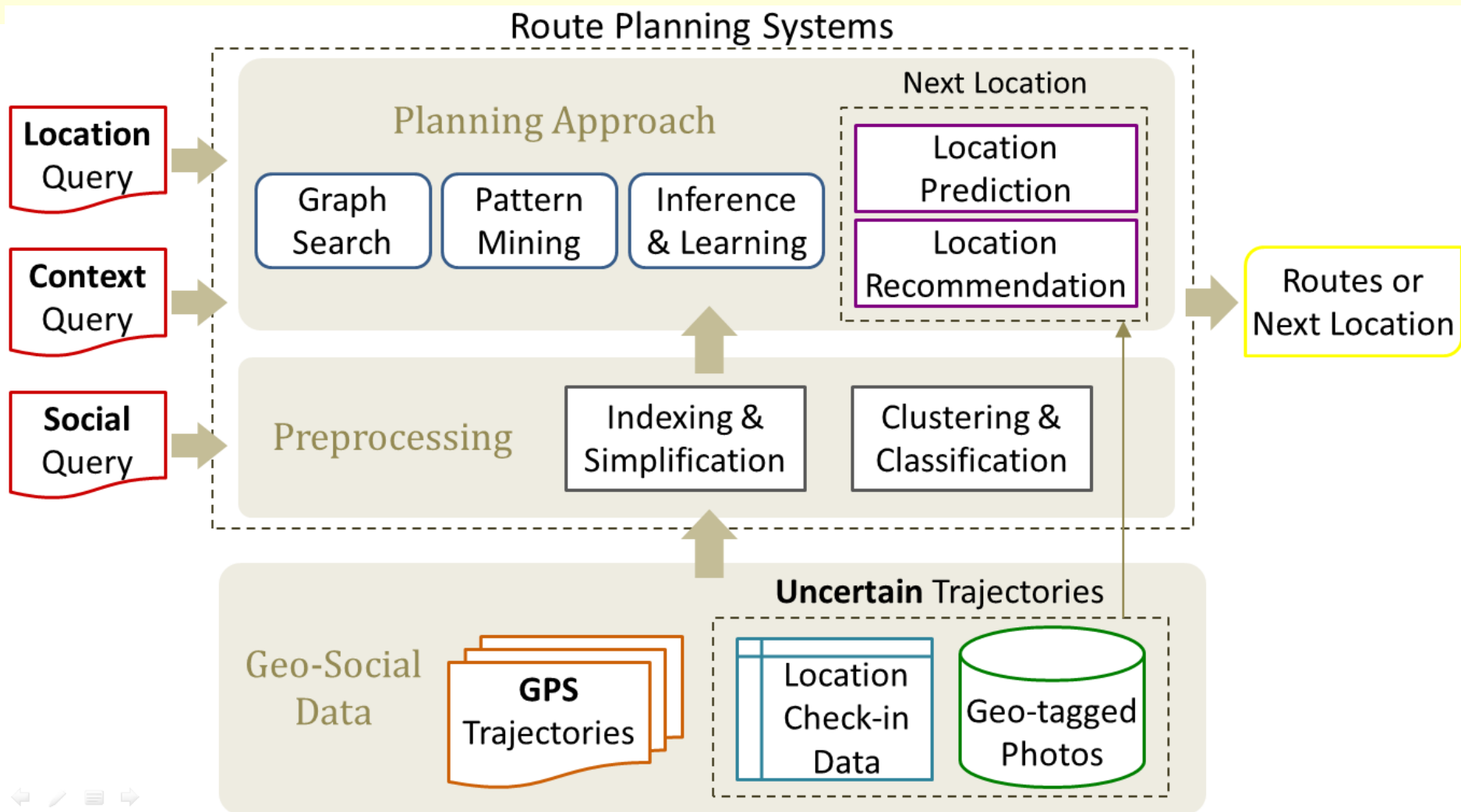
- How to find meaningful and/or popular places?
- How to tackle efficiently million-scale geo-data points for query processing?

## ■ Uncertain Trajectory

- Do not detail the sequences of movement
- Raise **uncertainty** between consecutive points



# Route Planning: Overview





# Approach Overview: Graph Search

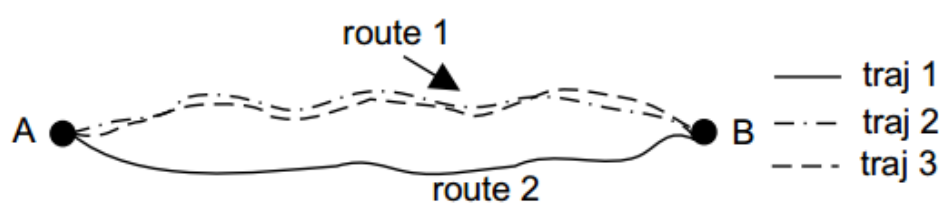
## ■ Graph Construction G

Trajectory Data		Road Net
Nodes	Locations	Road Segments
Edges	Traversal	Intersection
Node Weights	Popularity / Satisfaction / Traffic	
Edge Weight	Transition Probability / Frequency	

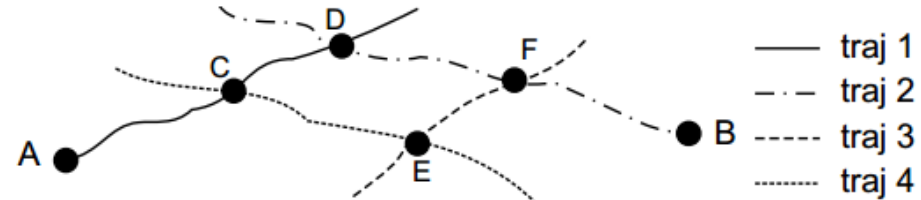
- Design an **objective function  $f(r)$**  based on query, e.g.
  - E.g. visiting/transition popularity, label cover
  - With some **constraints**, e.g. travel time, financial cost
- Find a route/path  $r$  in  $G$  such that  $f(r)$  is optimized

# Discovering Popular Routes

- Given a source and a destination location, find the **most popular route** in between



Count the number of trajectories on different paths connecting two locations

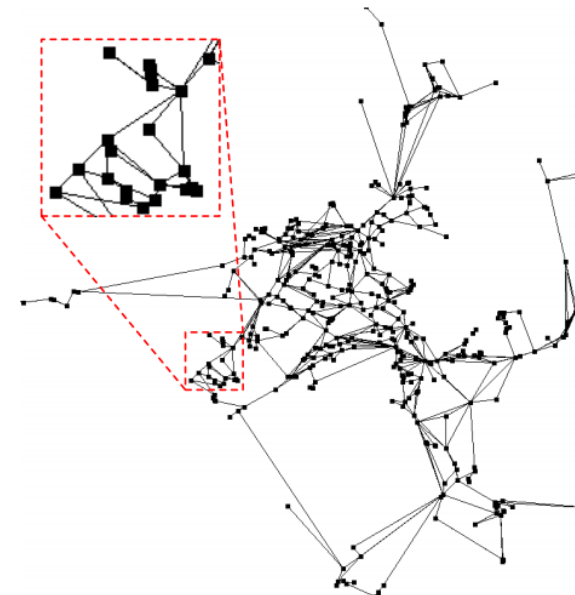


There could be no trajectory connecting two locations at all

- Construct a **transfer network**
  - Node: traj intersection, Edge: contiguous traj
  - Turning Probs on edges

$$Pr_d(n_i \rightarrow n_j) = \frac{\sum_{traj \in (n_i, n_j)} func(traj, d)}{\sum_{traj \in \text{all outgoing edges}} func(traj, d)}$$

- Extend **Dijkstra's algorithm** to find the route with highest probability



# Approach Overview:

## Pattern Matching/Mining

Each trajectory = a **sequence** of geo-points / locations

### ■ Pattern Mining

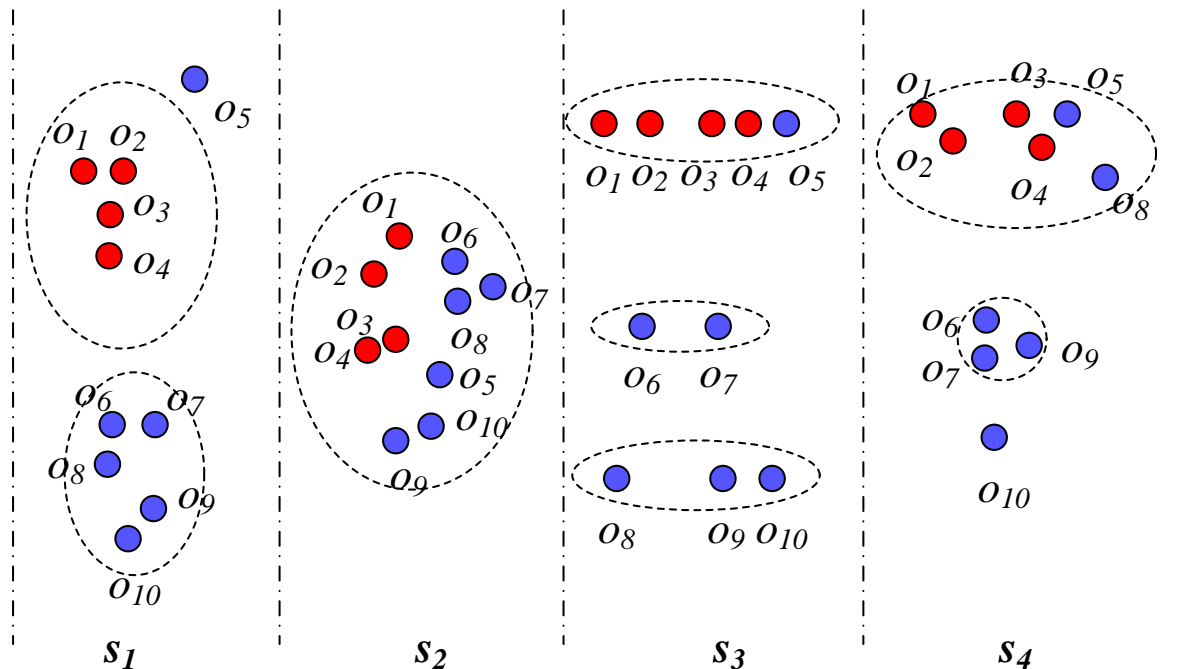
- Mining the **frequent subsequences** constrained by the query requirements
- Subsequence **Pruning**: keep closed ones (to save complexity)
- Subsequence **Merge**: from local route to global route

### ■ Pattern Matching

- Find individuals **with similar behaviors of movements**
- **Nearest-nearest query** processing (given some locations)

# Mining Traveling Companions

- Discover the **group of objects** that **move together** (with similar patterns of movements)
  - E.g. migration path, driving direction, travel paths
- Recommend routes from your companion
- **Clustering** objects and apply **sequential pattern mining**



Size threshold = 4  
Duration threshold = 4 snapshots

$\{o_1, o_2, o_3, o_4\}$  is the traveling companion

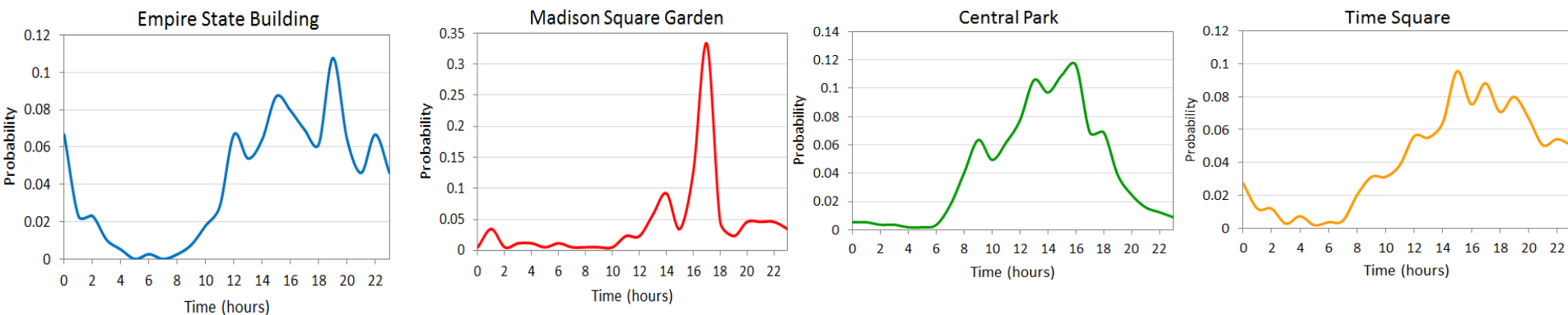
# Approach Overview:

## Recommendation/Prediction

- Given an existing sub-route, successively predict/recommend the next locations
  - **Till** the user requirement is satisfied
    - E.g. Route Length k, Travel Time. Arrive the destination
- Select the next locations
  - **Unsupervised** method
    - Location info. E.g. popularity, density, incoming flow
    - Estimate the probability  $P(\text{candidateLoc} \mid \text{curSubRoute})$
  - **Supervised** method
    - Choose a set of candidate locations
    - Extract route/Location-aware features
    - Apply supervised learning methods e.g. SVM

# Proper Visiting Time of a Place [Hsieh'14]

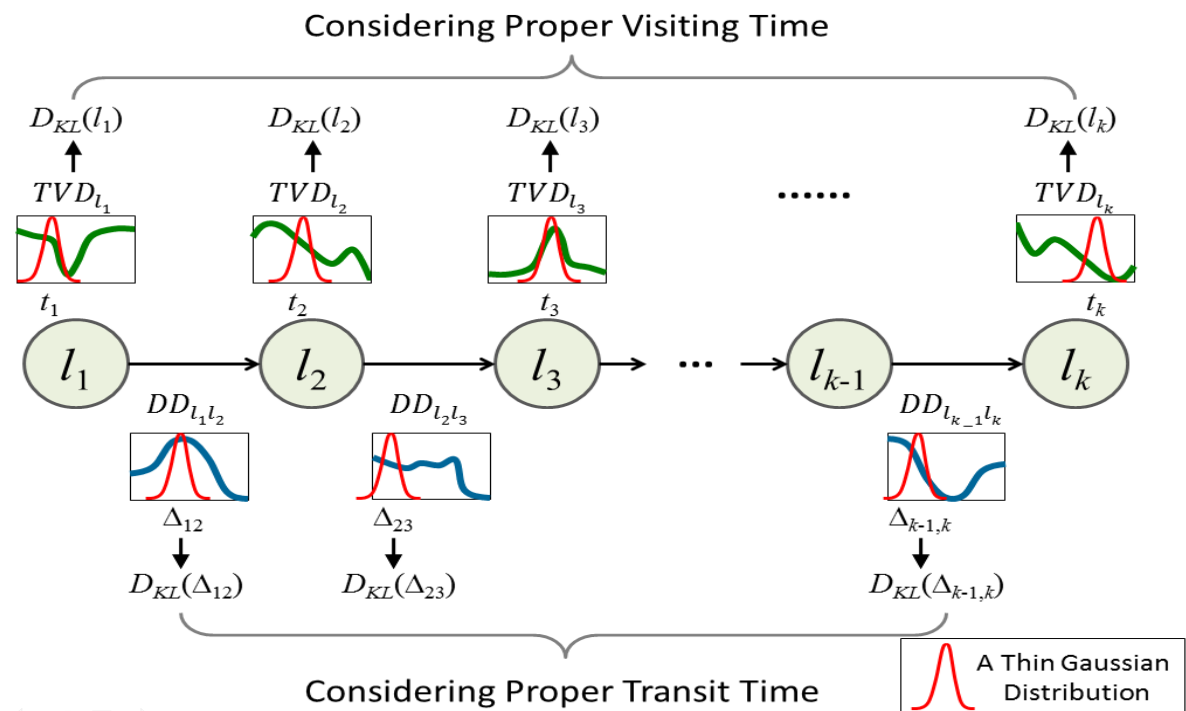
- Given a source and/or destination location, and the current time, can we recommend a route, in which each location can be visited with a **pleasant experience**
- Pleasant visiting of places should consider visiting time, e.g.
  - People usually visit the Empire State Building from about 12:00 to the mid night (night view is popular)
  - People tend to visit the Madison Square Garden in the early evening for a basketball game
  - The proper time to visit the Central Park is during daytime
  - Time Square is preferred from afternoon to midnight.





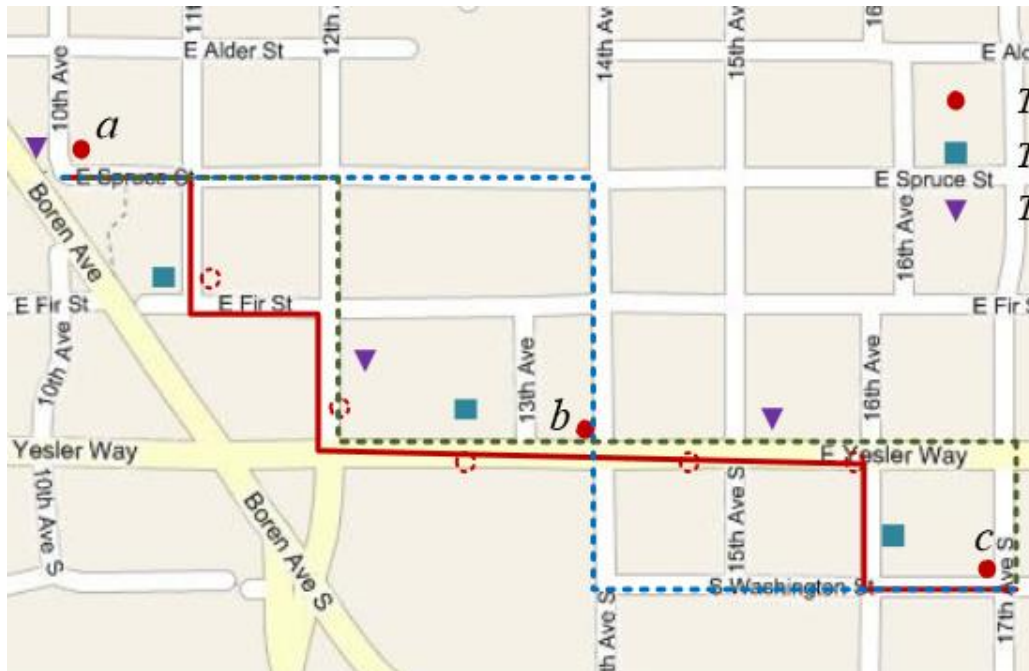
# Recommending Pleasant Routes

- Given a start location and time, recommend a route such that each location can be visited with the **best experience**
- **Successively predicting the next location**
  - Based on current location and time
- **Features**, e.g.
  - Geo-distance
  - Time difference
  - Transition time
  - Popularity
  - Transfer probability
  - Location category

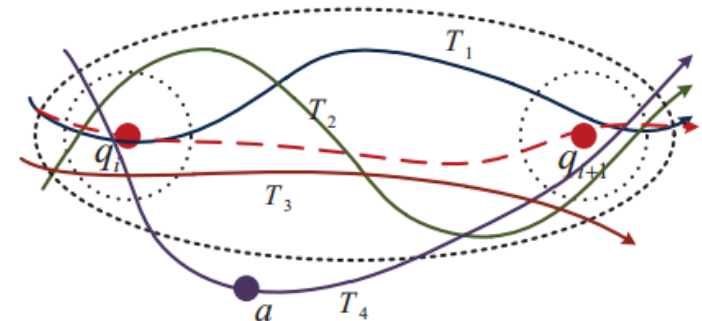


# Advanced Task: Tackling Uncertainty

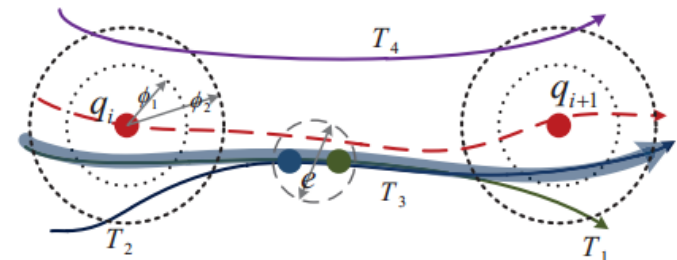
- Sequences of check-in data are uncertain, discrete, and considered as **low-sampling rate** routes
- Given the original check-in sequences, can we estimate its original route from the samples?



Simple Reference trajectory



Spliced Reference trajectory



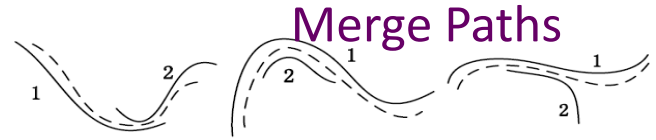
# Advanced Task: Internal Routes

## ■ Real Scenarios

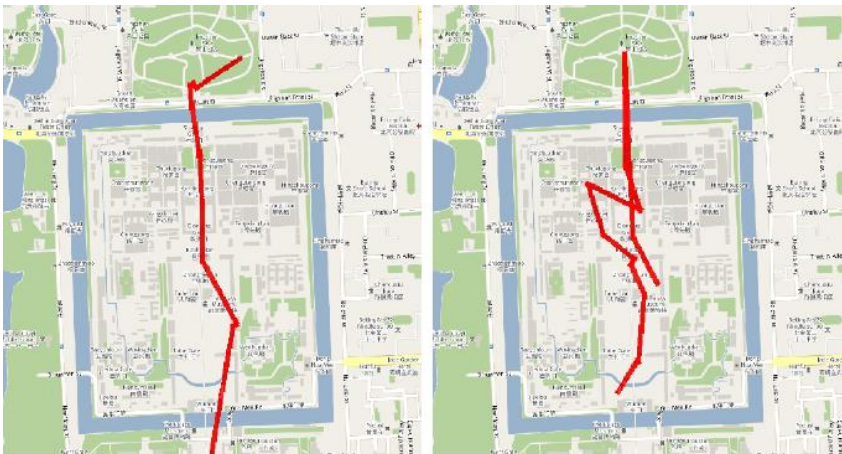
- “Want to have a **one-day** trip in an unfamiliar city, **Beijing**. Any route suggestion to visit famous places?”
- “I am going to visit the **Forbidden City** in Beijing, with 3 hours. What’s the route **within the palace**?”

## ■ Expected results

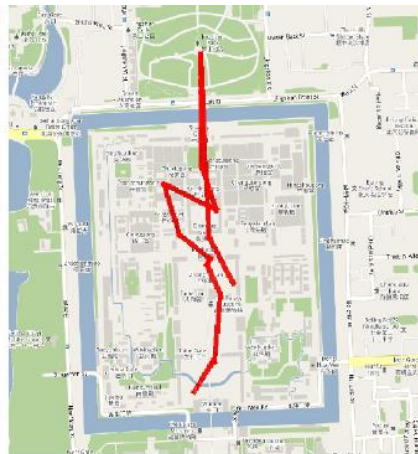
Using Geo-tagged Photos



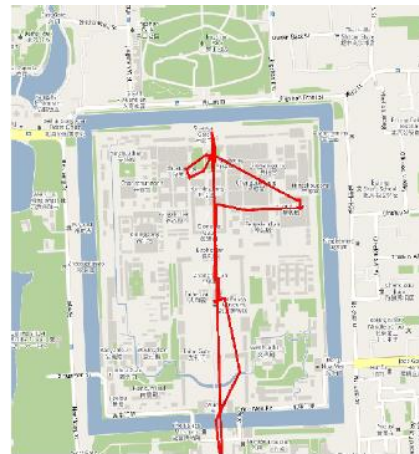
- One-day trip in Beijing: 3 hours in Forbidden City → 2 hours in Tian An Men Square → 2 hours in Qian Men.



(a) A 2-hour path.



(b) A 3.5-hour path.



(c) A 4.2-hour path.



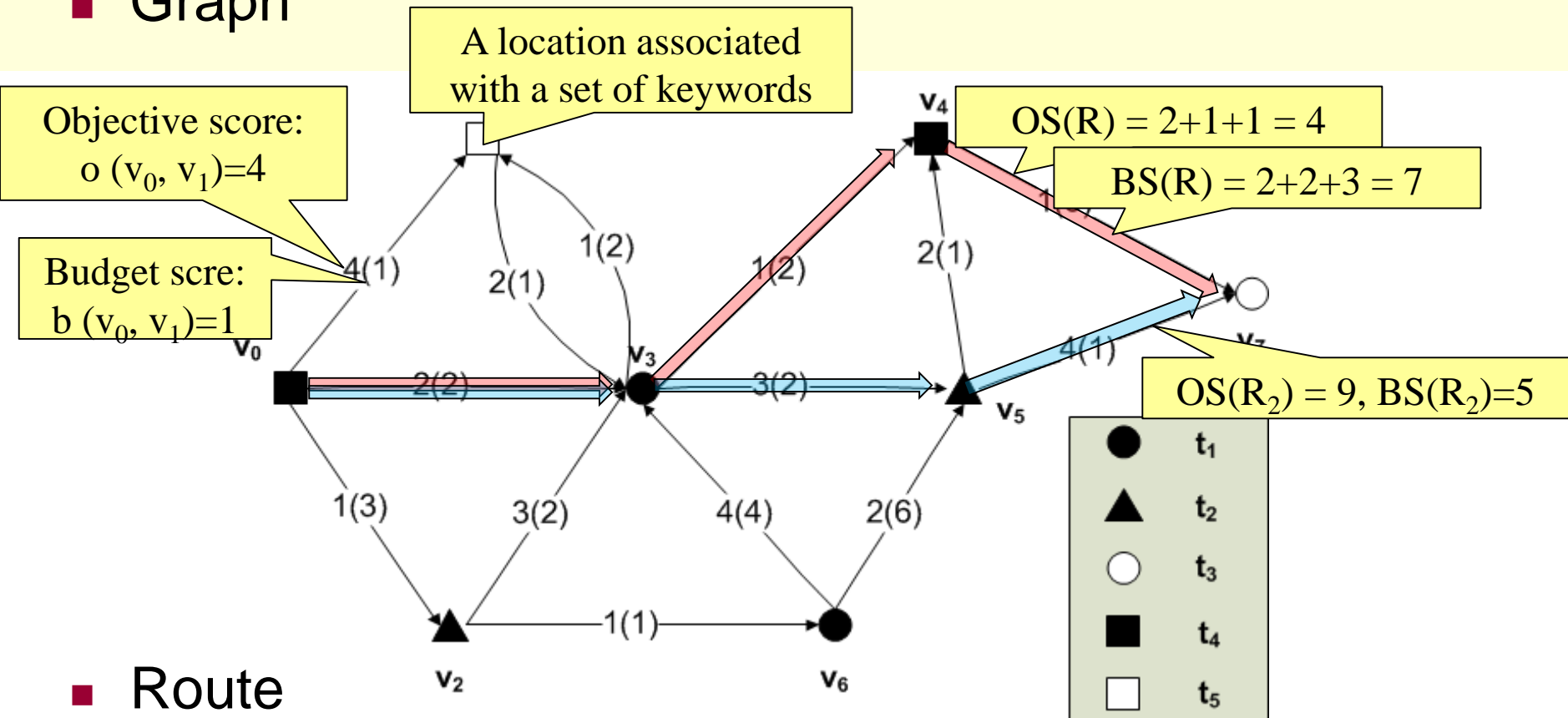
(d) A 5-hour path.

# Advanced Task: Route with Aux. Info.

- Consider a user who wants to a one-day trip for a unfamiliar city. She might pose a query:
  - Find the most **popular route** from my **hotel** such that it passes by “*shopping mall*”, “*restaurant*”, and “*museum*”, and time spent on the road is **within 4hr**
- **Keyword-aware Route Query**
  - (a) Start and end locations (**hotel**)
  - (b) A set of keywords (*shopping mall*, *restaurant*, *museum*)
  - (c) Budget limit (**with 4hr**)
  - (d) A function  $f$  calculating the score of a route (**popularity**)
- Goals: Satisfying (a)(b)(c) and optimizing  $f$

# Graph and Route: Illustration

## ■ Graph

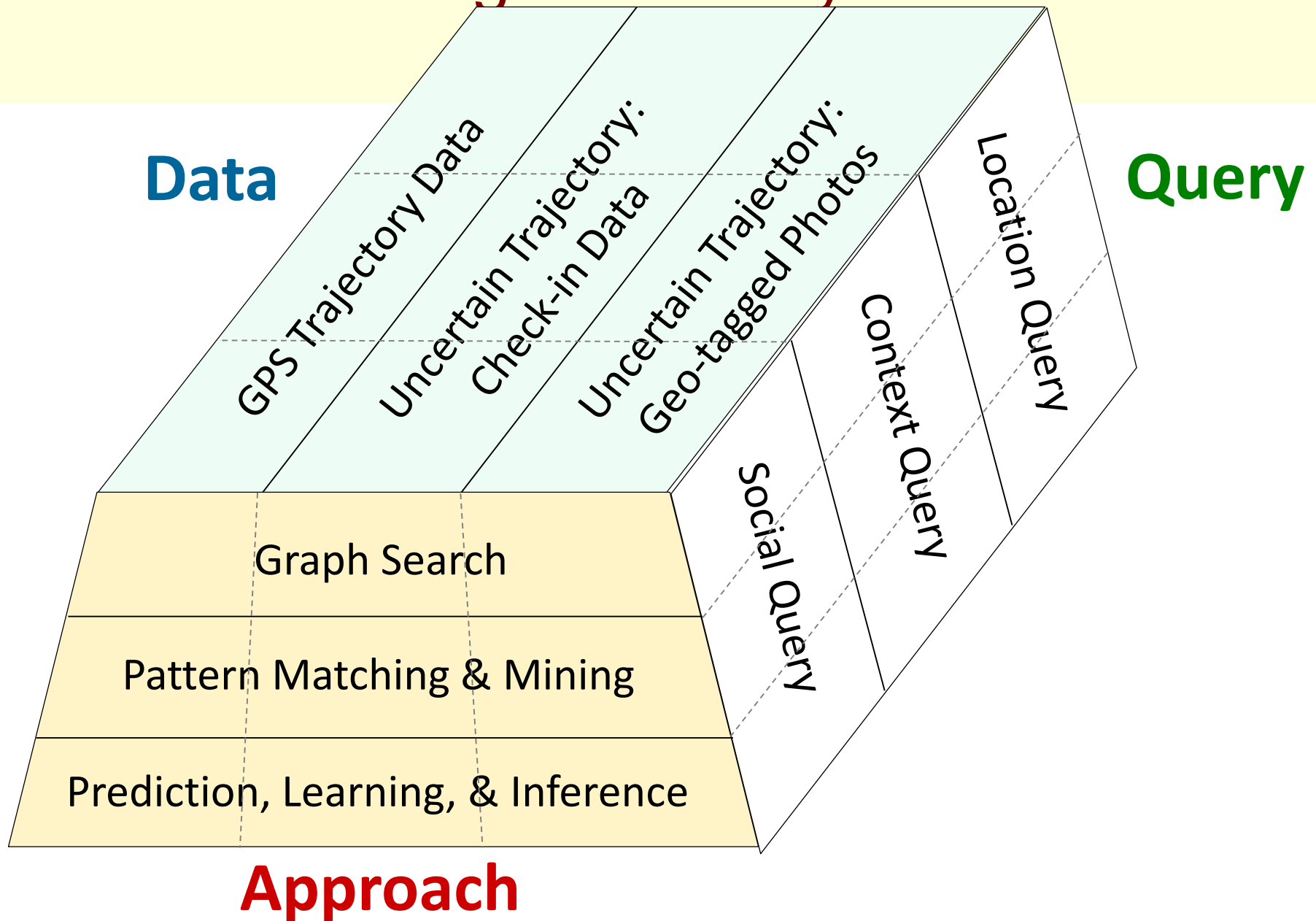


## ■ Route

- Objective score
  - Budget score
  - Feasible route
- Query =  $\langle v_0, v_7, \{t_1, t_2, t_3\}, 8 \rangle$



# Route Planning: Summary



# Location/Route Rec: Opportunities

## ■ Urban Computing

- Apply **real-time** and **heterogeneous** urban sensors data
  - E.g. air quality, traffic flow, weather info,
- Enable smarter / fine-grained route planning, e.g.

Potential Tasks	Data
Find fast driving routes	Instant Traffic Flow
Recommend healthy/fresh venues	Air Quality Monitoring
Provide routes with commuting time	Public Transportation and Road Network
Recommend weather-based locations	Temperature, weather conditions

# Location/Route Rec: Opportunities (cont.)

## ■ Microblogging

- **Social** contents provide rich **user experience** and **event information** on locations
  - E.g. **venue opinion, collective sentiments**
  - E.g. **exhibitions, ball games, movies, concerts**
- Planning routes based on sentiments and events

Potential Tasks	Data
Planning routes maximizing rating	Venue rating
Event-centric route planning	Event location, time, and schedule
Recommend “positive” locations	Sentiments detected
Coordinate the group trip members	Location-based social network

# References:

## Route Planning Approaches

### ■ Graph Search

- Z. Chen et al. Discovering Popular Routes from Trajectories. In *ICDE* 2011.
- Y. Zheng and X. Xie. Learning Travel Recommendations from User-generated GPS Traces. In *ACM TIST* 2011.

### ■ Pattern Mining

- L. A. Tang et al. A Framework of Traveling Companion Discovery on Trajectory Data Streams. In *ACM TIST* 2013.
- L.-A. Tang et al. Retrieving k-Nearest Neighboring Trajectories by a Set of Point Locations. In *SSTD* 2011.

### ■ Prediction/Inference

- H. Jeung et al. A Hybrid Prediction Model for Moving Objects, In *ICDE* 2008
- A. Y. Xue et al. Destination Prediction by Sub-Trajectory Synthesis and Privacy Protection Against Such Prediction, In *ICDE* 2013
- H.-P. Hsieh et al. Measuring and Recommending Time-Sensitive Routes from Location-based Data. In *ACM TIST* 2014

# References: Advanced Tasks

## ■ Deal with Data Uncertainty

- L.-Y. Wei et al. Constructing Popular Routes from Uncertain Trajectories. In ACM KDD 2012.
- K. Zheng et al. Reducing Uncertainty of Low-Sampling-Rate Trajectories. In IEEE ICDE 2012.

## ■ Internal Route Planning

- X. Lu et al. Photo2Trip: Generating Travel Routes from Geo-tagged Photos for Trip Planning. In ACM MM 2010.
- Y.-T. Zheng et al. Mining Travel Patterns from Geotagged Photos. In ACM TIST 2012.

## ■ Route with Auxiliary Information

- A.-J. Cheng et al. Personalized Travel Recommendation by Mining People Attributes from Community-Contributed Photos. In ACM MM 2011.
- X. Cao et al. Keyword-aware Optimal Route Search. In VLDB 2012.