Homework 2
Probe Data Analysis for Road Slope

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Objective

Input

Probe data and map.

The raw probe points in Germany collected in 9 months.

The link data for the links that probe points can be map-matched to.

Tasks

Map match probe points to road links.

Derive road slope for each road link

Evaluate the derived road slope with the surveyed road slope in the link data file.

Knowledge Area

Mentioned in class

Probe data

Data that is generated by monitoring the position of individual moving objects (i.e., probes) over space and time.

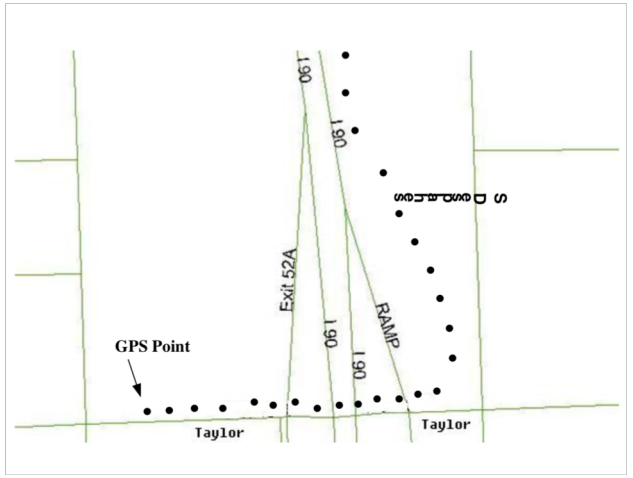
Data for each probe is a time series of locations or the other attributes such as speed, heading……

Probe data pre-processing

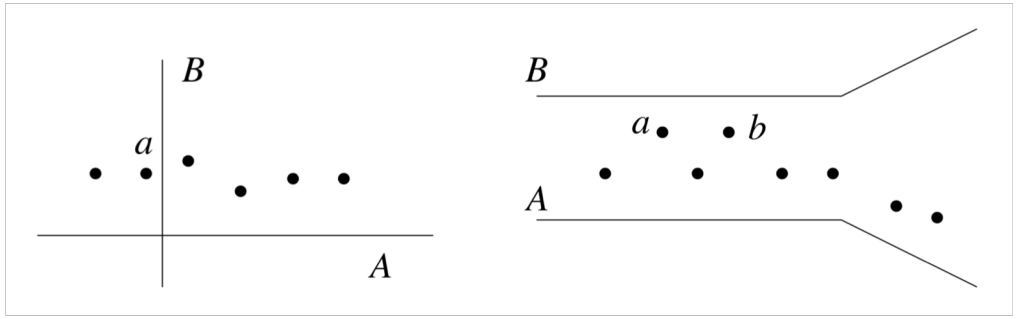
Inaccuracy of positioning

Off-the-road locations

The error of a GPS point can be corrected by snapping the GPS point onto the road network .



Status Quo



Road segment and GPS point

Knowledge Area

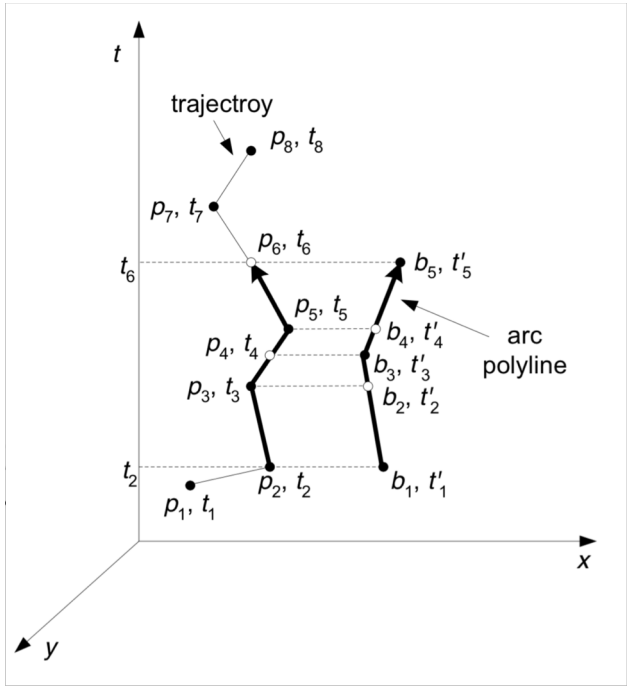
Mentioned in class

Weight-based Map-matching

Compute the weight of each road segment (block)

$$W = \frac{\int_{t_i}^{t_j} (g_{traj}(t) - g_{arc}(t))dt}{|t_j - t_i|}$$

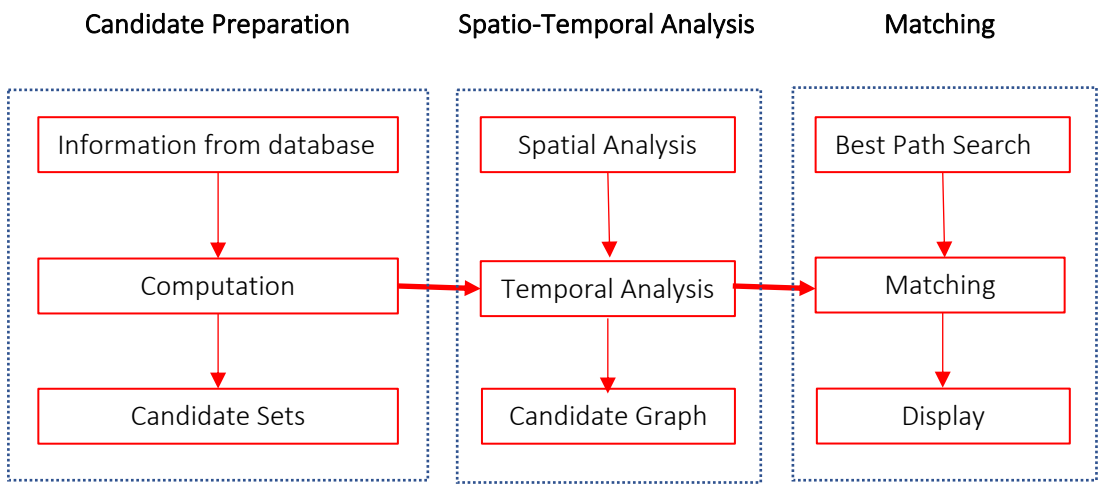
Compute the shortest weight path between the start and the end GPS points as the route of the moving object



Weight-based Map Matching

Approach

Matching



Procedure of matching

Candidate Preparation

Contains the database's specific information with the road.

Spatial Analysis

Performs spatial analysis followed by temporal analysis on the retrieved candidate sets and the trajectory to be matched.

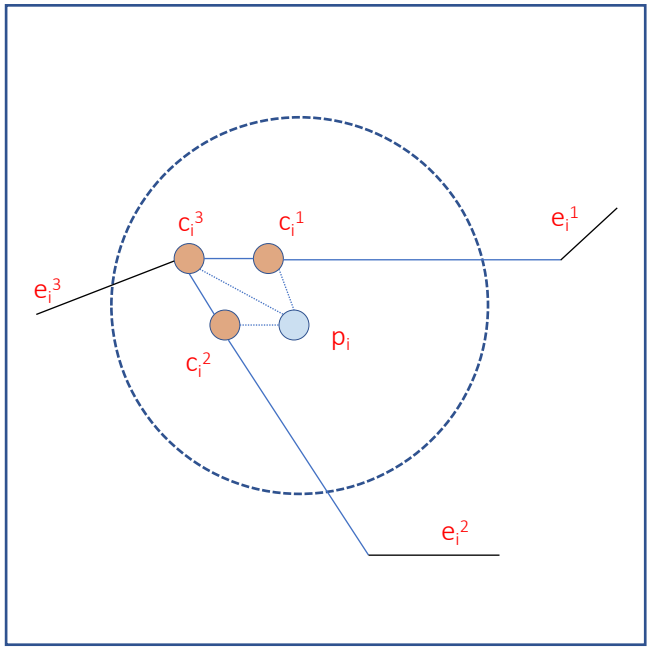
Result Matching

Evaluates the candidate graph using the weight information assigned during spatial/temporal analysis.

Candidate Preparation

We synthesize p_i with c_i^1, c_i^2, c_i^3, and use e_i^j and c_i^j to locate the edge of the c_i^j.

We set the radius of the link in 20 meters.



Candidate points for sampling point $\boldsymbol{p_i}$

Spatial Analysis

After we have the points of the candidates, we attempt to do the spatial analysis.

We use both of the geometric and topological information from the database.

x_i^j is the distance between c_i^j and p_i.

The formula represent the probability of the candidate point match the GPS point.

The second one is the Transmission probability, which represent the probability of the path.

The transmission probability from c_{i-1}^t to c_i^s is the true path from p_{i-1} to p_i in the link.

Spatial Analysis is the match function. Find the highest value of each candidate point, that could be the best path.

$$N(c_i^j) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{(x_i^j-\mu)^2}{2\sigma^2}}$$

The product of observation probability and transmission probability

$$V(c_{i-1}^t \rightarrow c_i^s) = \frac{d_{i-1 \rightarrow i}}{w_{(i-1,t)\rightarrow(i,s)}}$$

Transmission Probability

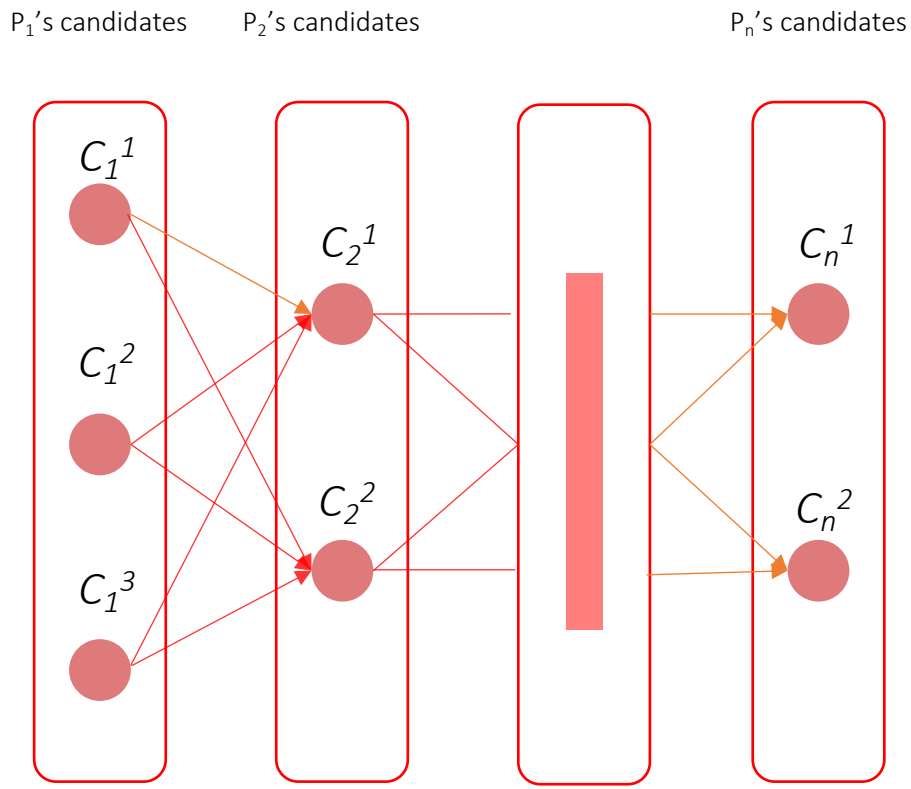
$$F_s(c_{i-1}^t \rightarrow c_i^s) = V(c_{i-1}^t \rightarrow c_i^s) * N(c_i^s) \ , \ 2 \leq i \leq n$$

Spatial Analysis

Result Matching

We form a candidate graph, which includes a sequence of candidates for the GPS sampling point. The graph is associated with the candidate point. E'_T is the shortest path between two adjacent candidates.

We locate the edges and the sampling point first. Then we do the spatial analysis and the candidate graph. Finally we use the graph match to find the sequence of the point and the ST-matching algorithm to match the result.



Candidate Graph $G'_T(V'_T,E'_T)$

Slope

Slope formula:

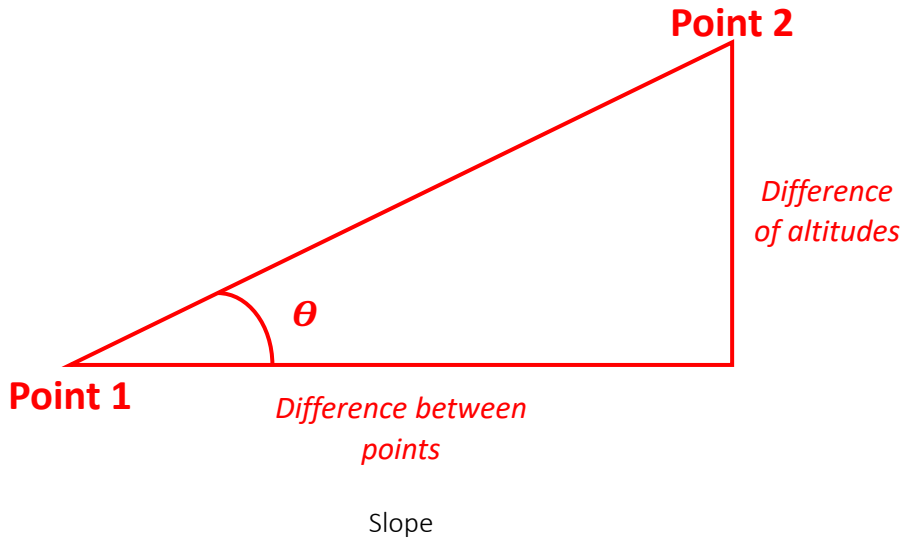
$$\theta = \arctan \frac{Difference\ of\ Altitudes\ of\ Each\ Pair\ of\ Points}{Distance\ between\ Each\ Pari\ of\ Points}$$

Method:

Use the same LinkPVID, pair the matched points.

Between the points, calculate the distance, altitude, the angle of the slope via the sine function.

Evaluate the derived road slope with the surveyed road slope in the database.



Slope

Evaluation

Method

Extract: Extract latitude and longitude of each point of the matching pair.

Convert: Convert each latitude and longitude from degree to meter.

Calculate: Using the distance equation to calculate the distance between each matching pair.

Calculate: Calculate the altitude between each pair by subtracting the elevation of each point.

Calculate: Calculate the slope using the sine function.

Evaluate: Evaluate the slope.

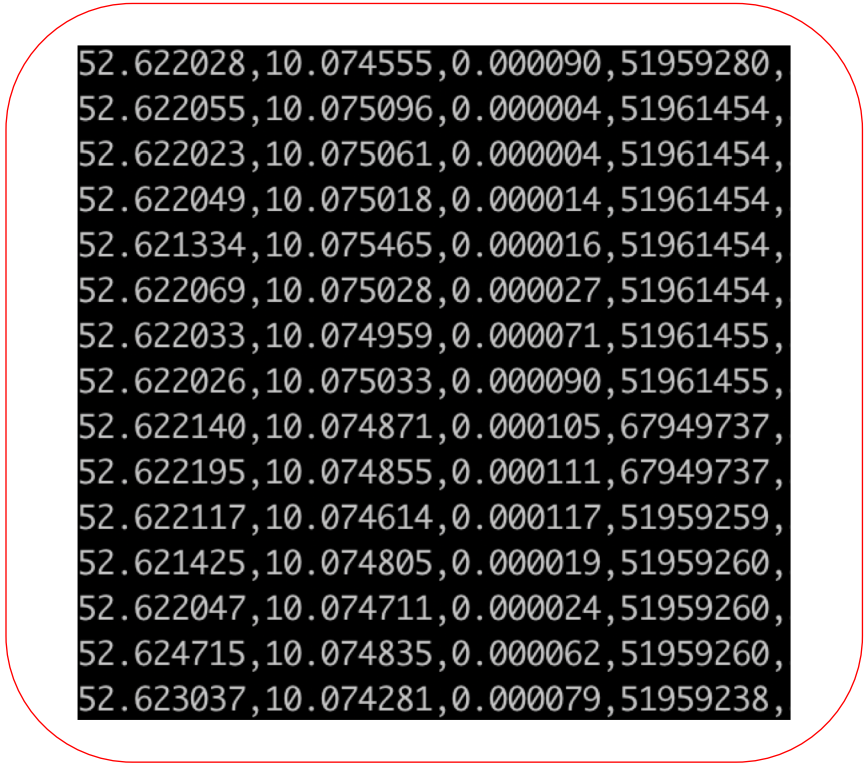
Result

6218	2009-06-16 06:00:57	13	51.530441	9.953561	223	0	147	51830206	T	0.000951	0.012048
6218	2009-06-16 06:01:03	13	51.530568	9.953536	223	17	352	51830206	T	0.001017	0.012568
6218	2009-06-16 06:01:08	13	51.530696	9.953521	223	2	3	51830206	F	0.001085	0.013088
6218	2009-06-16 06:01:13	13	51.53072	9.953524	223	1	359	51830206	T	0.001097	0.013183
6218	2009-06-16 06:01:18	13	51.530788	9.953519	224	5	357	51830206	T	0.001133	0.013457
6218	2009-06-16 06:01:23	13	51.530949	9.953498	224	14	355	51830206	T	0.001216	0.014108
6218	2009-06-16 06:01:28	13	51.53114	9.953454	225	16	354	51829953	T	0.000109	0.000005
6218	2009-06-16 06:01:33	13	51.531468	9.953371	225	31	350	51829953	T	0.740295	0.000007
6218	2009-06-16 06:01:38	13	51.53193	9.953224	225	39	347	51829953	T	0.740411	0.000021
6218	2009-06-16 06:01:43	13	51.532432	9.95304	223	41	348	51829953	T	0.74054	0.000034

Part of matched points

The column name from left to right:
sampleID, dateTime, sourceCode, latitude, longitude, altitude,
speed, heading, linkPVID, direction, distFromRef, distFromLink

Result



Part of the slope data

The number from left to right are:
linkID, computed slope, observed slope and deviation

Conclusion

More probes can get the slope of the link more accurately.

On the same link, there maybe more than two nodes, which may decrease the accuracy and have the different results.

The ST Matching algorithm has good performance in map-matching.

For future work, we can use the dynamic parameters or other matching algorithms to do the different tests and make comparison among them.