Probe Data Analysis for Road Slope

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Introduction

- Probe data is generated by monitoring the position of moving objects over space and time. These moving objects can be dedicated vehicles used to collect information
- Probe points consist of ProbeID, dateTime, latitude, longitude, altitude, speed, heading etc.
- These probe points can be used to derive the slope of road links by map matching these points to their corresponding links

Problem Statement

- Given a the raw probe points and link data the objective is to derive the road slope such that the derived road slope is closest to the surveyed road slope (ground truth).

Methodology

1) Partition the whole data points into several sub-regions

2) For every sub-region map match the probe points to road links

3) Derive road slope for each road link

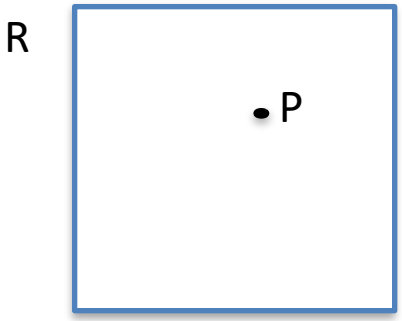
4) Evaluate the derived road slope with the surveyed road slope

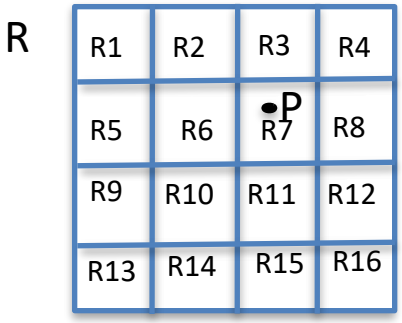
Partitioning the data points into sub regions

- The time required to process the whole data is very high since it requires iterating through all the probe points for every link.
- In order to boost data processing, we partition the data into n sub regions and process each sub region independently.

Partitioning the data points into sub regions

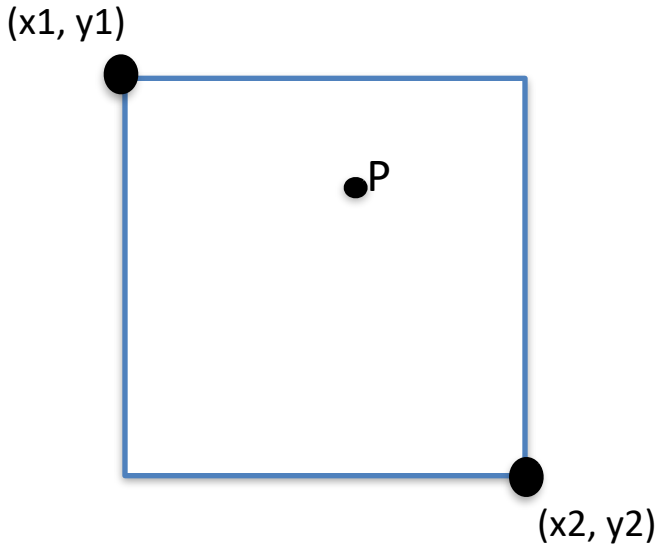
- In order to understand the partitioning process, let us consider a toy example, where we want to create 16 sub regions for the region R.
- Let P be a probe point.
- Given the co-ordinates of P, task is to find the sub-region it belongs to.
- We can do this in O(n) time complexity for n points





Partitioning the data points into sub regions

- We will first find the points (x1, y1) and (x2, y2) such that x1 = min xi, x2 = max xi, y1 = max yi, y2 = min yi for all the points in the entire data



Partitioning the data points into sub regions

- To find the sub region that a point P (a, b) belongs to, we need to find the row number I and the col number j of the grid for point P.
  - i = (a-x1) // d_x
  - j = (b-y2) // d_y
- Where d_x and d_y are the widths of each grid block for each axis.
  - d_x = (x2 - x1) / n
  - d_y = (y1 - y2) / n
- Finally the grid number is given by : (i*n) + j

Partitioning the data points into sub regions

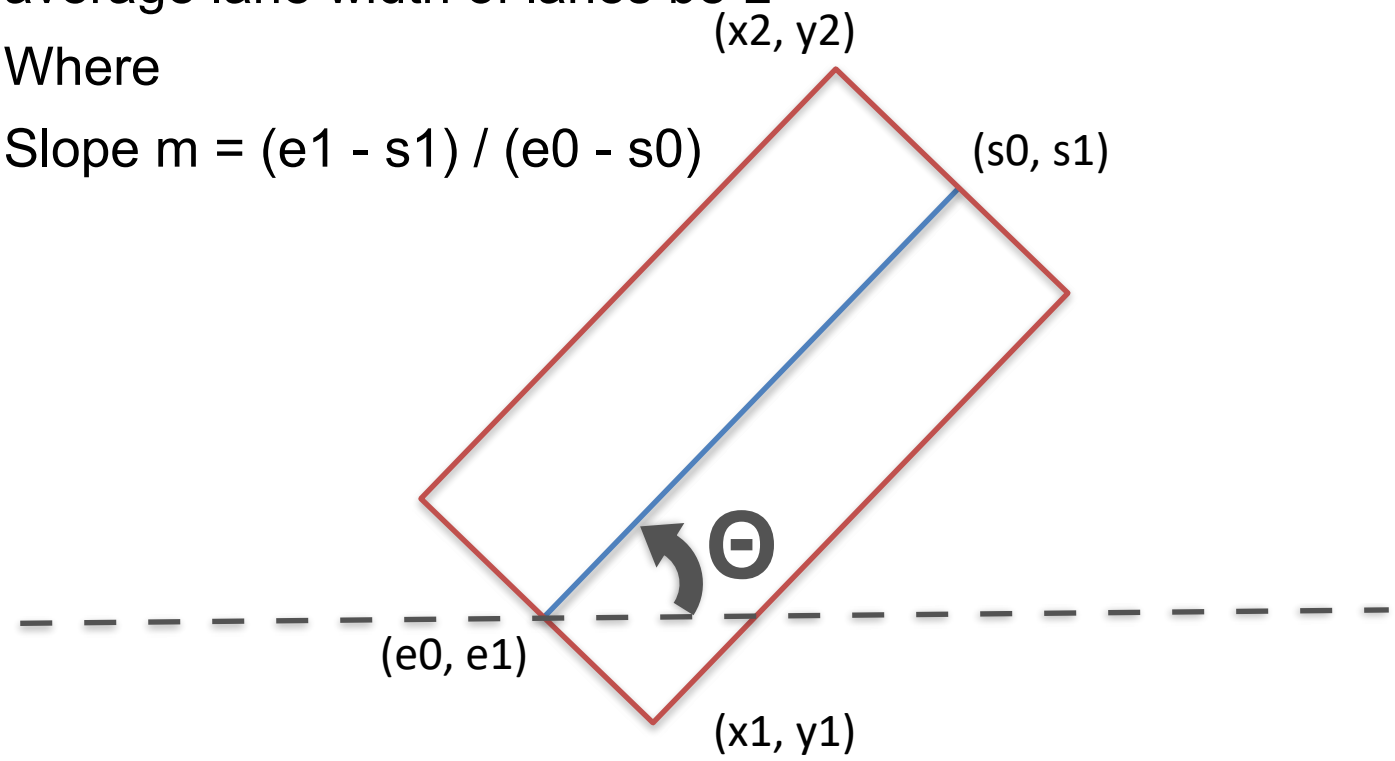
- We can find the sub-region that each link belongs to by using the same method using the start and end points of each sub link.
- If both the points belong to same sub region, then the link belongs to that sub-region.
- However, if the two points belong to different sub-regions then we have assign the link to the subregion which contains that maximum portion of the link

Map match the probe points to road links

- In order, to map match the probe points to road links for each subregion we have constructed a bounding box for each sub-link of the road link.
- The probe points that fall inside the bounding box of a sub-link are the candidate probe points for that sub-link.
- In order assign the probe points to a particular sub-link, we examine only the candidate probe points that belong to that sub-link by considering the following factors:
  - If points with the same probeID in the list of candidate probe points is greater than a particular threshold, then we assign those points to that sub-link. The threshold is calculated using: 3rd Quartile of the points data * (0.5)
  - If the speed of the points is in the range of (-40: +10) of the speed limit of the lane in which the probe is traveling, we keep the point, else discard it.

Construction of bounding box for a sub-link

- Consider blue sub-link s-e.
- Let fromRefNumLanes and toRefNumLanes be 1 each and let the average lane width of lanes be L
- Where
- Slope m = (e1 - s1) / (e0 - s0)



Construction of bounding box for a sub-link

- We can find the co-ordinates (x1, y1) and (x2, y2) of the red bounding box using the following formulae:
- x1 = s0 + d1 * sin(Θ) + err
- y1 = s1 - d1 * cos(Θ) + err
- x1 = e0 + d2 * sin(Θ) + err
- y1 = e1 - d2 * cos(Θ) + err

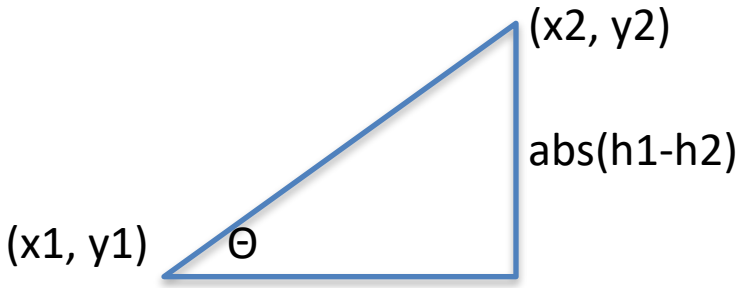
- Where
- Θ = atan(m)
- d1 = toRefNumLanes * lane_width
- d2 = fromRefNumLanes * lane_width
- err = error to consider the error in GPS location
- lane_width = 3.75 meters considering the average lane width of Germany

Map match the probe points to road links

- All the probe points that lie inside the bounding box are considered as candidate probe points.
- Consider a point (x, y)
- If it satisfies the following inequalities then it lies inside the bounding box
- $y - y1 - m(x - x1) >= 0$
- $y - y1 + 1/m(x - x1) <= 0$
- $y - y2 - m(x - x2) <= 0$
- $y - y2 + 1/m(x - x2) >= 0$

Derive the slope for each sub-link

- In order to find the slope for each sub-link we perform the following operation for each probe point that belongs to it
- Let (x1, y1) and (x2, y2) be the start and end point co-ordinates of the sub-link. Let P1 and P2 be two probe points assigned to the sub-link and let their altitude be h1 and h2



- Θ = asin(abs(h1 - h2)/ sq. root((x1 - x2)**2 + (y1 - y2) **2))
- Slope = atan(Θ)

Evaluation Results

- Accuracy (r2-score) on our results and ground truth = -0.4436

- GitHub repo link: https://github.com/rautnikita77/Geospatial/tree/master/Slope_Estimation