# Probe Point Analysis for Road Slope

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# Introduction

- The first task is to match over 3.3 million probe points to one of over 200 thousand road links in partition 6467 in Germany
  - Bounding rectangle - 50.62500, 8.43751 and 53.43750, 11.25000
- The second task is to find a derived slope for each road link using the probe data
- The third task is to evaluate the derived slope and the surveyed slope data for each road link

# Background

- Mapping companies can map out roads by either:
  - Having surveying cars that drive over every road to collect data
  - Collecting probe data from people over time

- It is much more efficient to use probing data because roads are constantly changing. It would be time consuming to hire someone to drive over every road every year in order to collect data

- Probing data needs to be processed and matched to road links in order to be useful

# Approach

- Use geohash in order to find a list of candidate links that a probe point can belong to
  - This is way more efficient than trying to match each probe point to one of 200,089 road links
- Match probe points to the link with the smallest perpendicular distance
- To decide whether the probe point is traveling towards or away from a reference node:
  - Calculate the heading of the link
  - Compare it to the heading of the probe point

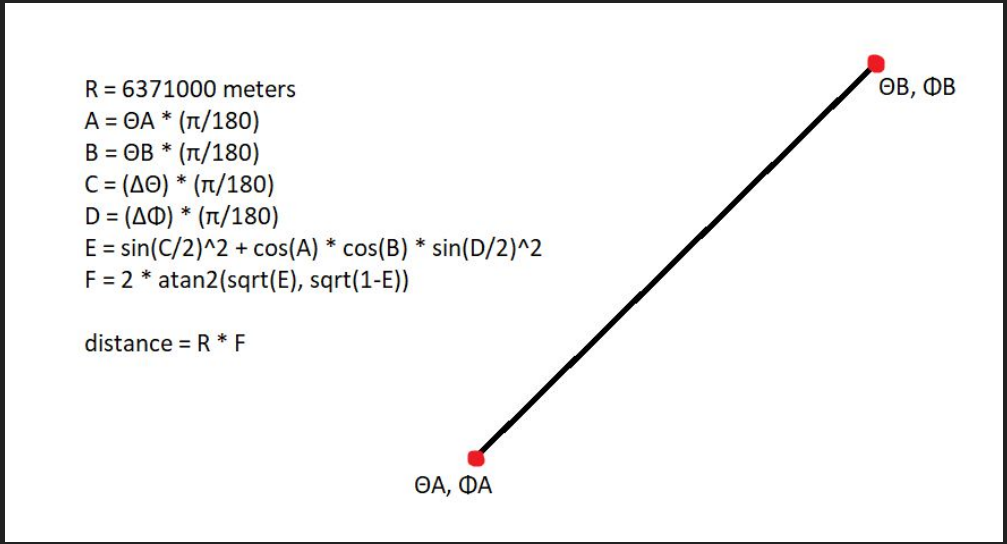
# Approach

- To find the derived slope of a link:
  - Find the closest probe point to the reference node
  - Find the closest probe point to the non-reference node
  - Calculate the slope from the difference in altitude and the distance between the two probe points

- To evaluate derived slope and surveyed slope:
  - Find the surveyed altitude of the reference node
  - Find the surveyed altitude of the non-reference node
  - Calculate the slope from the difference in altitude and the distance between the nodes
  - Compare it with the derived slope

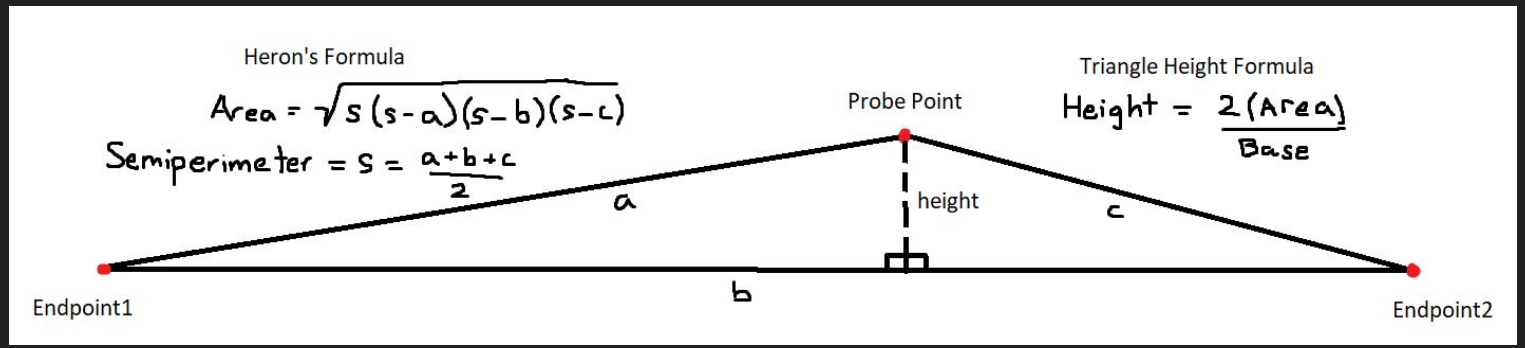
# Approach

- To find the distance between two lat/long coordinates:
  - Use Haversine formula



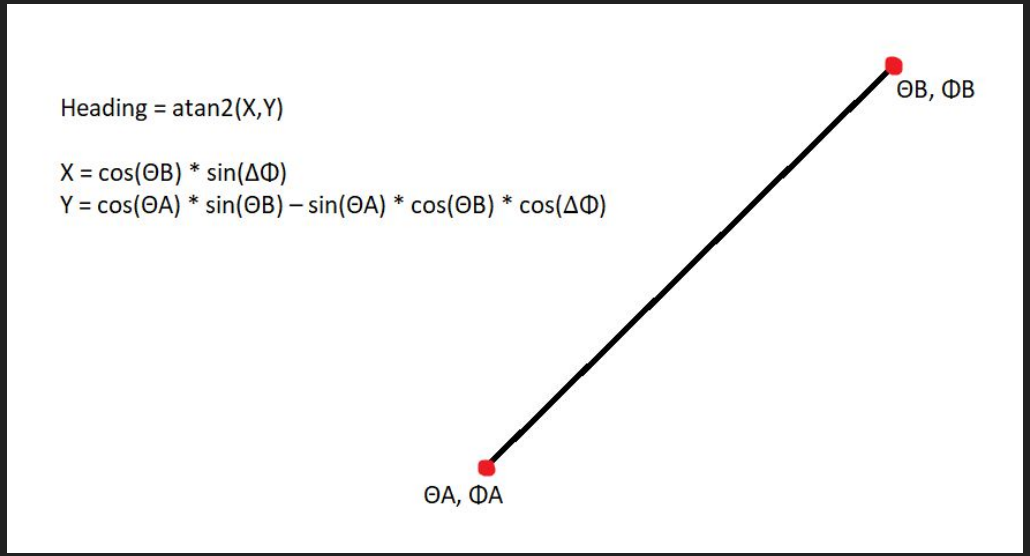
# Approach

- To find perpendicular distance from a probe point to a link:
  - Assume each road link is the base of a triangle.
    - The reference node and non-reference node are the two bottom vertices
  - Assume the probe point is the third vertex
  - Use Heron's formula to find the area of the triangle
  - Calculate the height of the triangle



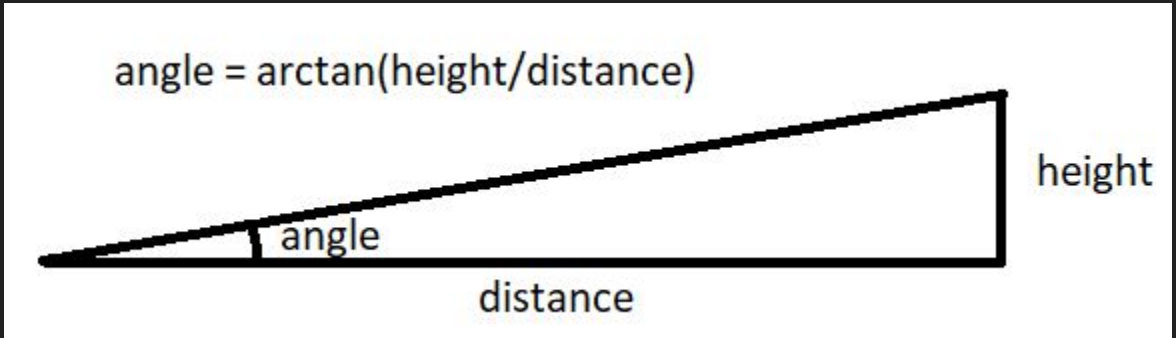
# Approach

- To find the heading of a link:



# Approach

- To find the slope of a link:
  - Use arctangent trigonometry to find the slope angle



# Results

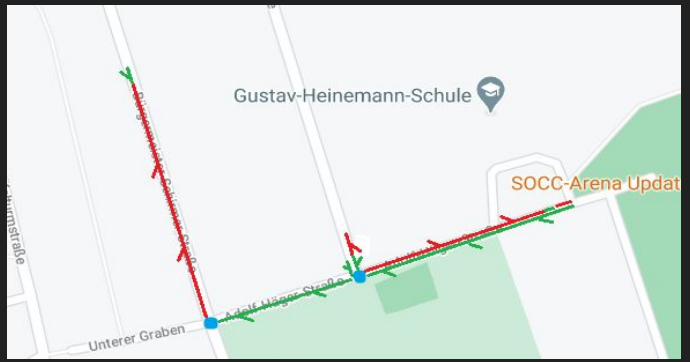
- 2,938,973 probe points were successfully matched to a link
  - Partition6467MatchedPoints.csv
- 149,581 links have enough probe points to calculate slope
  - Partition6467DerivedSlopes.csv
- 48,402 links have both surveyed 3D data and probe points to evaluate slope
  - Partition6467EvaluatedSlopes.csv

# Results

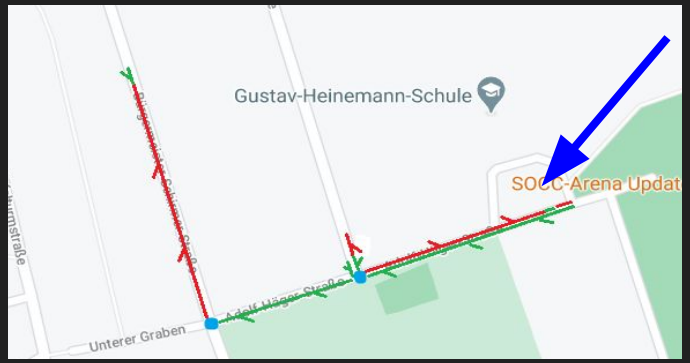
- This is one of the probe paths
- Each probe point is a red dot
- Each reference node is a blue dot
- Red lines show the probe point moving away from a reference node
- Green lines show the probe point moving towards a reference node

Probe Points


Matched Links



# Results

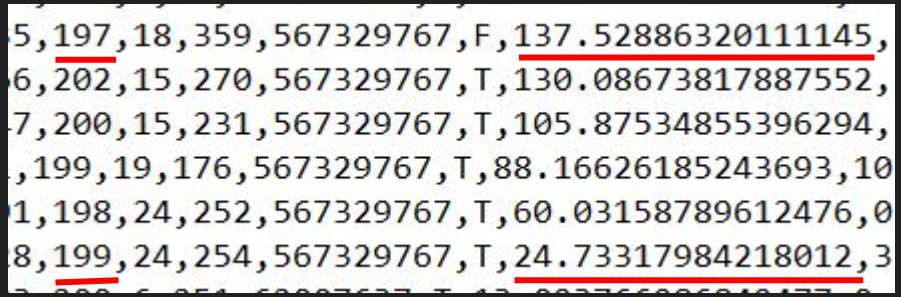




- Notice how there is no road link data for the loop that the probe point traveled
- The algorithm matched the movement onto the nearest link
- As a result, the perpendicular distance from the link is larger

```
9767,T,120.57933927990803,4.250329104989715
767,F,124.96033429012128,2.4499811835482945
29767,F,137.52886320111145,11.472706158362996
29767,T,130.08673817887552,33.13469865806398
29767,T,105.87534855396294,32.388099363784534
9767,T,88.16626185243693,10.619076255597538
29767,T,60.03158789612476,0.26755926299575783
29767,T,24.73317984218012,3.0281580270609885
637,T,13.093766986849477,0.22615669348660278
```

# Results

MatchedPoints Data




Altitude

Distance to reference node

DerivedSlopes Data

```
567329767,-1.9367308302530166
```

Slope angle

- The derived slope was calculated by using the difference in altitude and the distance between the closest and farthest probe points to the reference node

# Results

EvaluatedSlopes Data

```
51881767,-3.012330158172121,0.13763518114613485
51881768,-2.9328742365417098,-0.03695096021416953
51881825,-0.6976623831540031,-0.12279655313079371
51881938,-0.8839795913554389,0.1408139938017661
811768915,4.953257503633249,0.12540389188420836
```

Derived slope  Surveyed slope

- The derived slope doesn’t compare well with the surveyed slope
- There are some reasons why this might be:
  - There are not enough probe point data to calculate a precise slope
  - Probe points may be matched to the wrong links
  - The altitude measurement does not have enough significant figures to calculate a precise slope

# Conclusion

- Geohashing allows probe points to efficiently locate candidate links
- Probe data can help detect new roads that do not have links yet
- Probe data can detect old roads that do not exist anymore
- Probe data can help map altitude and road slopes for link data

# References


- Murphy, J., Pao, Y., & Yuen, A. (2019, November). Map matching when the map is wrong: Efficient on/off road vehicle tracking and map learning. In *Proceedings of the 12th ACM SIGSPATIAL International Workshop* on *Computational Transportation Science* (pp. 1-10).

- Map images are captured from Google Maps