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"Geospatial Information for a Smarter Life and Environmental Resilience"

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Realignment of road network maps with GPS tracking data

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Map Realignment: A process of improving spatial accuracy of the maps

Motivation:

- **Navigation Domain**
  - ✓ More accurate spatial information of the vehicle's position relative to the road network
  - ✓ More accurate calculation of the length of the path and accurate estimated arrival time to a destination (important for an Emergency services)
- **Map-matching:**
  - ✓ Improved performance of map-matching algorithms
  - ✓ The level of certainty increases when the road closest to the GPS data is the suitable road
  - ✓ A higher success rate

Realignment of road network maps with GPS tracking data

- How to improve a road network maps quality ?
  - Precisely Map digitizing
  - Connecting newly and updated Measurements
  - Identifying roads from an Orthophoto (aerial photograph)
    - High coast of preparation
    - Needs human resources
    - Real time Updated data (coastly)

The Suggested solution

- Using GPS tracking data acquired for an open source database

(We assume that the GPS location quality accurate more than the map quality)

Contents of the Lecture

1. Literature survey - matching a road segment to GPS data
2. Data collection - Preparing the data for map matching and map alignment processes.
3. Map matching – a process of Matching the GPS points to the roads.
4. Map alignment –a process of fixing the location of a map to GPS points location.
5. Additional improvements
6. future work

1. Literature Review

- (He et al.2003) proposed two methods for matching a road segment to the GPS points

Method 1:

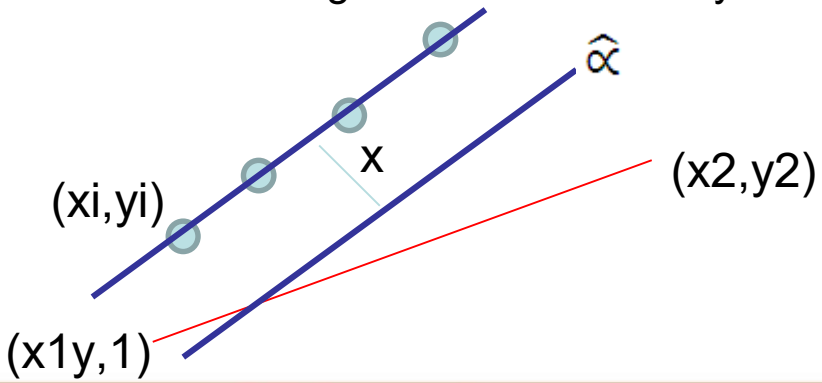
- Average orientation calculation
- Calculation of the average displacement value

$$\hat{\alpha} = \sum_{i=1..M} \alpha_i / M$$

$$x = \left(\sum_{I} D_i - \sum_{J} D_j\right)/(I + J)$$

Method 2:

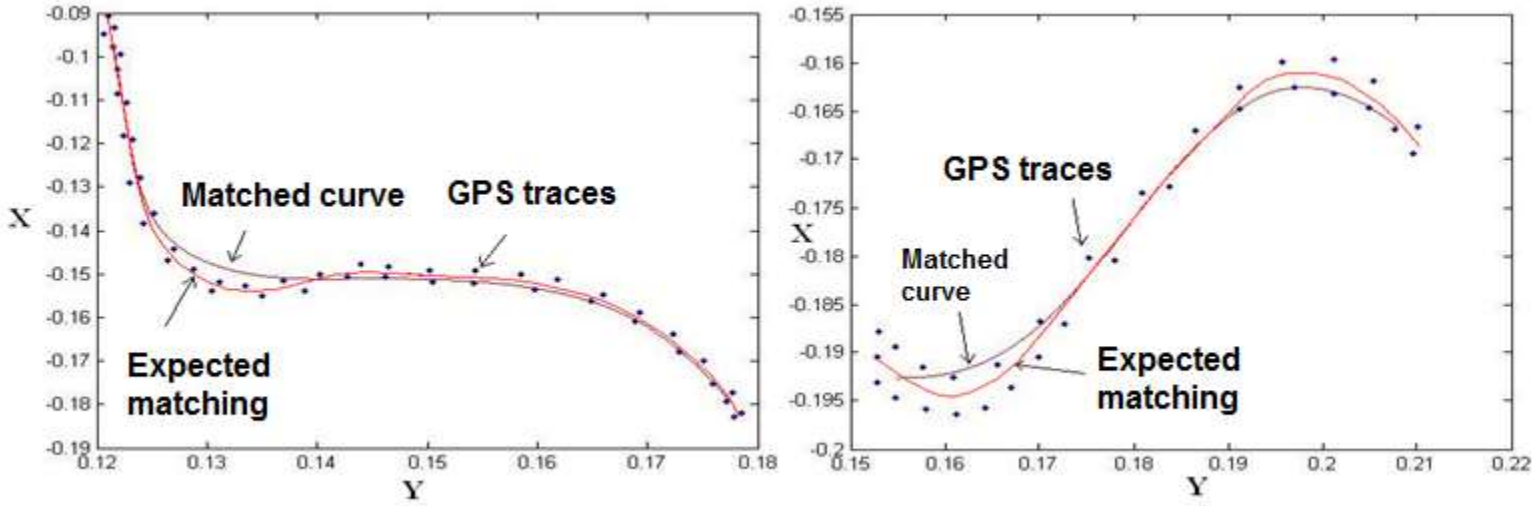
- Calculation of a cost function for a single road segment
- segment coordinates by minimizing the cost function



$$\$ = A \times \sum_{i} \alpha_i^{\,2} + B \times \sum_{i} D_i^2$$

1. Literature Review

More studies about matching lines to a cloud of GPS points



• In the work of (Verbeek et al., 2002) they matched a curve that satisfies the condition of the minimum sum of the vertical distances

K-segments principal curves

•It was not possible to automatically determine the optimal number of iterations to match the curve to the data, so the method is not suitable for automatically processing the data

1. Literature Review

Conclusions

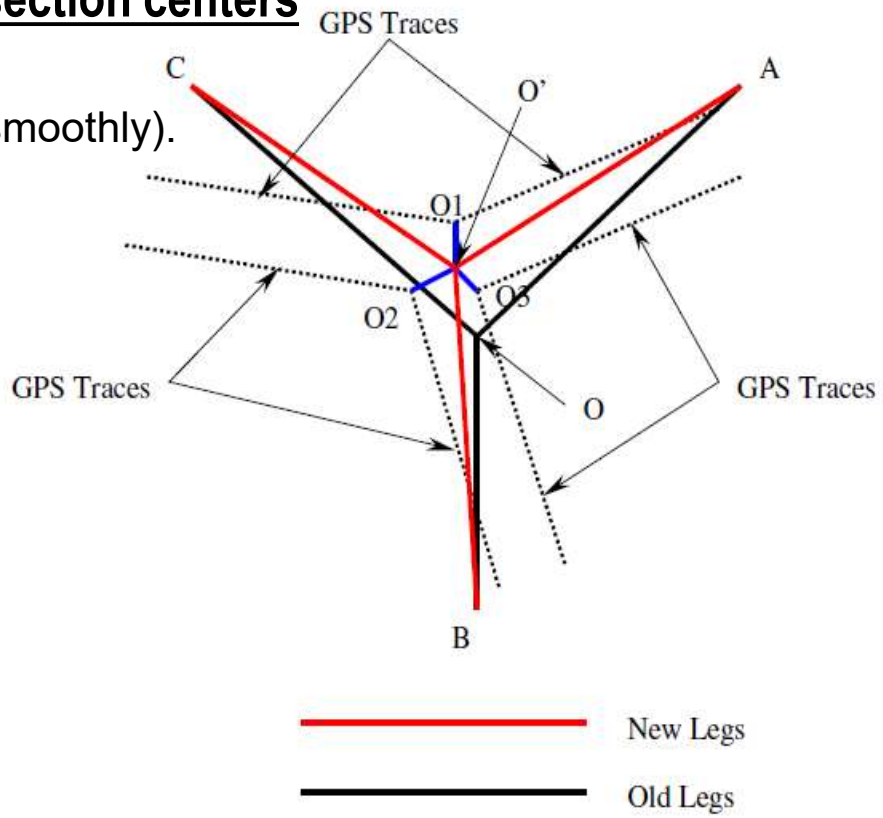
- Matching segments is not an efficient solution.
- There is no global solution for the problem

target:

– Finding a global solution for aligning a road network map to a GPS data

Difficulties in calculating the location of intersection centers

- The difficulty in identifying the rotation points O1, O2, O3 (vehicle passing the intersection smoothly).
- Unequal density of points Crossing the intersection (Depends on vehicle speed).
- Multiplicity of diverse rides Crossing the intersection. (difficulty in computing the average location of the Intersection point).



1.Handling the GPS points

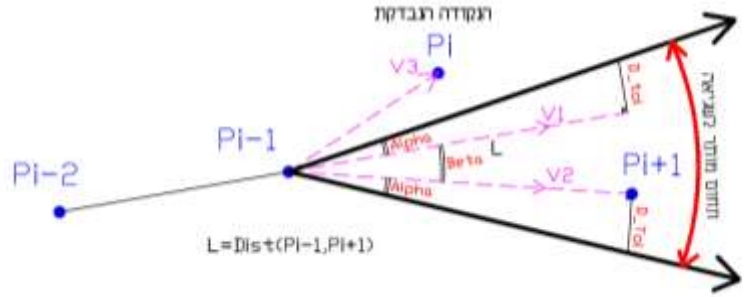
Two processes before fixing the maps

1. GPS outlier points:

- Filtering points which have a low accuracy evaluation ⟶ $CQ_{Threshold} = \bar{x} + C \cdot \sigma_x$
- Filtering unnecessary points when the vehicle is standing or traveling at a very slow speed

$$d = 2 * x_{max} \qquad x_{max} = \bar{x} + \sigma_{\bar{x}} * Z_{1-\alpha}$$

- Filtering Exceptional Points (with a rough location error)



$$Error = 2 * \alpha + \beta$$

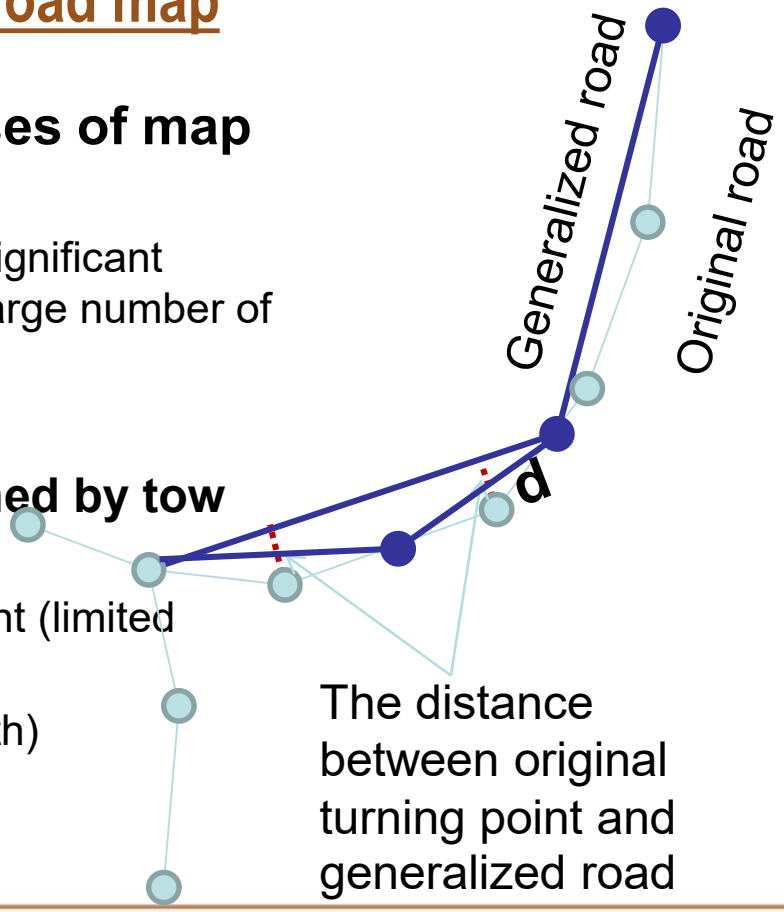
2. Handling the road map

2. Preparing the map for the processes of map matching and map alignment

Increasing the length of road segments without significant distortion of the road shape in order to obtain a large number of GPS points on the same segment

The length of a new segment is determined by tow parameters:

1. Minimum number of GPS points per segment (limited speed)
2. Maximum Perpendicular distance (road width)



The distance between original turning point and generalized road

Map matching algorithm (literature review)

(Greenfeld 2002) developed a map matching algorithm based on weights

$$W_{Intersect} = C_I \cdot \cos^{n_I}(\Delta AZ)$$

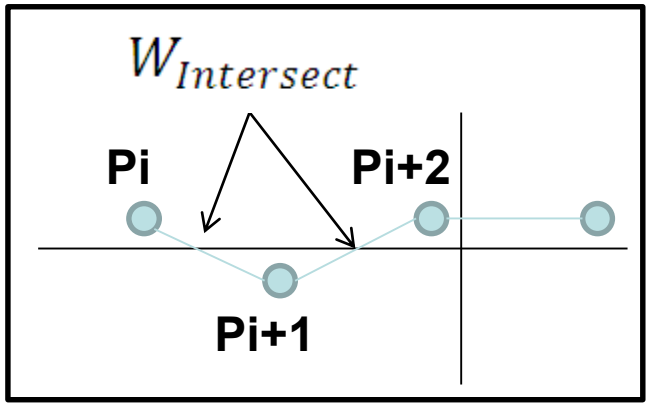
• Weight for cutting with a road segment

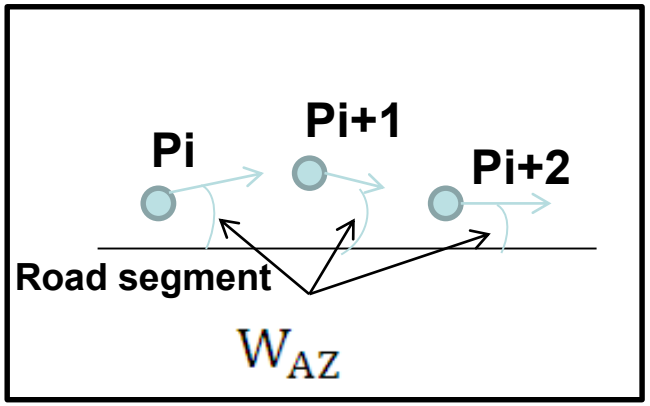
$$W_{AZ} = C_{AZ} \cdot \cos^{n_{AZ}}(\Delta AZ)$$

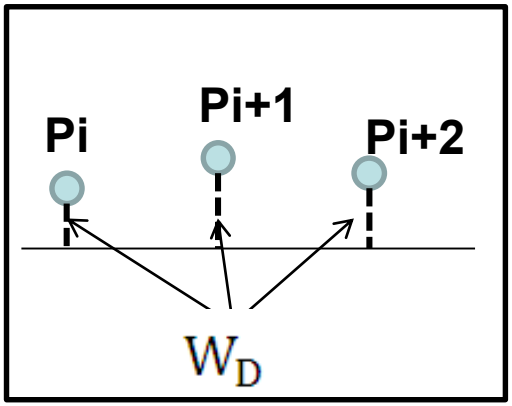
• Weight for the angle between the road segment and travel direction

$$W_D = C_D - a * D^{n_D}$$

• Weight for the vertical distance between the GPS point and the road segment

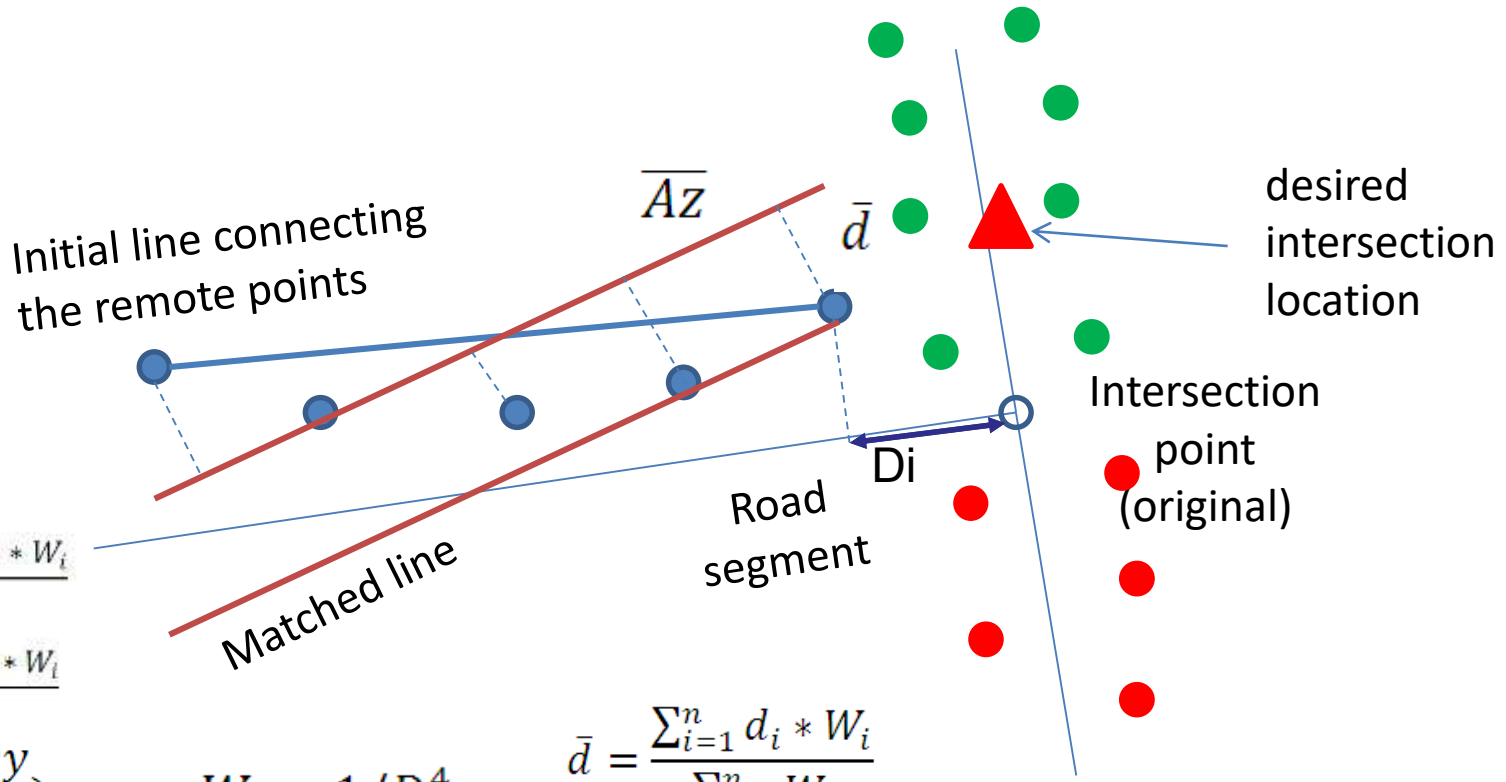






Road segment

Fitting lines to a GPS points at the intersection



$$Dx = \frac{\sum_{i=1}^{n} \sin(Az_i) * W_i}{\sum_{i=1}^{n} W_i}$$

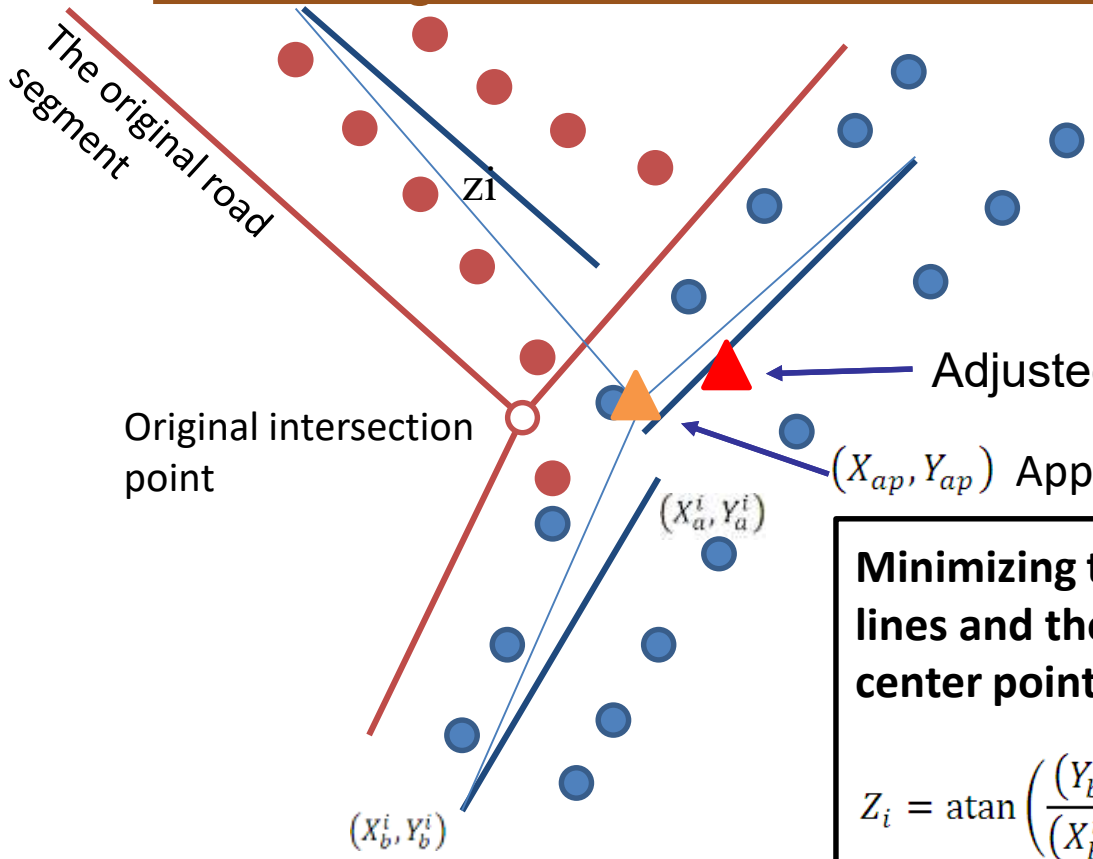
$$D_y = \frac{\sum_{i=1}^{n} \cos(Az_i) * W_i}{\sum_{i=1}^{n} W_i}$$

$$\overline{Az} = \text{atan}\left(\frac{Dy}{Dx}\right)$$

$$W_i = 1/D_i^4$$

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i * W_i}{\sum_{i=1}^{n} W_i}$$

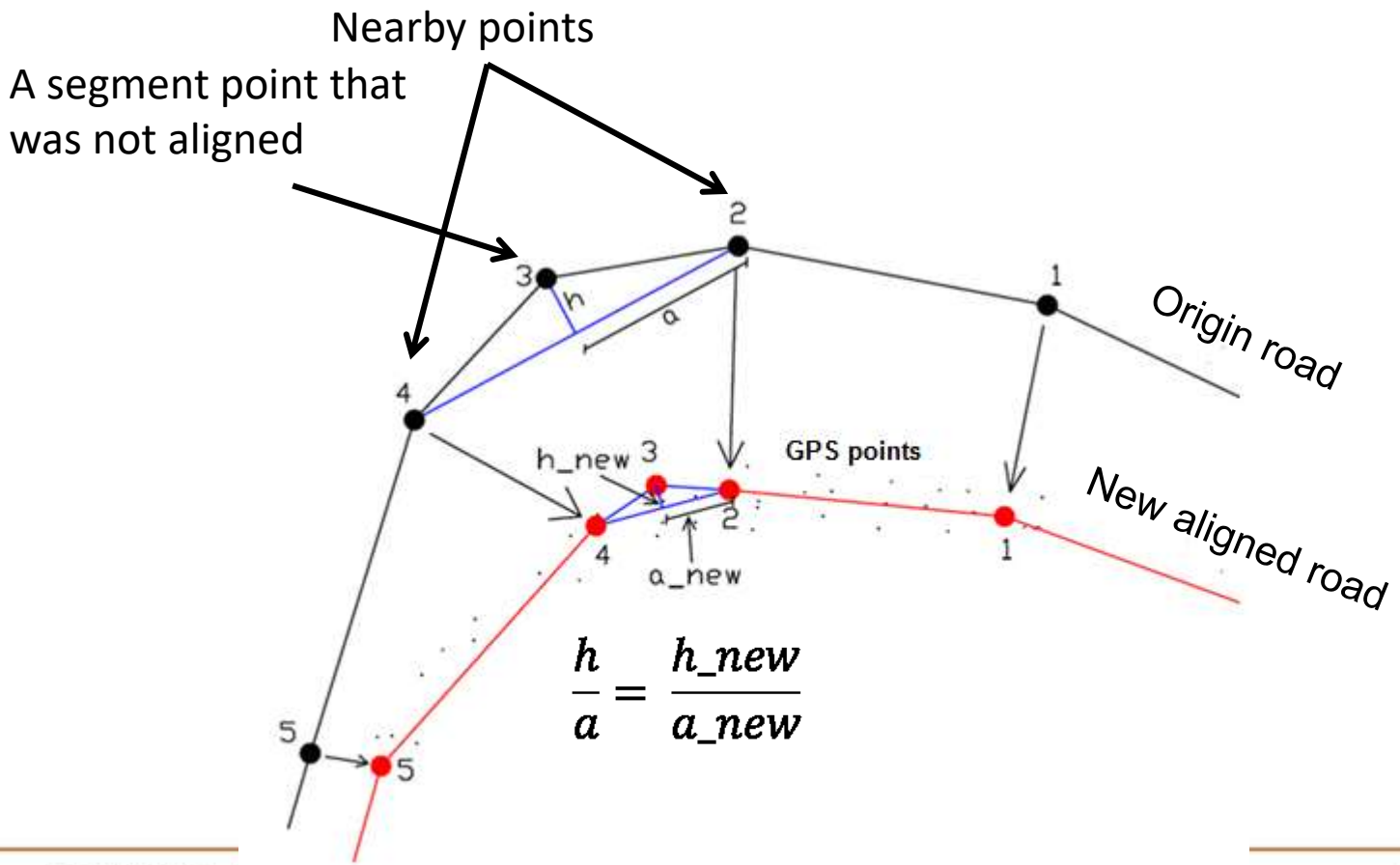
Calculating the "best " location of an intersection point



Minimizing the angles between the matched lines and the line connected to the geometric center point of the intersection.

$$Z_i = \text{atan}\left(\frac{(Y_b^i - Y_{ap})}{(X_b^i - X_{ap})}\right) - \text{atan}\left(\frac{Y_b^i - Y_a^i}{X_b^i - X_a^i}\right)$$

Realigning segment's points by preserving the road shape



$$\frac{h}{a} = \frac{h\_new}{a\_new}$$

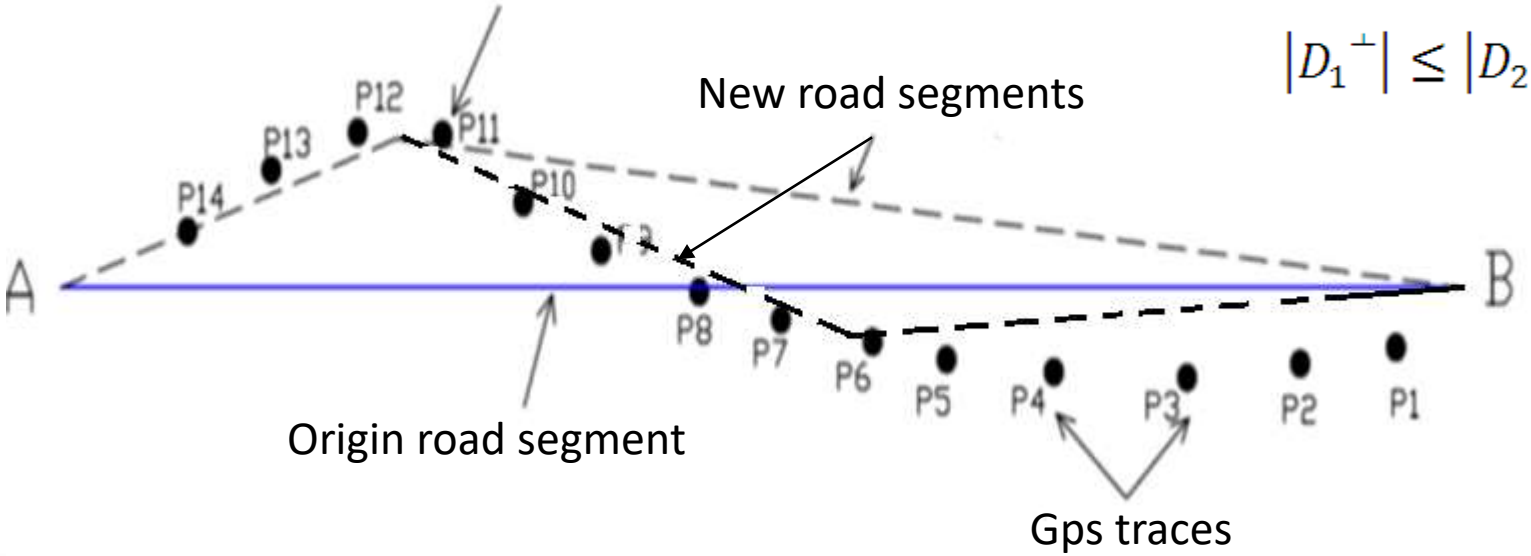
Adding new segments to fit the GPS points

- **stop condition:**
  - When the sum of the perpendicular distances increases after adding a new turning point

$$D^{\perp} = \frac{\sum_{i=1}^{n} |d_i^{\perp}|}{n}$$

$$|D_1{}^{\perp}| \leq |D_2{}^{\perp}|$$

Maximum perpendicular distance

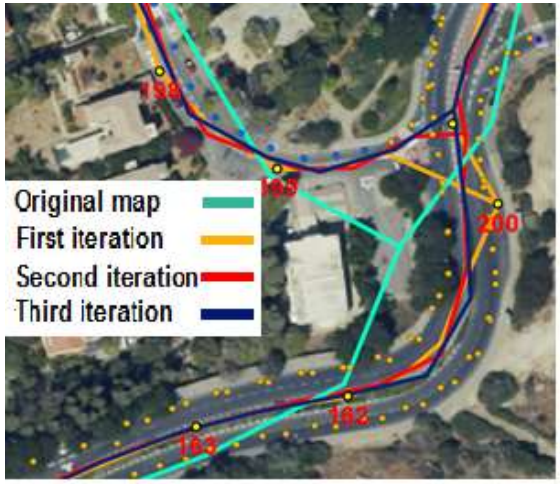


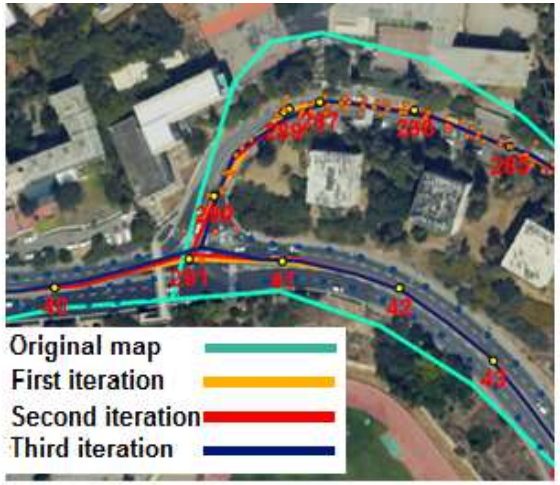
Results of algorithm

The averaged distances of the intersection points of the original map and the orthophoto : 16.31m

The averaged distances of the intersection points of the revised map and the orthophoto : 6.58m

An improvement of 9.73m in the average of the location intersection points

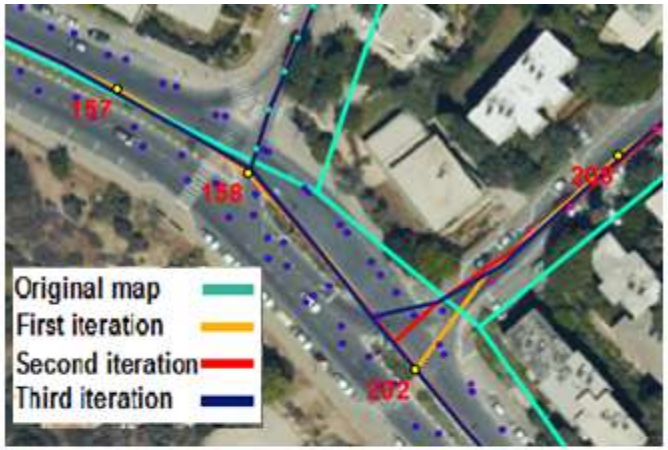




Future work

- Improving the map matching algorithm results.
- Testing the algorithm at different urban places.
- Upgrading the Map Alignment algorithm to deal with a lane resolution maps.
- Upgrading the Map Alignment algorithm by identifying new intersections and roads.


Original map
First iteration
Second iteration
Third iteration


Original map
First iteration
Second iteration
Third iteration


Original map
First iteration
Second iteration
Third iteration


Original map
First iteration
Second iteration
Third iteration


Original map
First iteration
Second iteration
Third iteration
8
7
273
222
221
63
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Thanks

Any questions ?