Inferring Maps from GPS Data

1. Why infer maps from GPS traces?
2. Biagioni/Eriksson algorithm
3. Evaluation metrics
4. Similar approaches: satellite images, map update
5. Lab 4

Map making

Uber is planning on investing $500 million to map the world's roads

This will reduce Uber's reliance on Google Maps

by Andrew Liptak | @AndrewLiptak | Jul 31, 2016, 5:54pm EDT

Will Your Next New Car Help Build Maps for Self-Driving?

Mobileye will use cameras on a growing list of automakers' cars to build maps for self-driving vehicles.

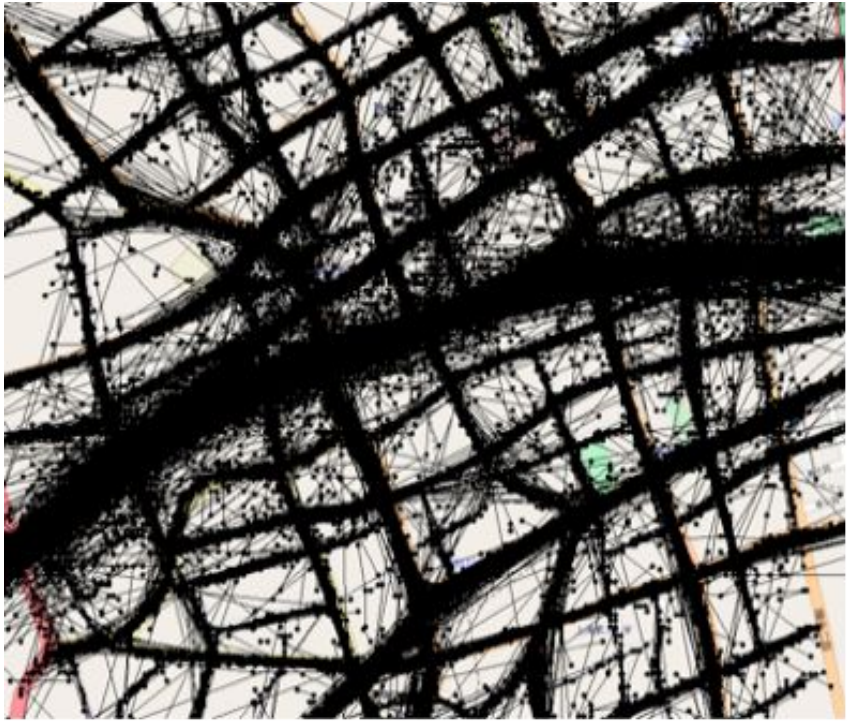
Why Ford Motor Is Investing in 3D Mapping Startup Civil Maps

Tencent, partners invest in HERE's digital maps to get a leg up on self-driving cars

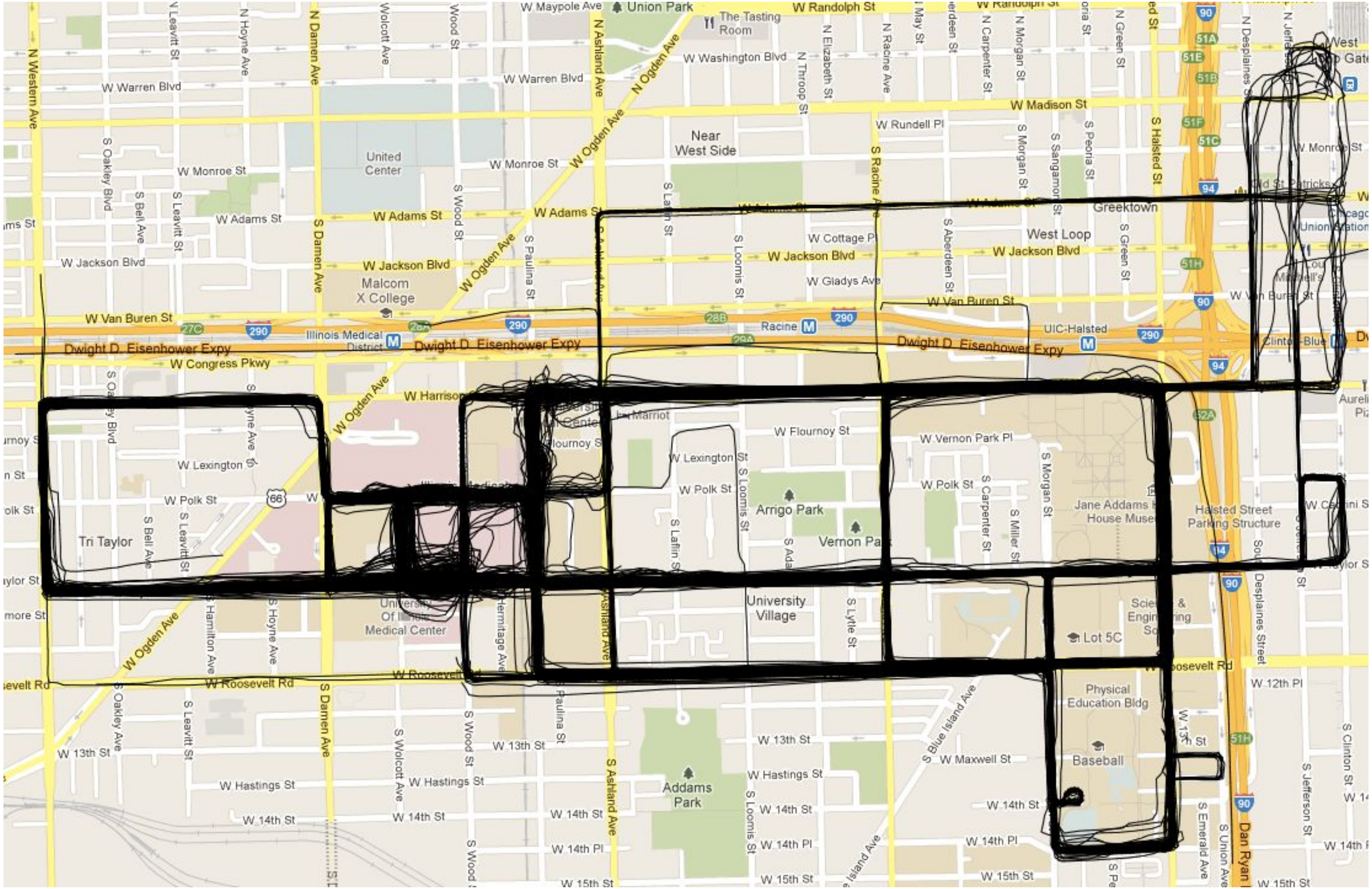
OpenStreetMap

- Licensed under Open Data Commons Open Database License
- Built using several data sources:
  - U.S. Census Bureau's TIGER data
  - GPS traces
  - Aerial images
- Humans process traces and images to update the map
- Decent coverage in large cities where there are many contributors, but often inaccurate or incomplete elsewhere

Opportunistic data collection



GPS traces, e.g., from smartphone apps, taxis, etc



W Maypole Ave
Union Park
The Tasting Room
W Randolph St
W Washington Blvd
W Warren Blvd
W Madison St
W Rundell Pl
Near West Side
United Center
W Monroe St
W Adams St
W Jackson Blvd
Malcom X College
W Van Buren St
Greektown
West Loop
W Cottage Pl
W Gladys Ave
Illinois Medical District
Racine
UIC-Halsted
Dwight D. Eisenhower Expy
W Congress Pkwy
W Harrison St
W Flournoy St
W Vernon Park Pl
W Lexington St
W Polk St
Arrigo Park
Vernon Park
Tri Taylor
Jane Addams Hull House Museum
Halsted Street Parking Structure
University Village
University Of Illinois Medical Center
Lot 5C
W Roosevelt Rd
Physical Education Bldg
Baseball
W 13th St
W Hastings St
W 14th St
W 14th Pl
W 15th St
W Maxwell St
W 12th Pl
Addams Park
N Western Ave
N Damen Ave
S Damen Ave
N Ashland Ave
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W Ogden Ave
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S Racine Ave
S Halsted St
S Morgan St
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S Loomis St
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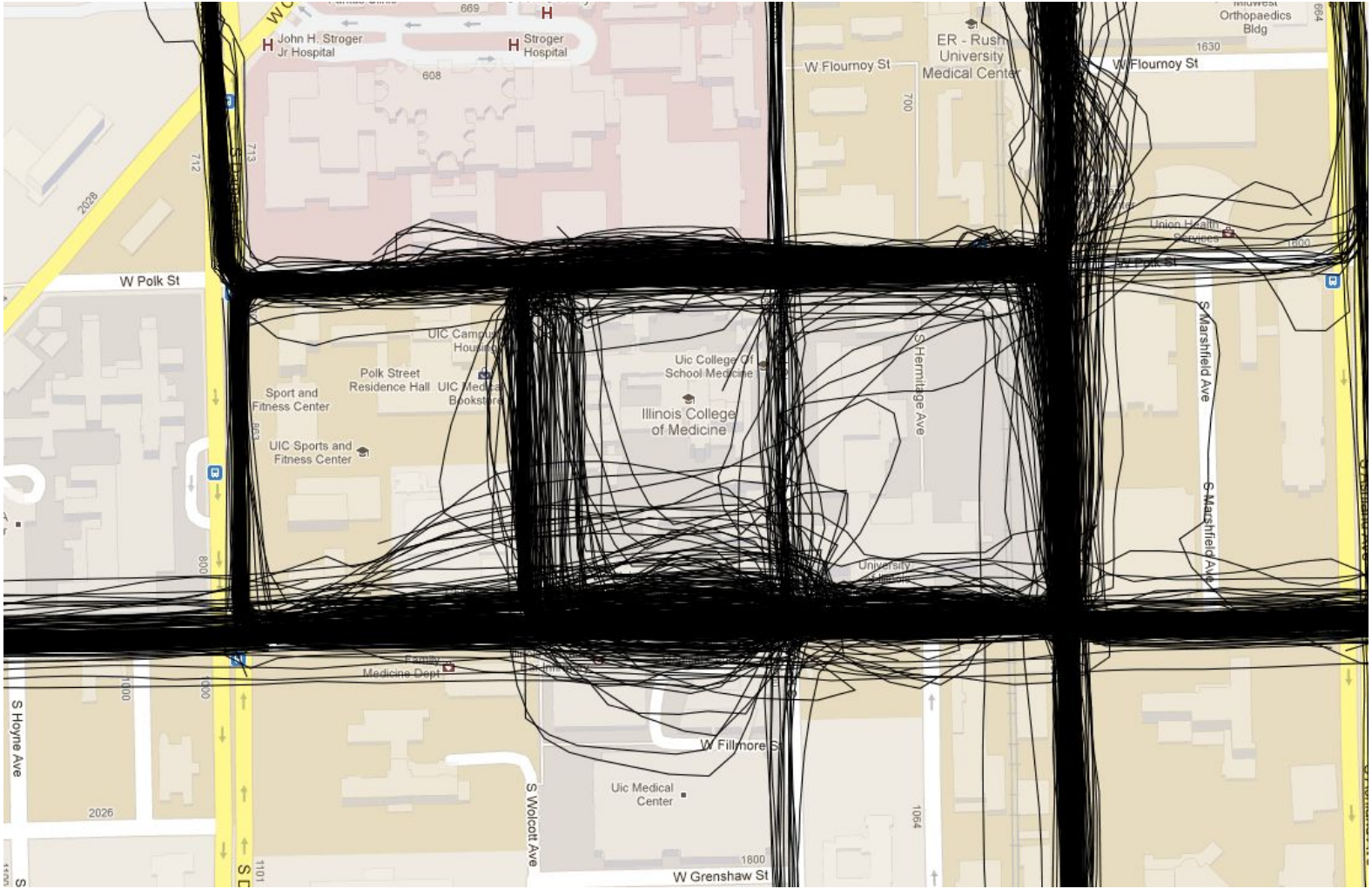
S Jefferson St
S Union Ave
S Emerald Ave
Dan Ryan Expy
Chicago Union Station
Clinton-Blue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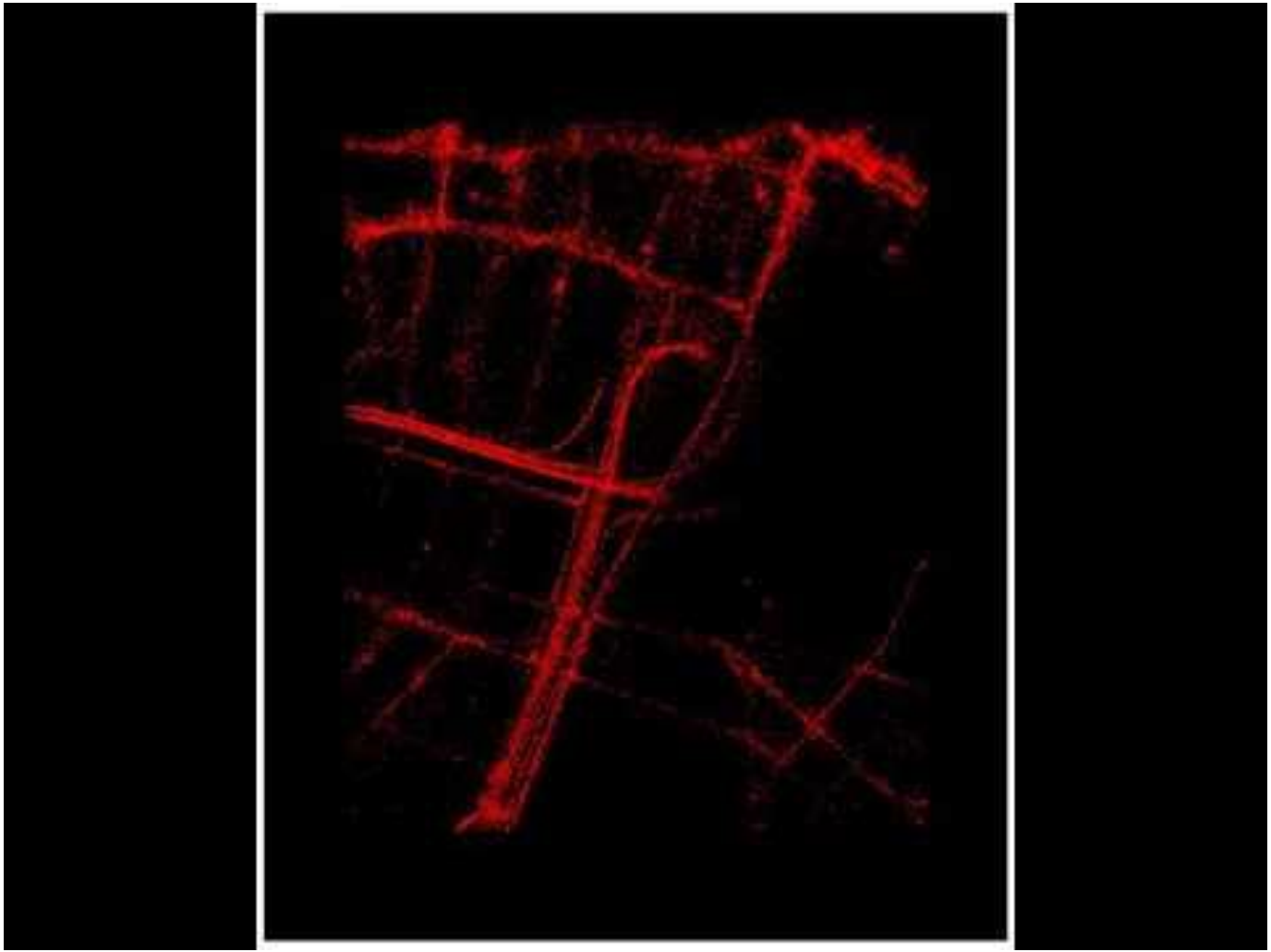
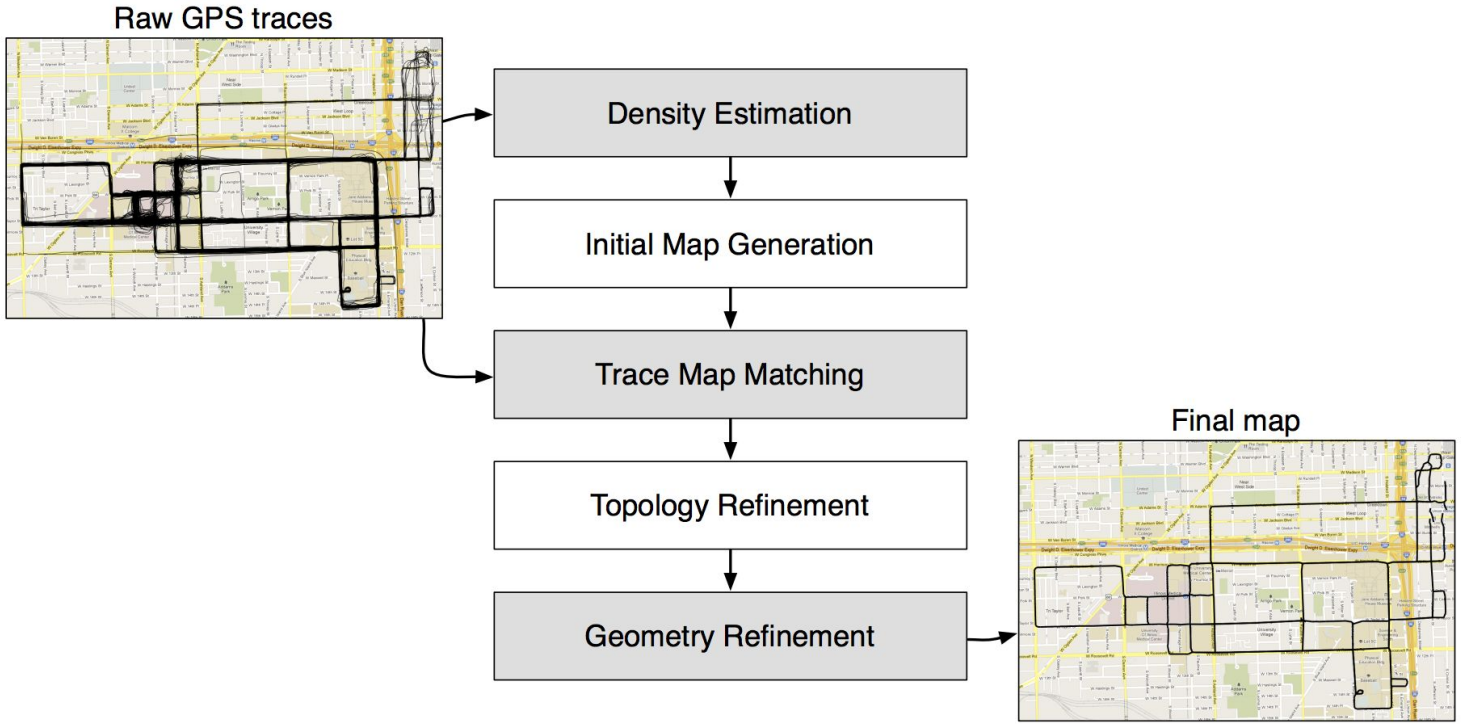
Stroger Hospital
ER - Rush University Medical Center
Midwest Orthopaedics Bldg
W Flournoy St
W Polk St
Polk Street Residence Hall
Sport and Fitness Center
UIC Sports and Fitness Center
Illinois College of Medicine
Uic College Of School Medicine
S Hermitage Ave
S Marshfield Ave
Union Health Services
Family Medicine Dept
S Hoyne Ave
W Fillmore St
Uic Medical Center
S Wolcott Ave
W Grenshaw St

Challenges

- GPS errors
- Sparsity of data
- Differential sampling rate (1s, 10s, 1m)
- Urban Canyons
- Complex intersections such as roundabouts, highway intersections



Map inference in the face of noise and disparity



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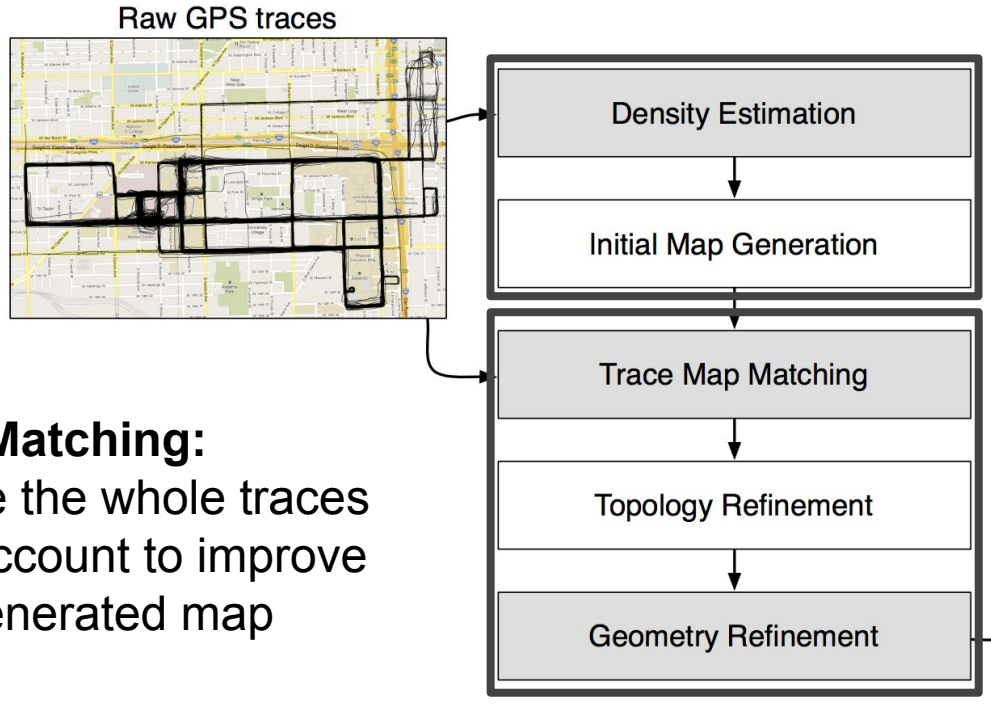

Gray-scale Skeletonization
- Cope with noise and disparity

Map Matching:
- Take the whole traces into account to improve the generated map

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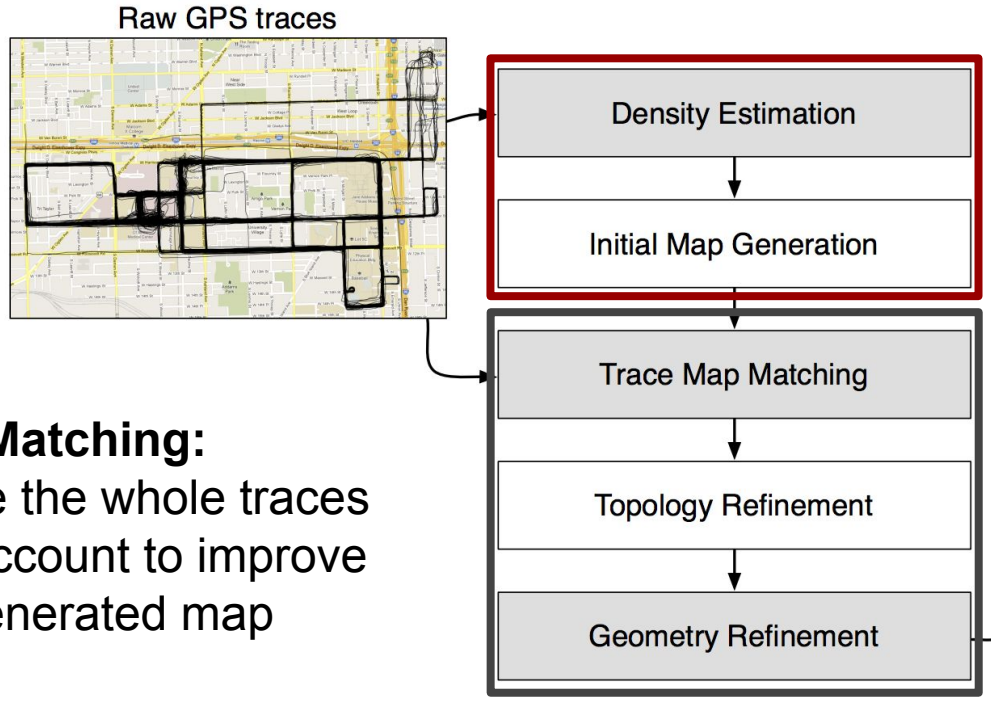

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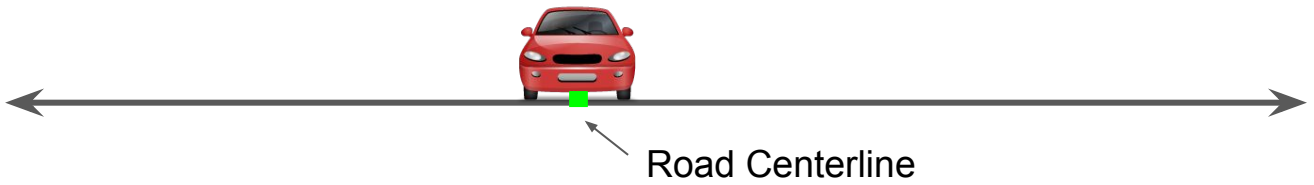
Density Estimation

- 1D Example
  - What does a density estimation based map-inference algorithm look like?
  - What is the problem with it?

Density Estimation

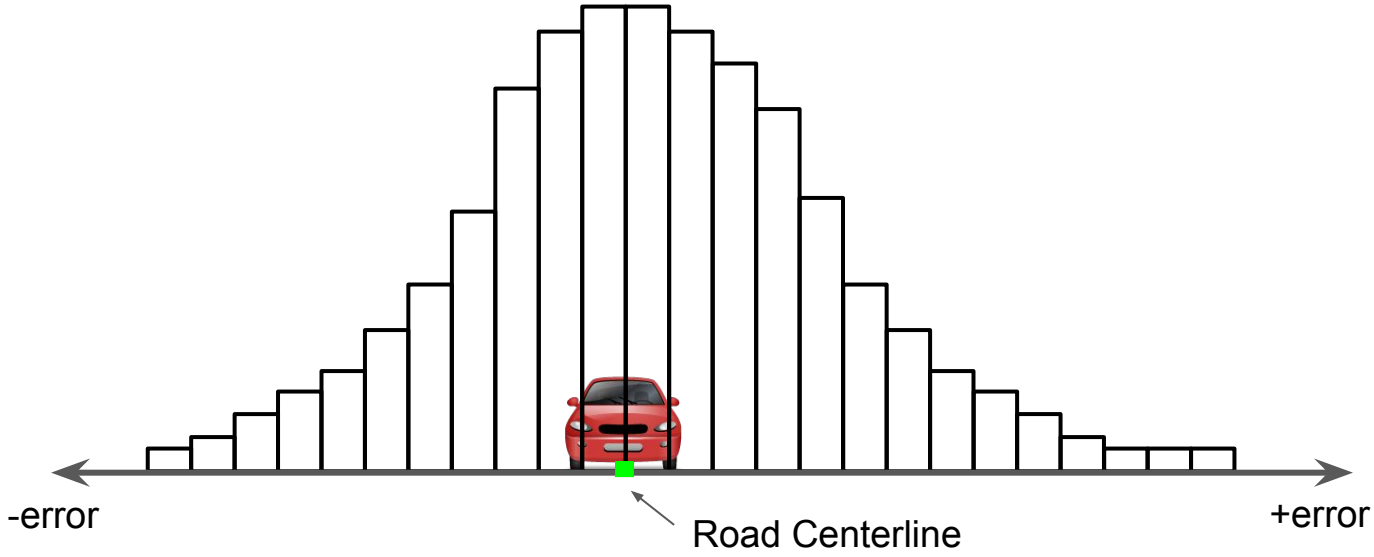
- 1D Example



Density Estimation

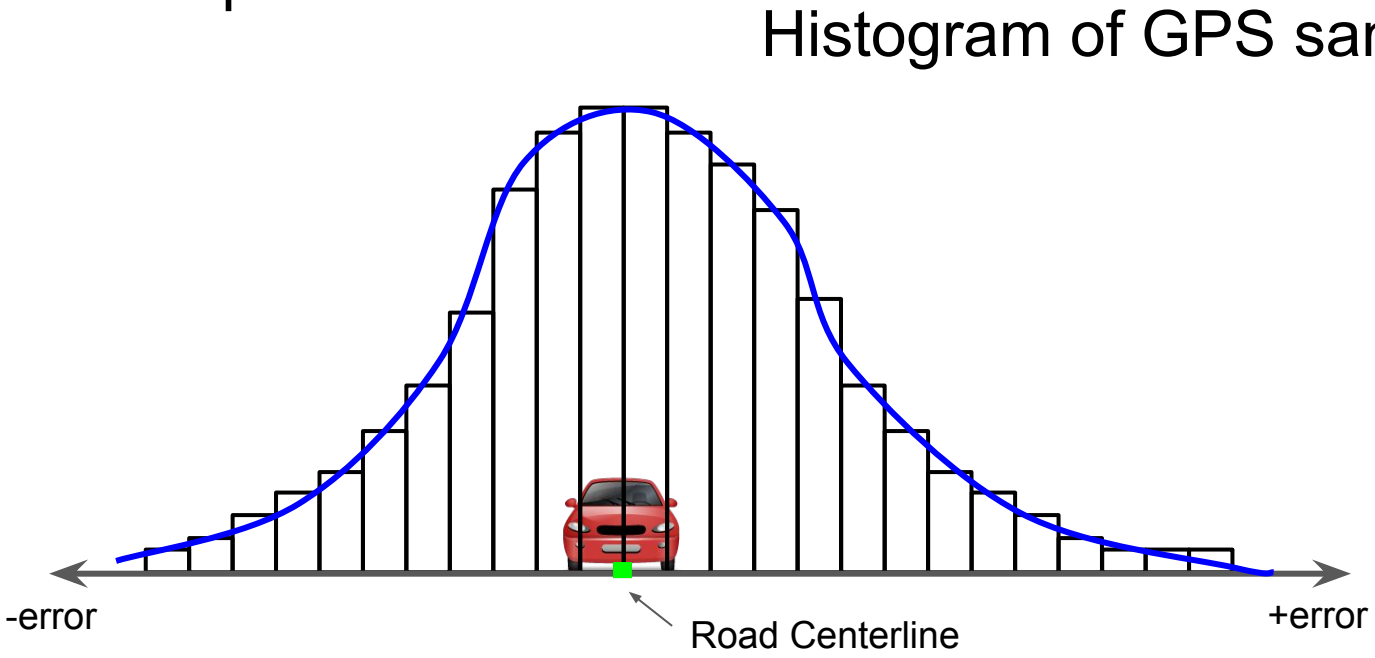
- 1D Example

Histogram of GPS samples



Density Estimation

- 1D Example



Density Estimation

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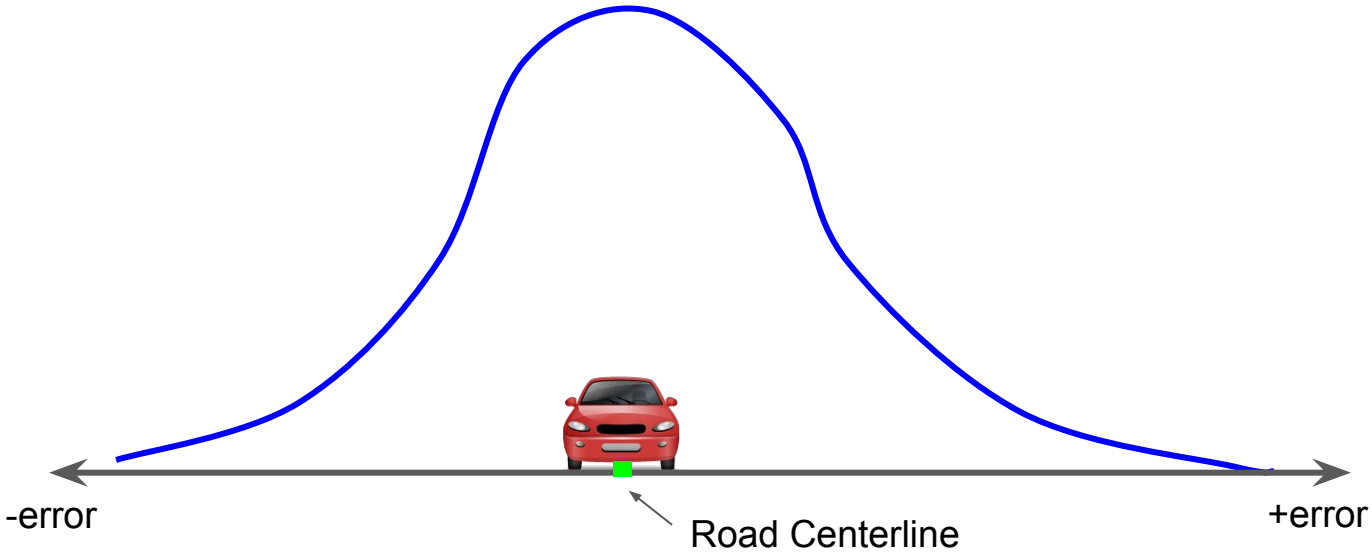
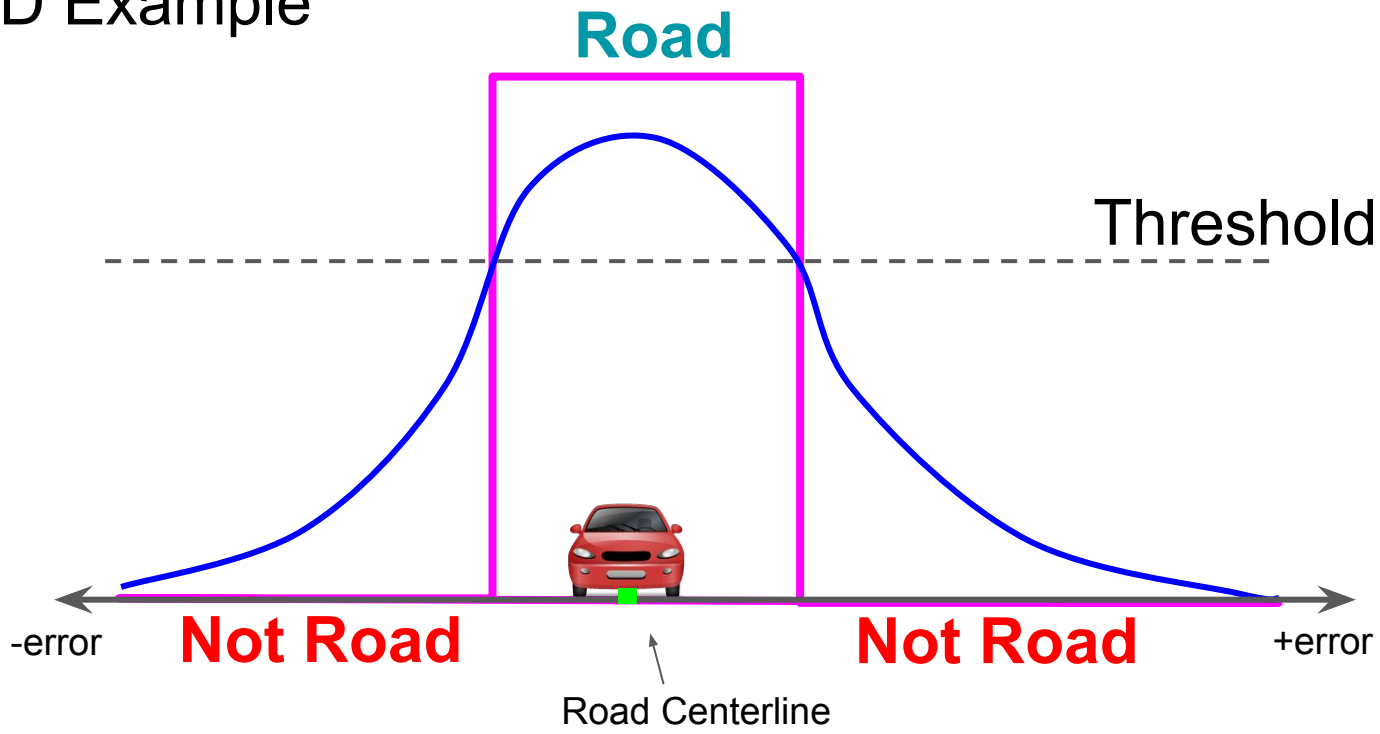


Density Estimation

- 1D Example



Density Estimation

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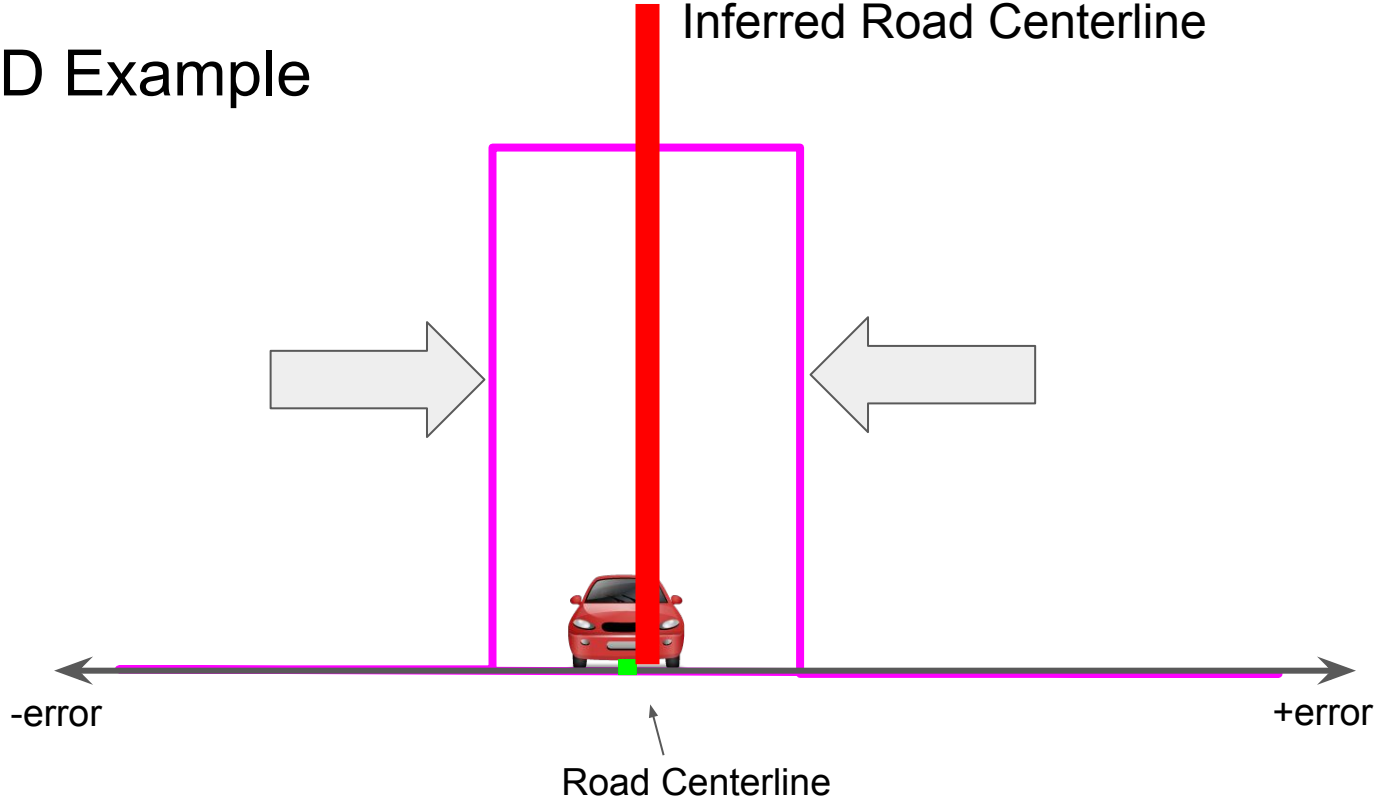
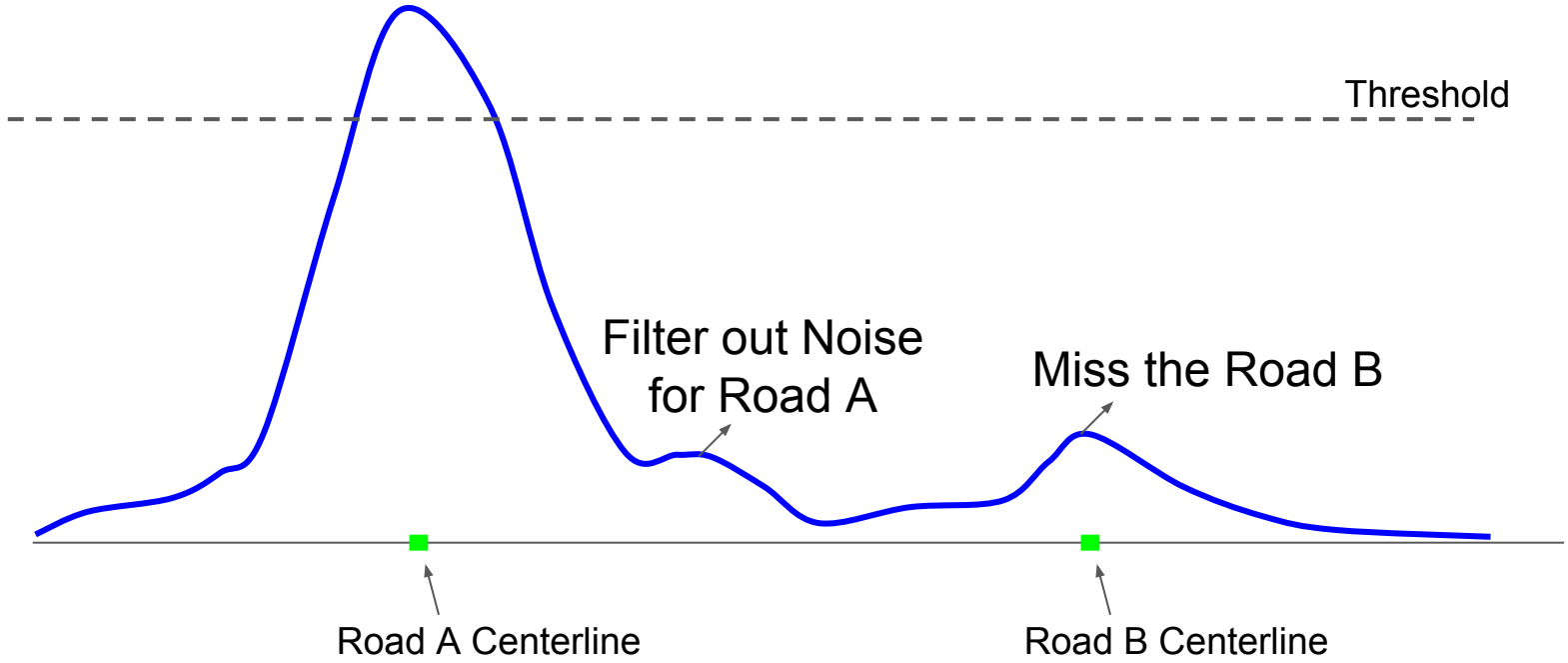


Density Estimation

- 1D Example
  - What’s the problem with this algorithm?

Density Estimation

Single threshold doesn’t work well



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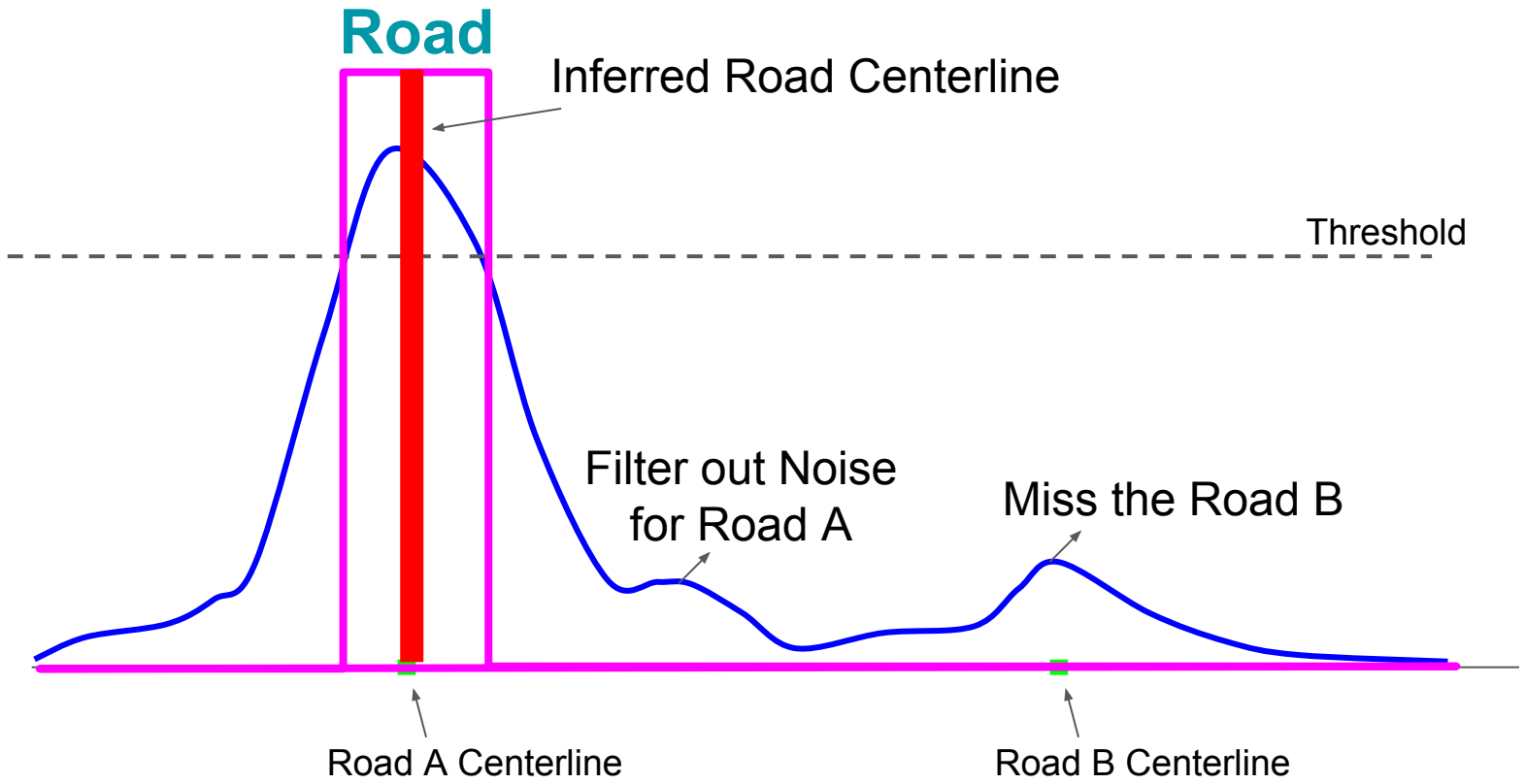
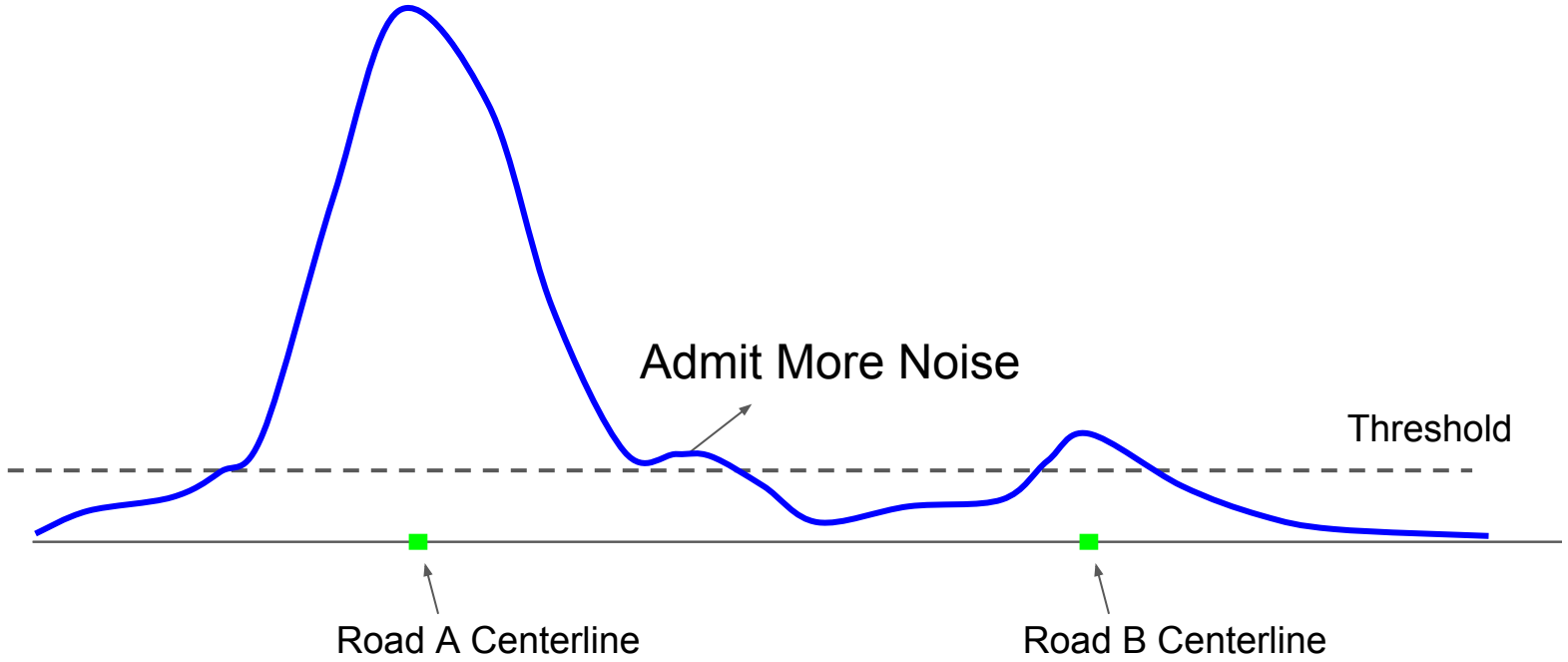


Density Estimation

Single threshold doesn't work well



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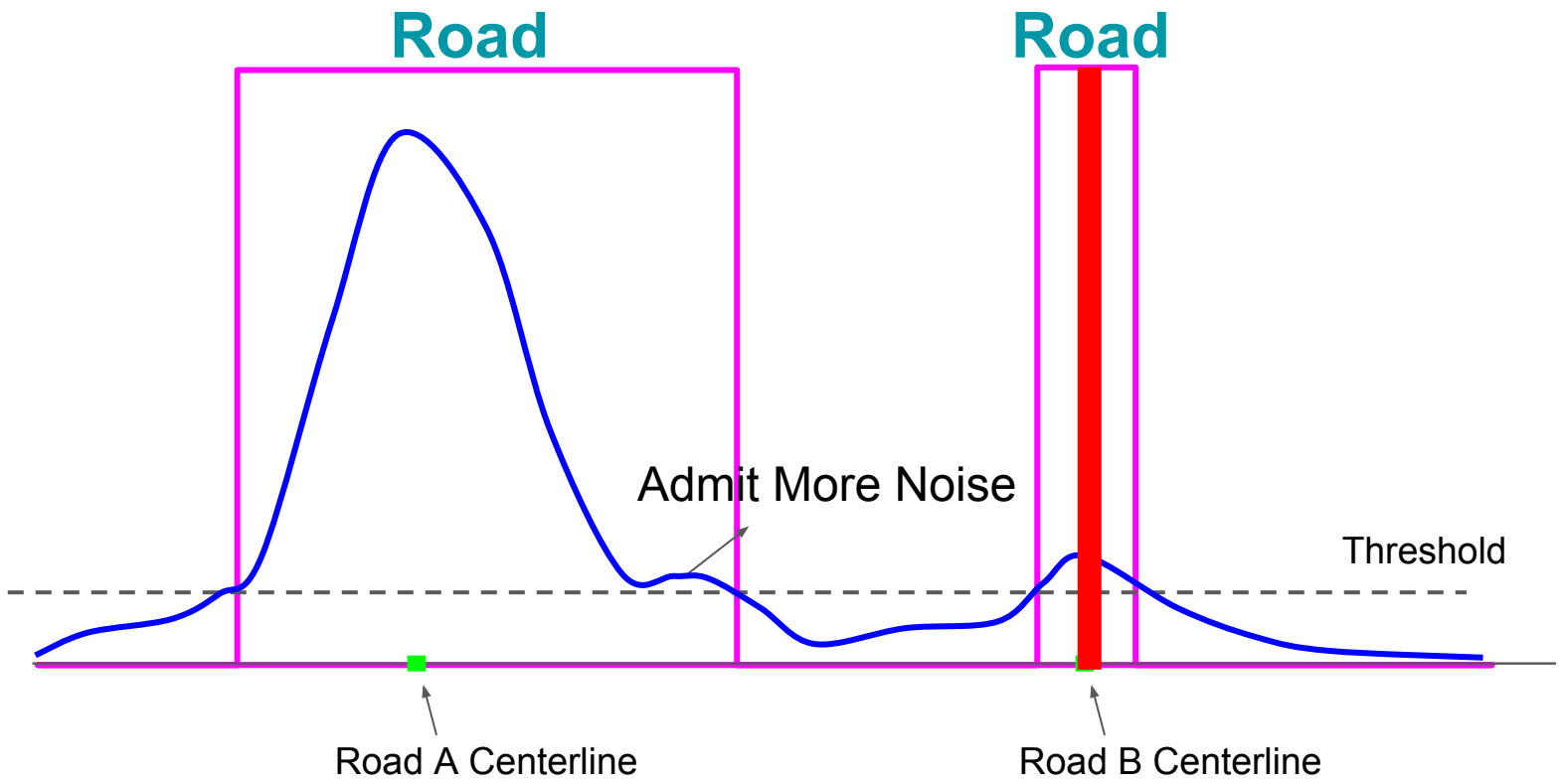

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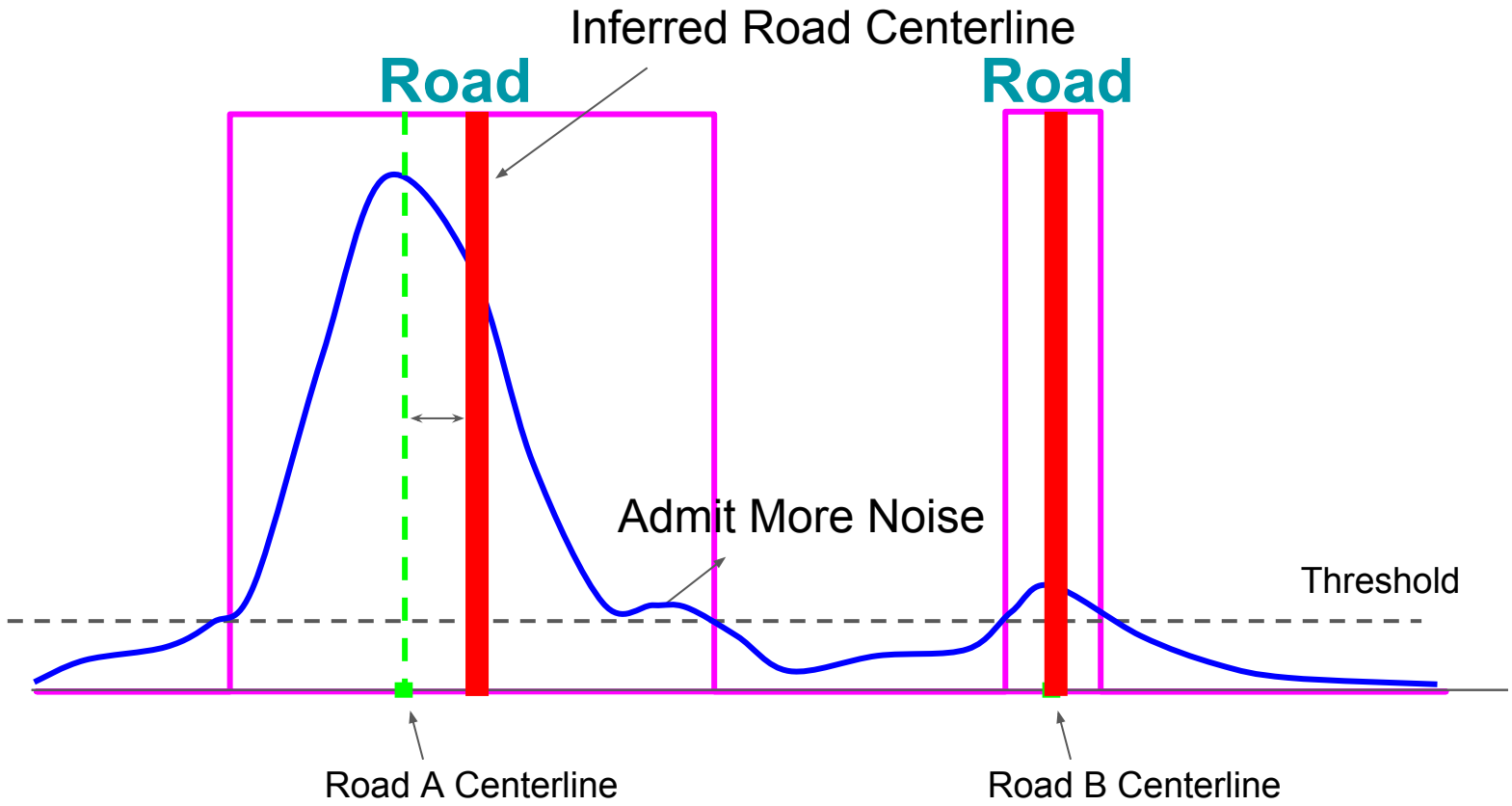

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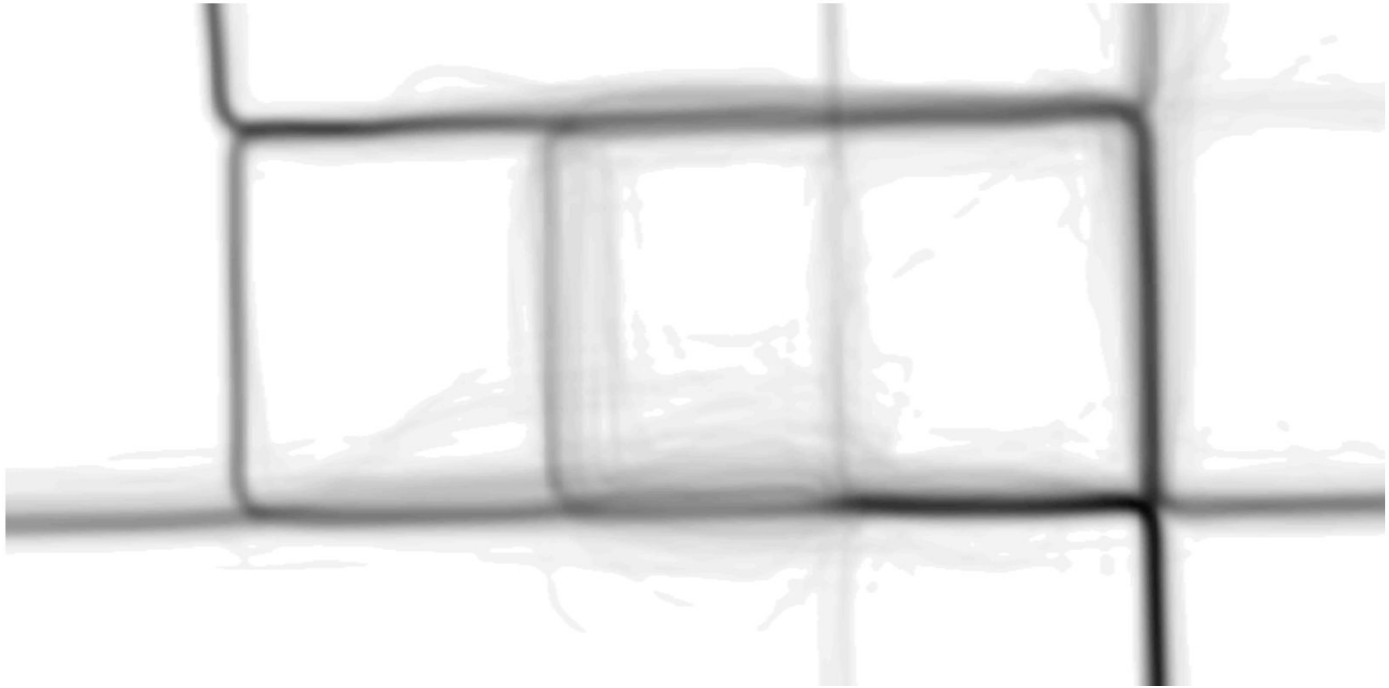
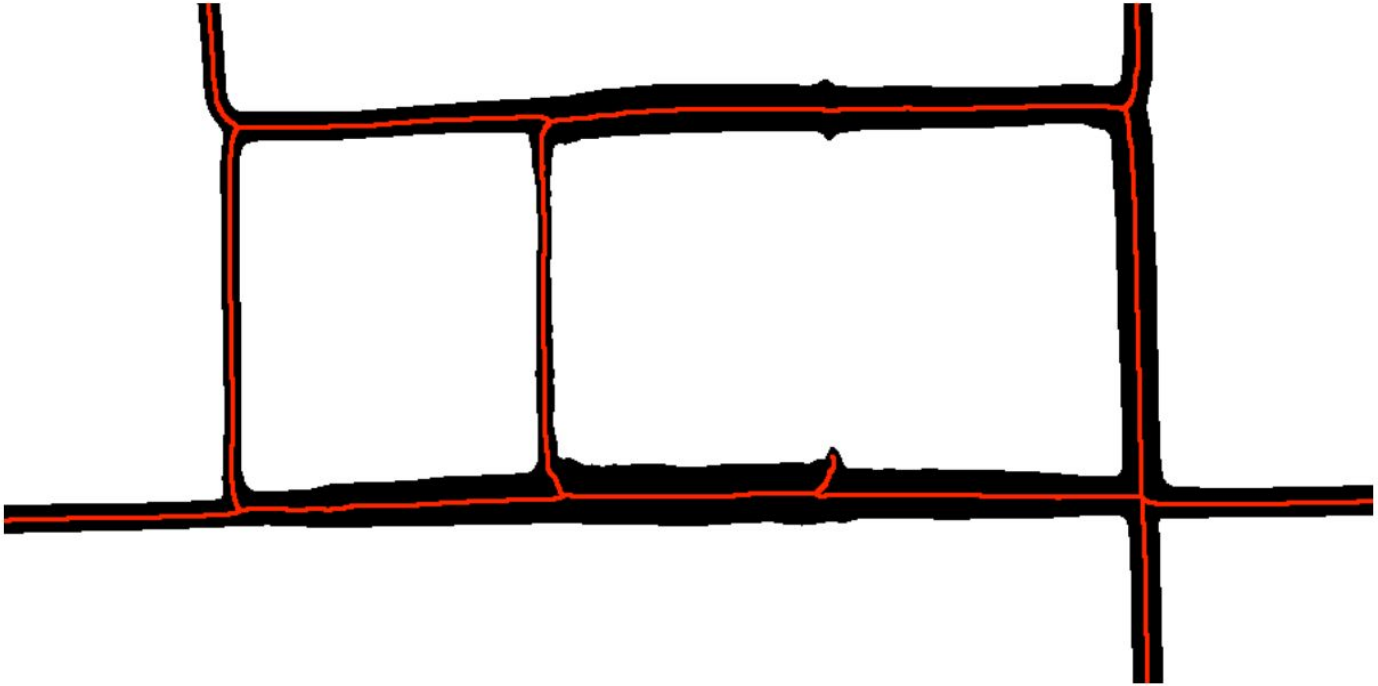


Density Estimation

High Threshold



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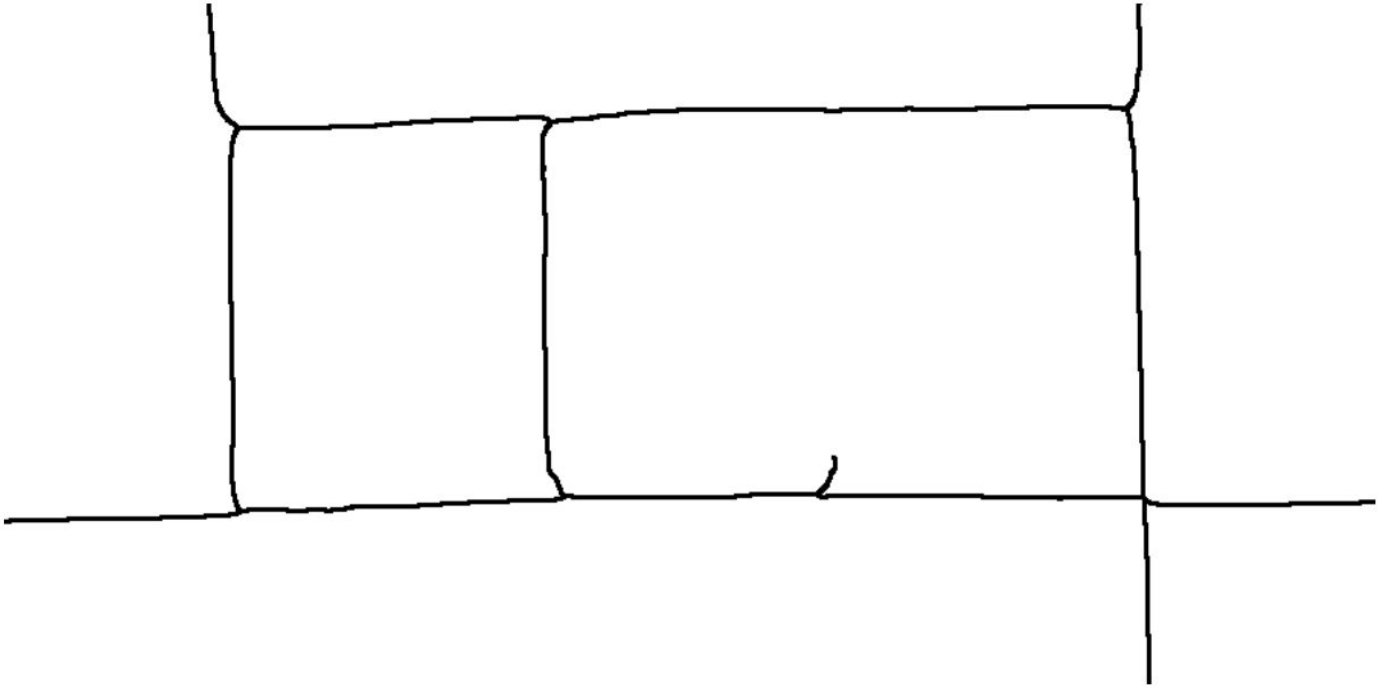

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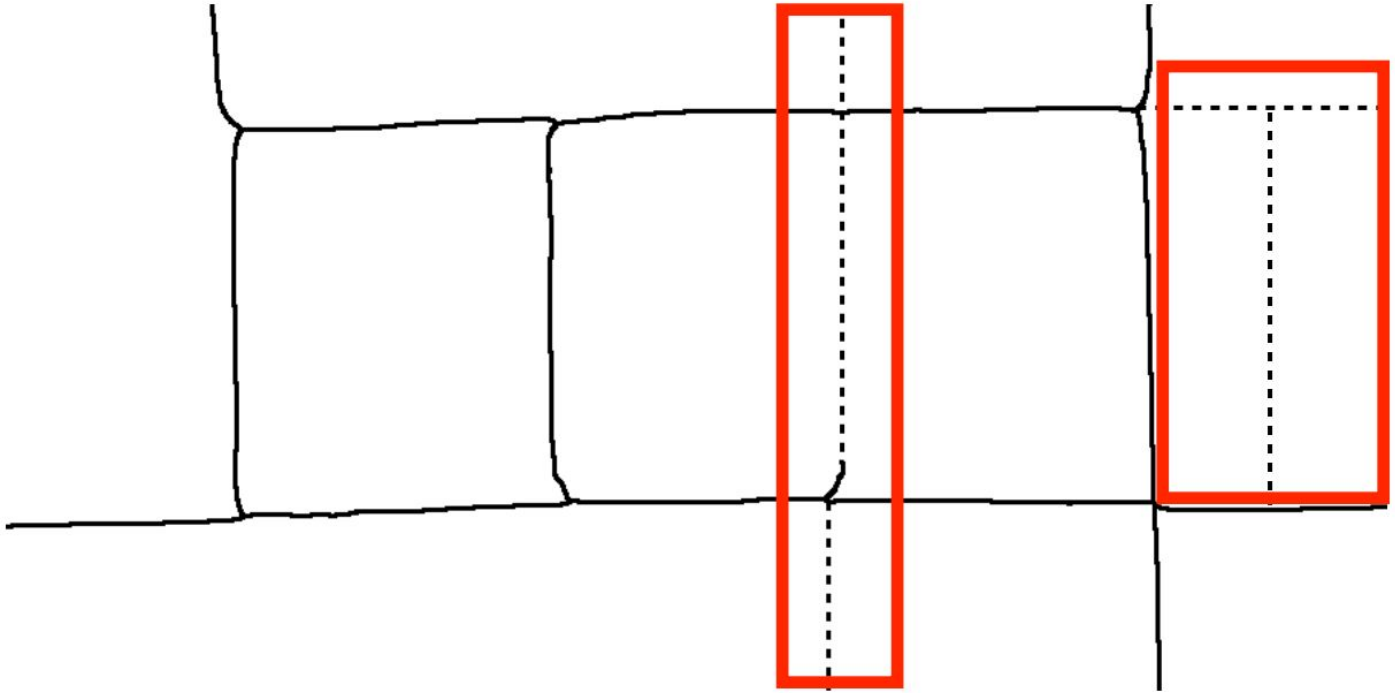
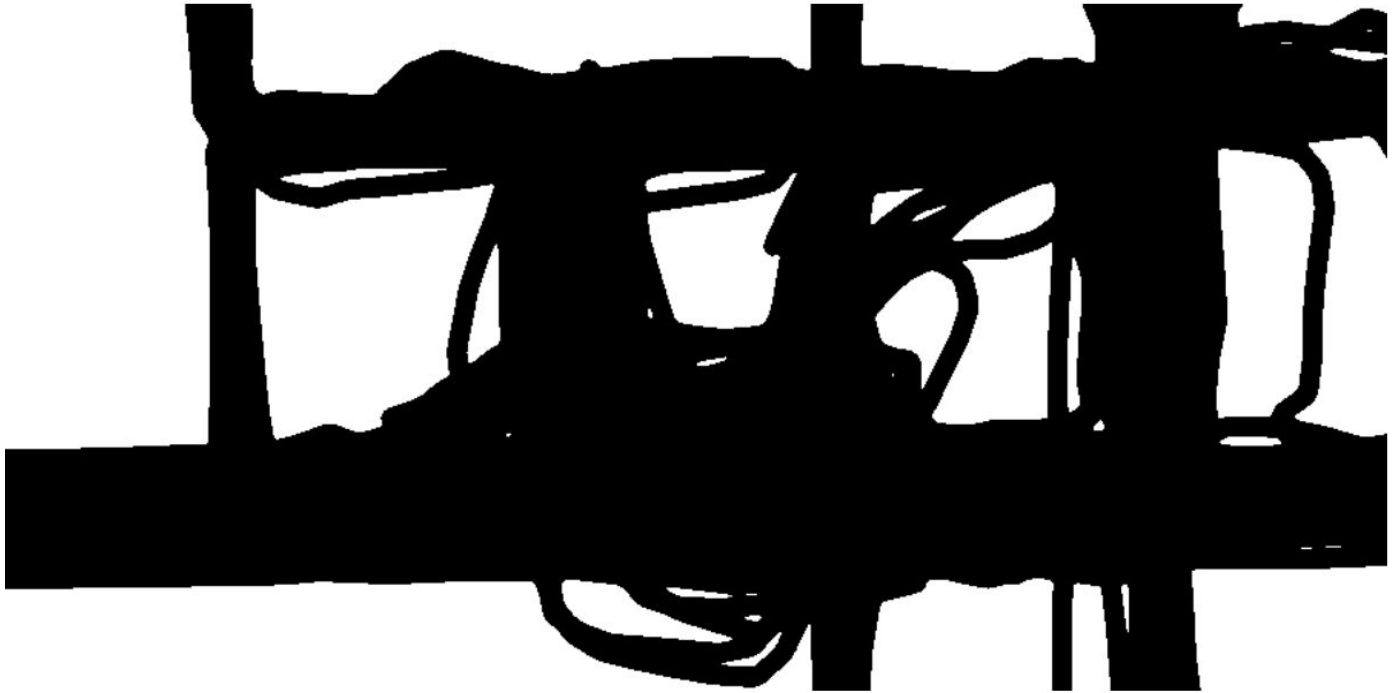


Density Estimation

Low Threshold



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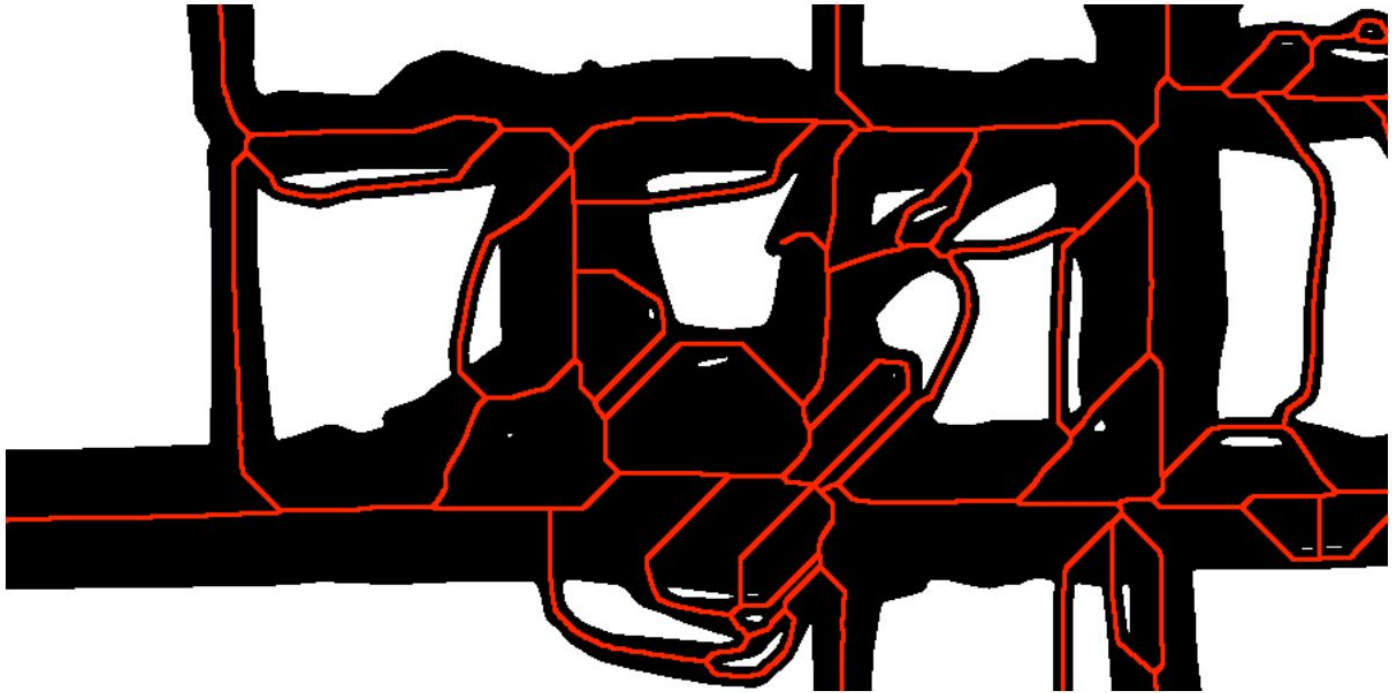
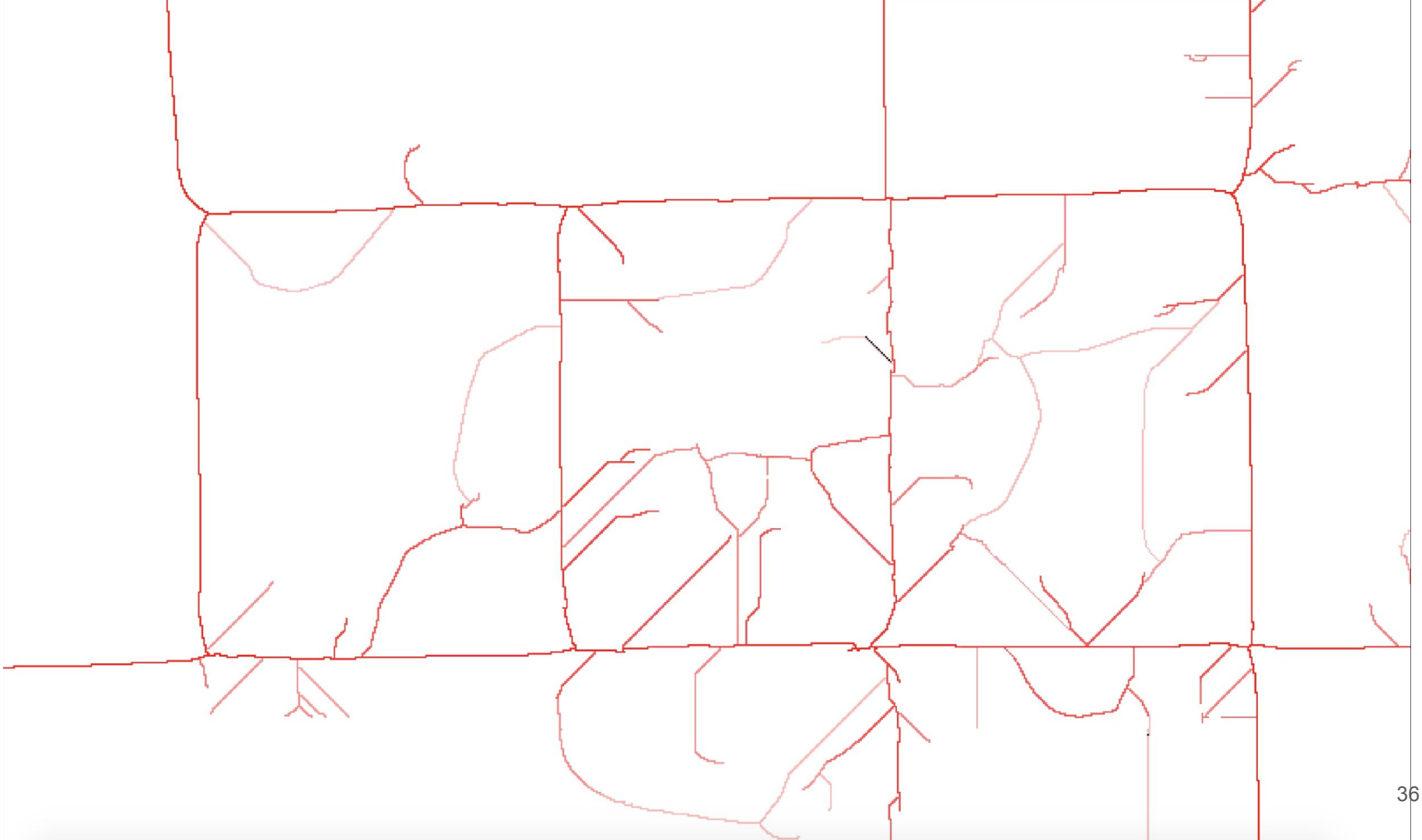
Low Threshold

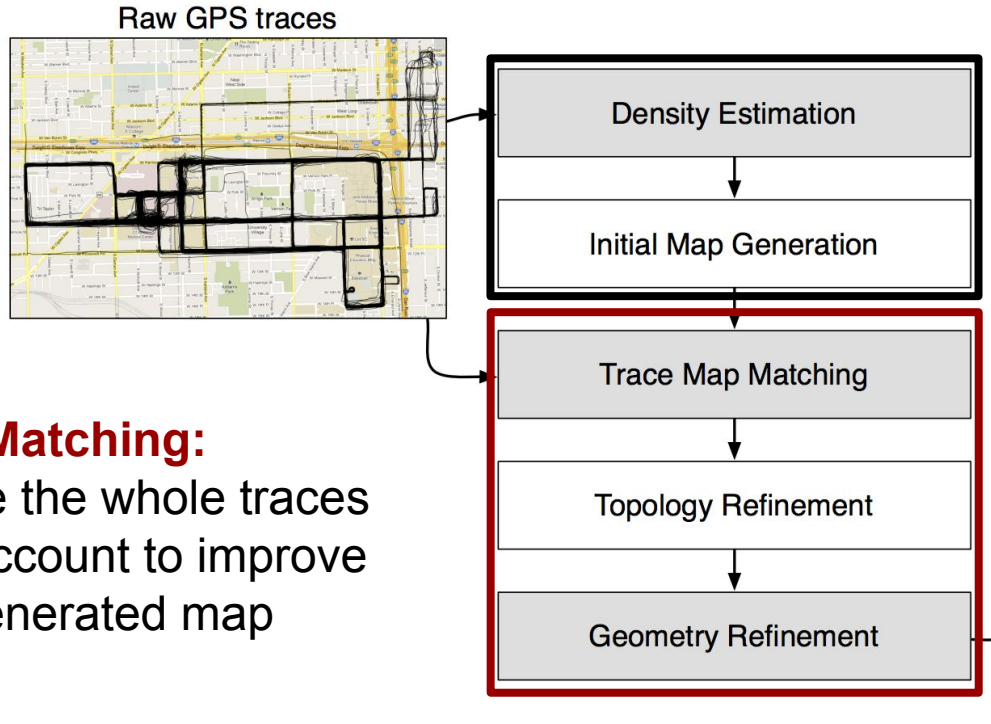


Density Estimation - Gray-scale Skeletonization

- Skeletonization with different thresholds, from high to low
- Remain the results from high thresholds
- Assign weights to each pixel



Map inference in the face of noise and disparity



Gray-scale Skeletonization
- Cope with noise and disparity

Map Matching:
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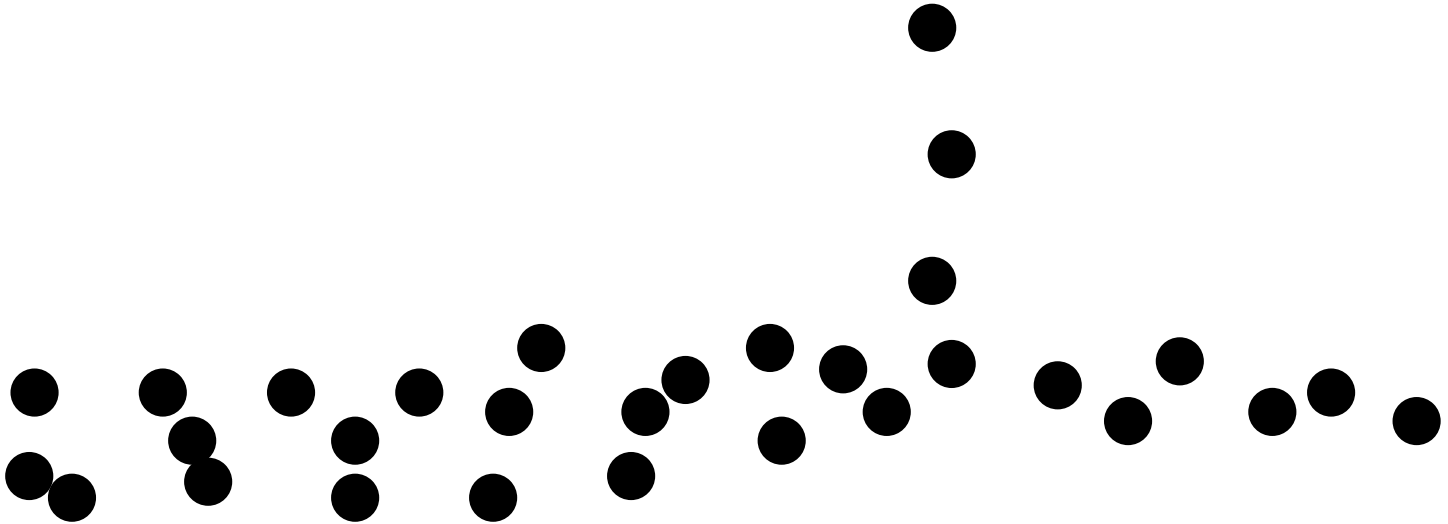
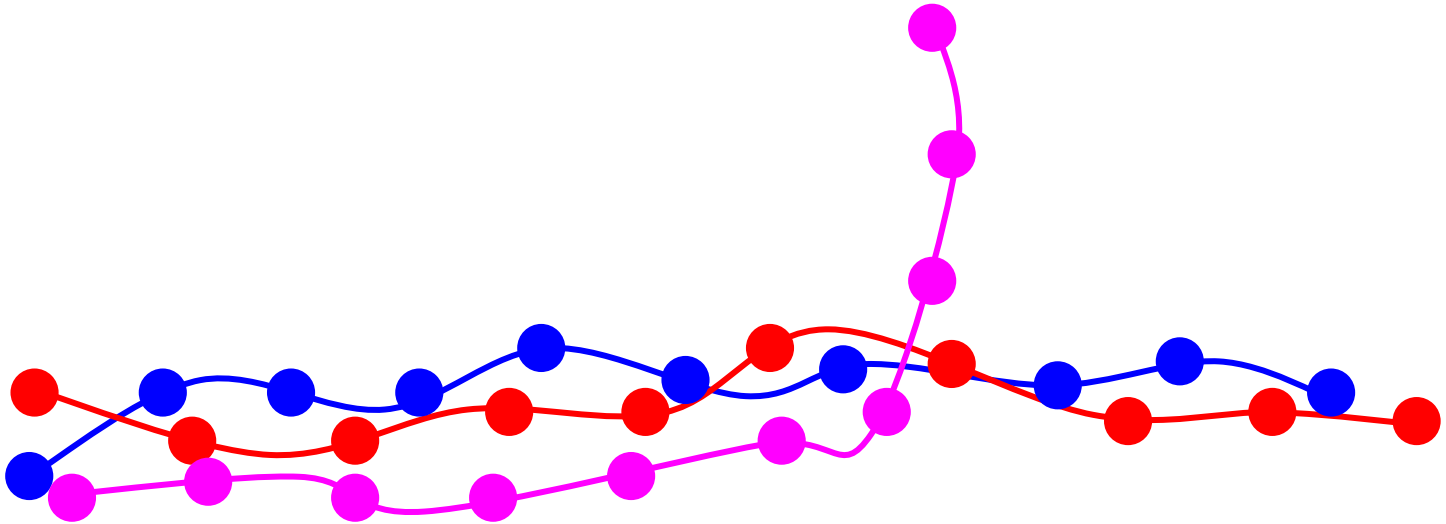
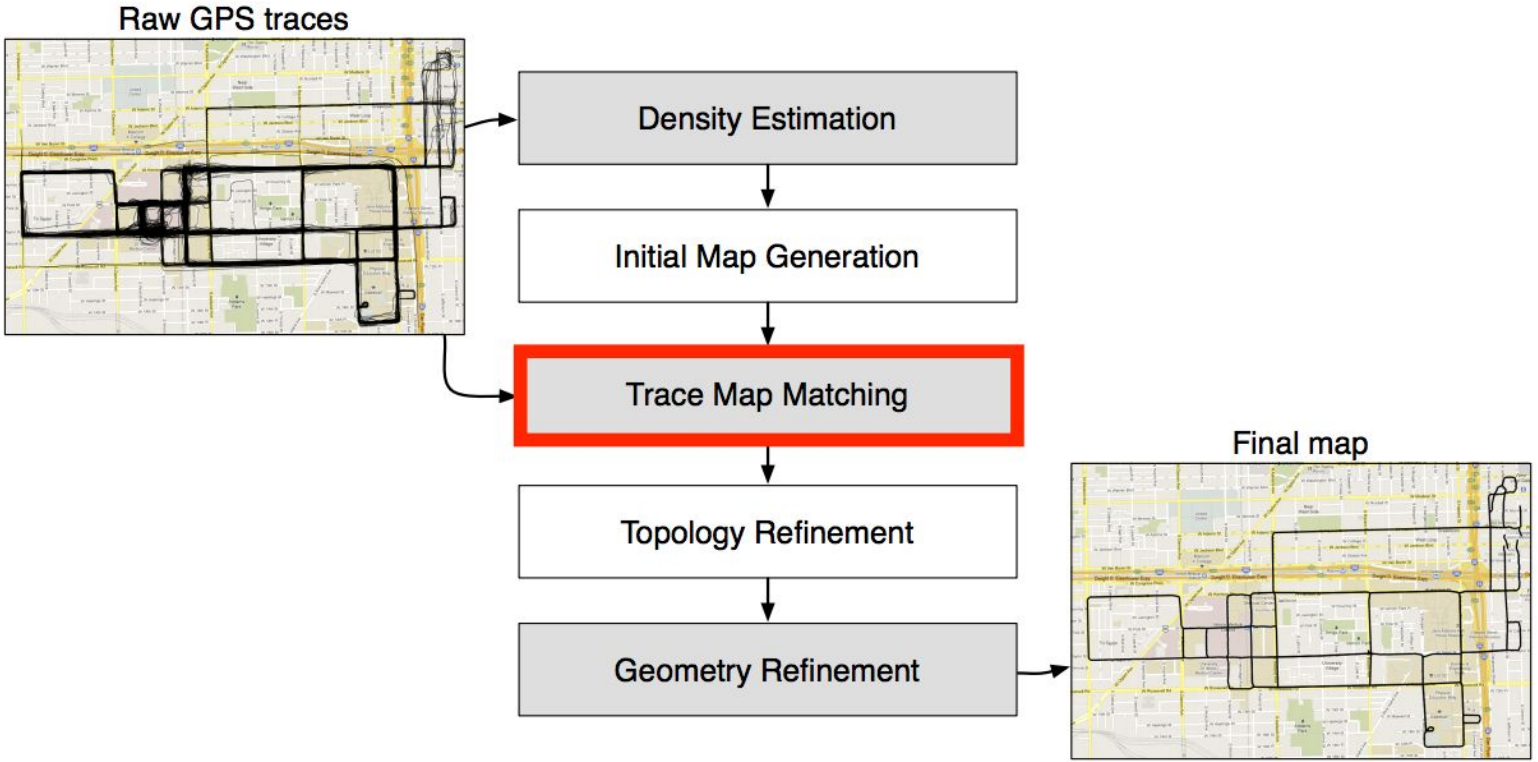
The View of Traces from Density Estimation



More Information if You Consider the Whole Trace



Map Matching



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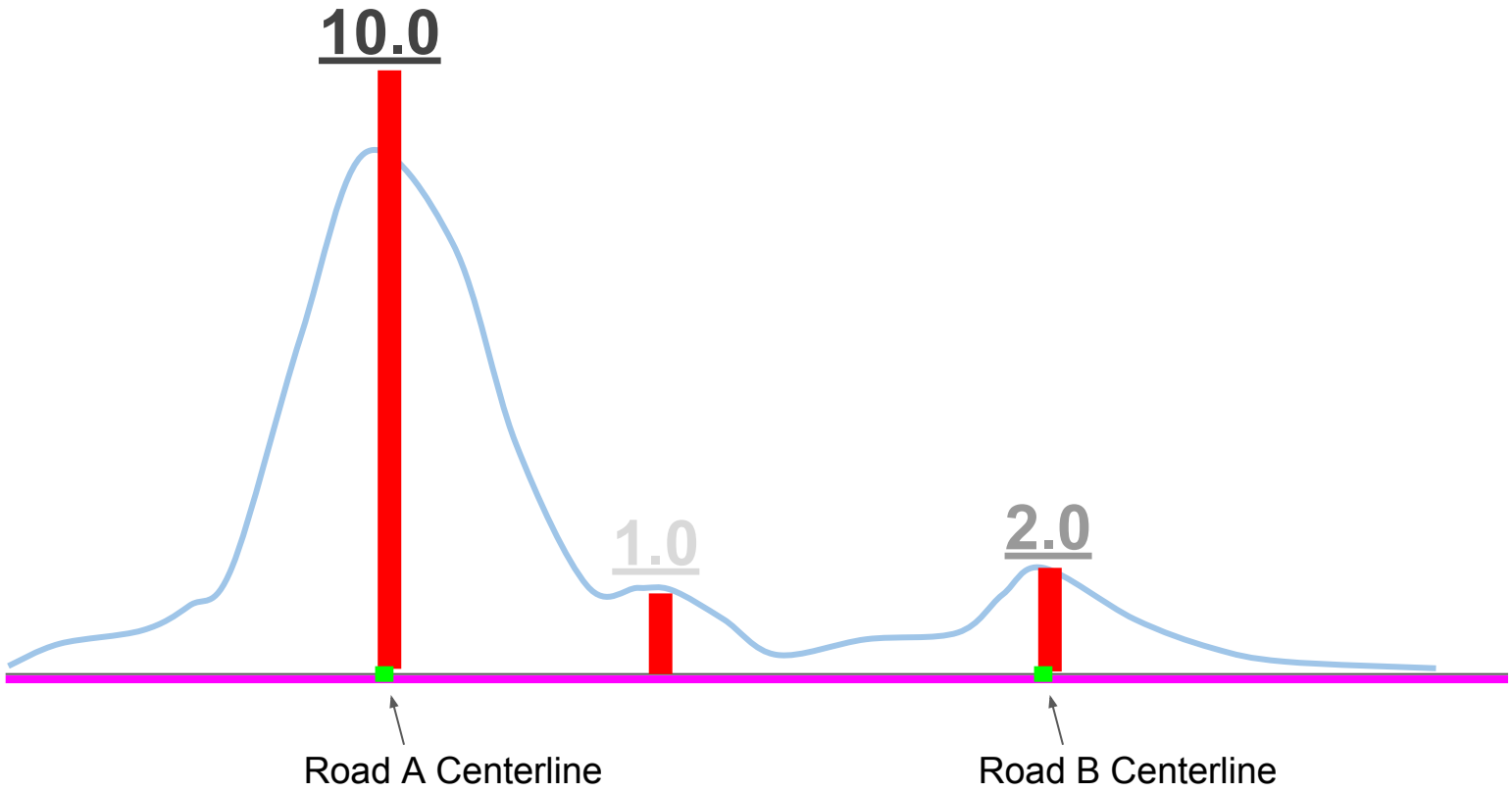

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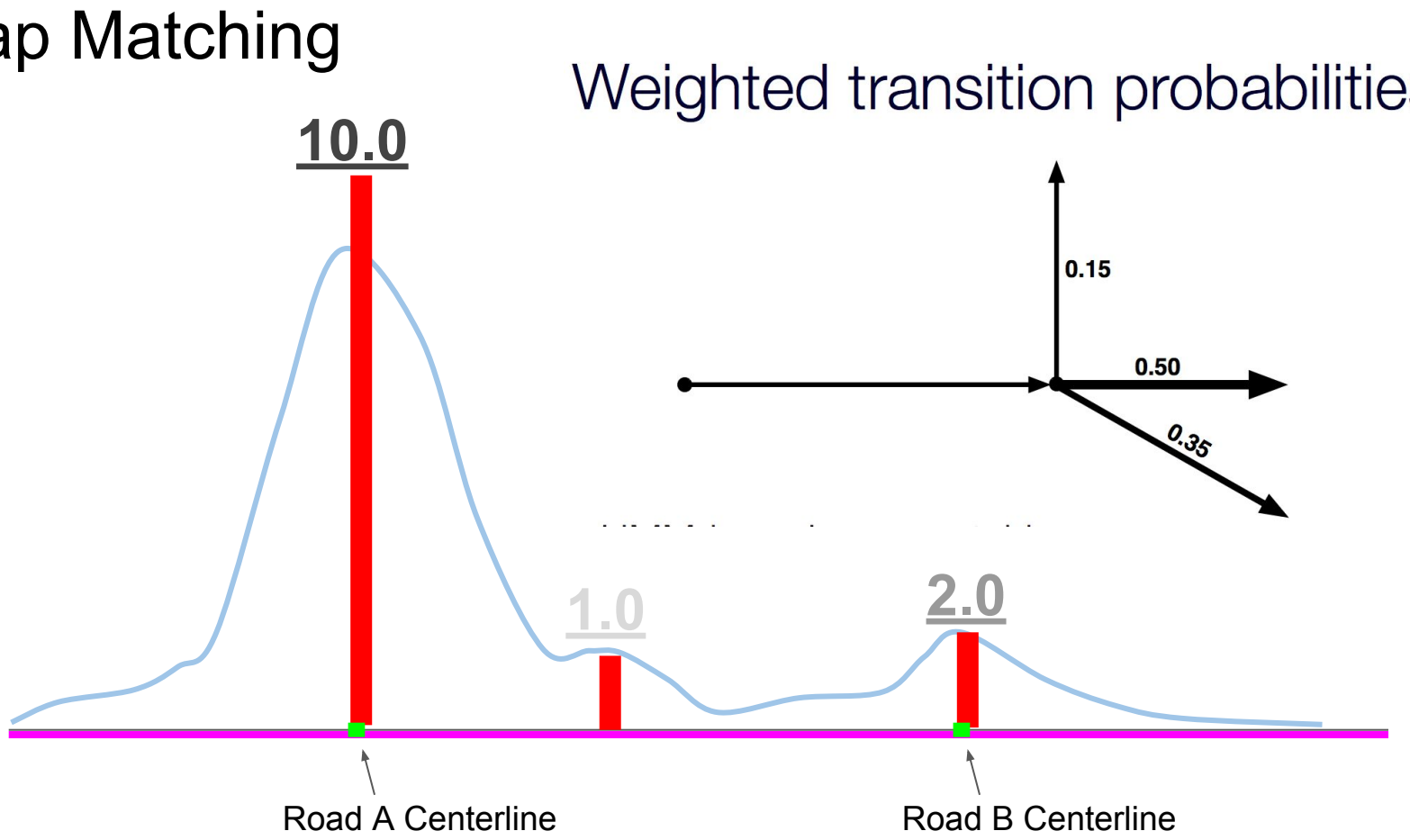

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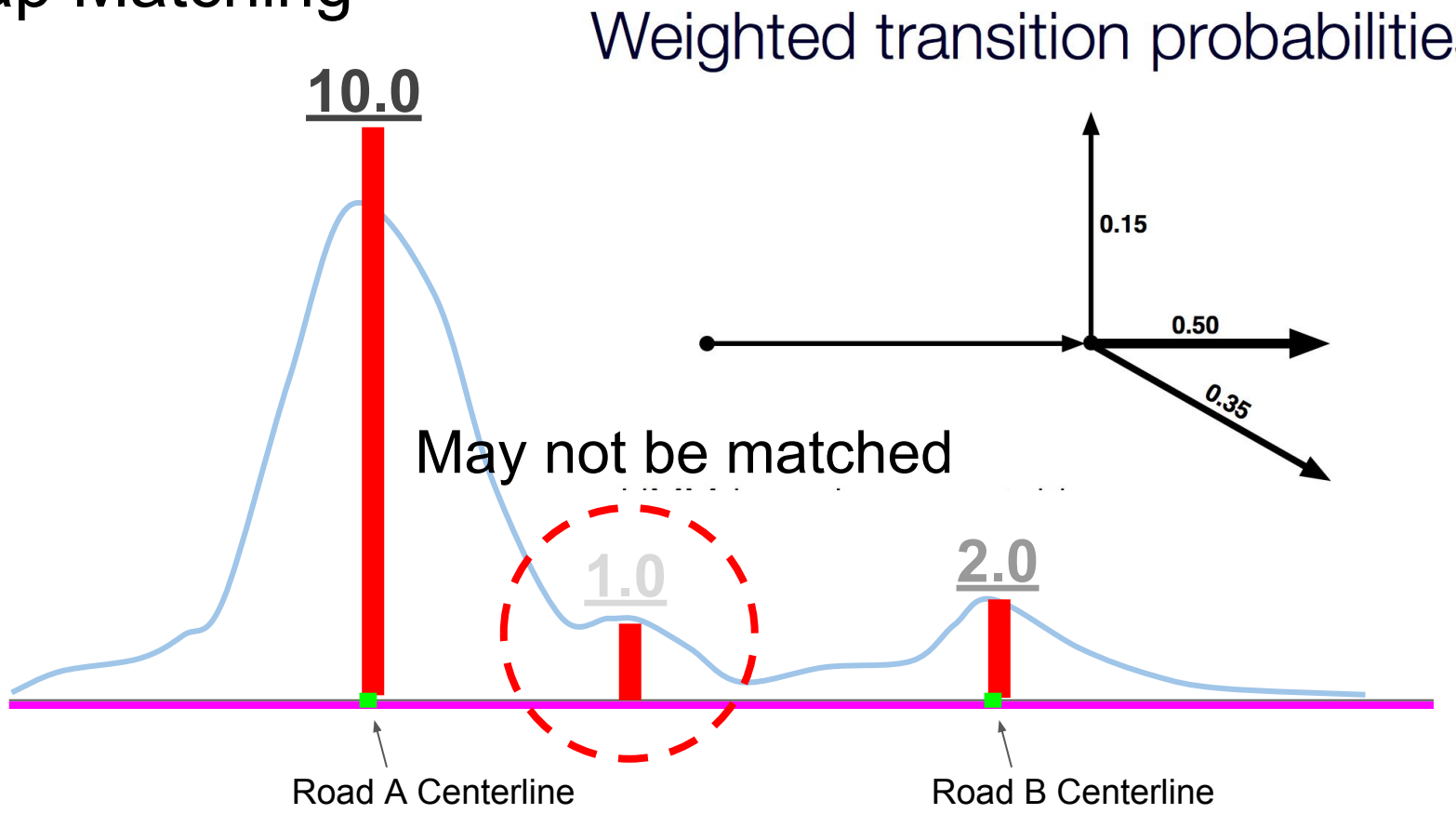
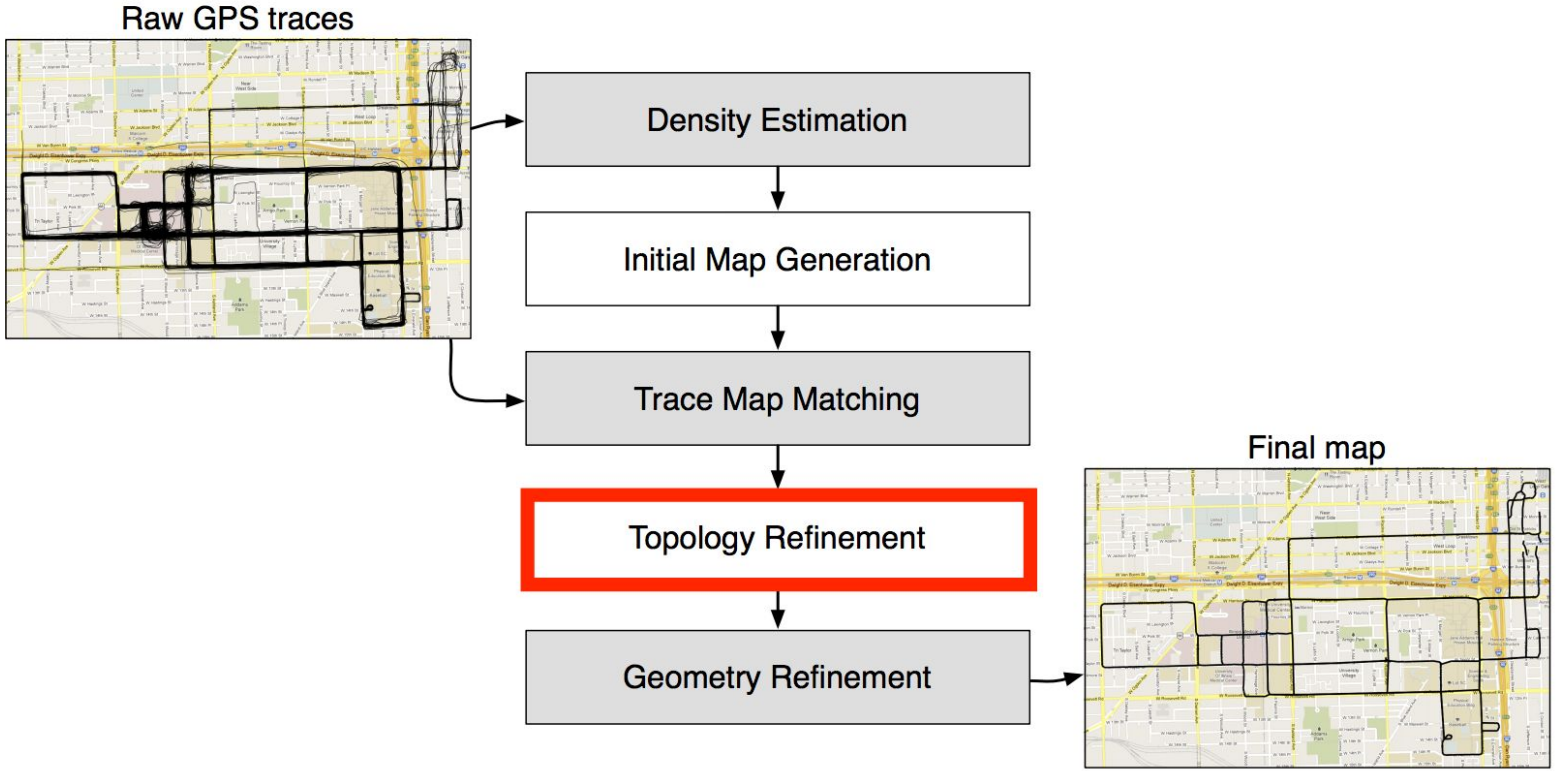


Topology Refinement



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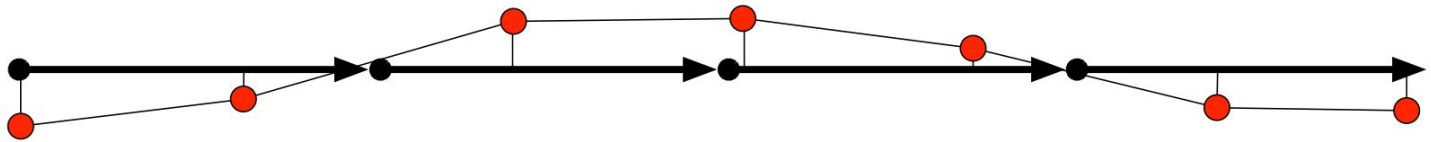
Topology Refinement

Well-matched Traversal

Goodness of fit

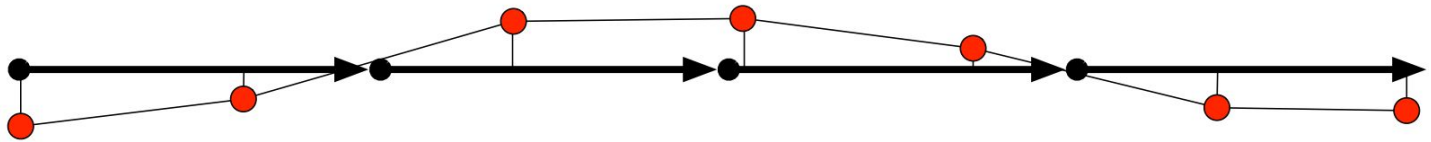


$$RMSD(\tau, e) = \sqrt{\frac{1}{|\tau|} \sum_{p \in \tau} dist(p, e)^2}$$

$$RMSD(\tau, e) < RMSD_{max}$$

Topology Refinement

Remove edges with less than two well-matched traversals



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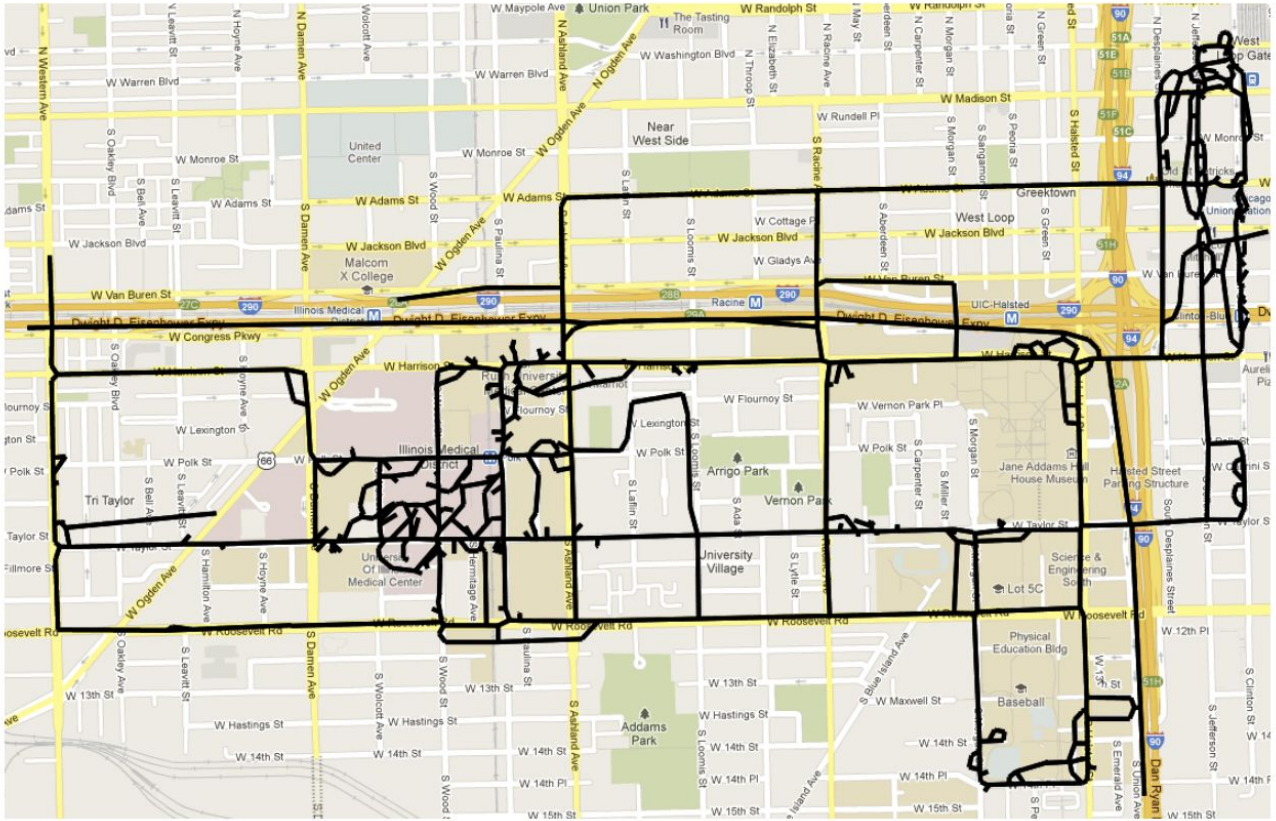
Topology Refinement - Before Pruning



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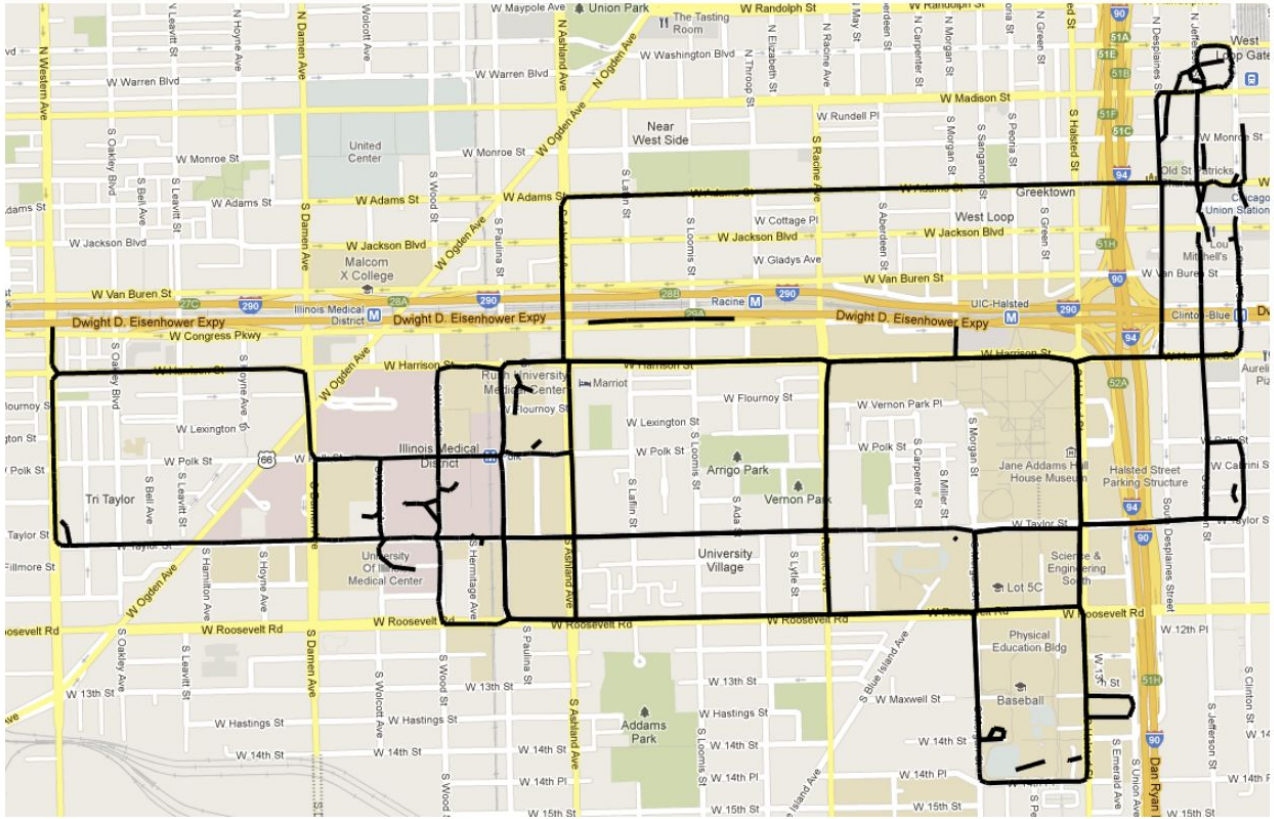
Topology Refinement - After Pruning



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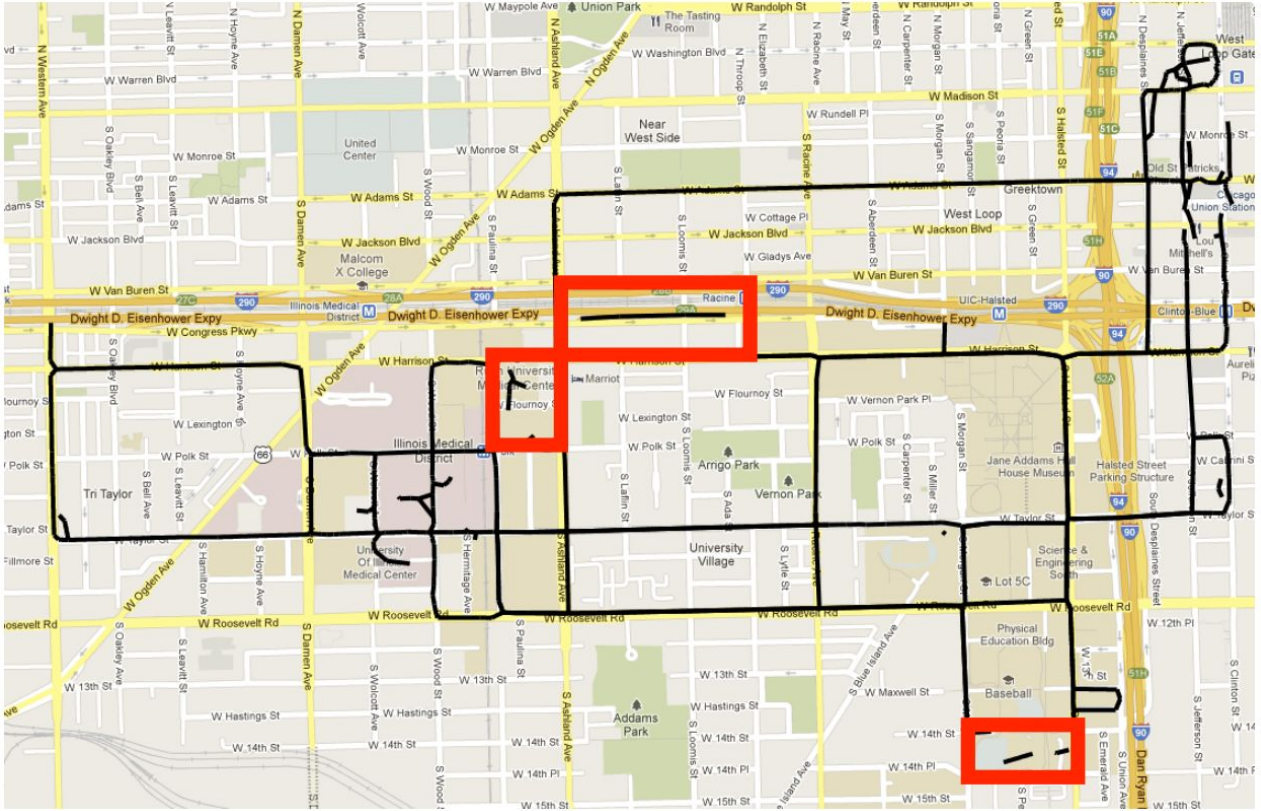

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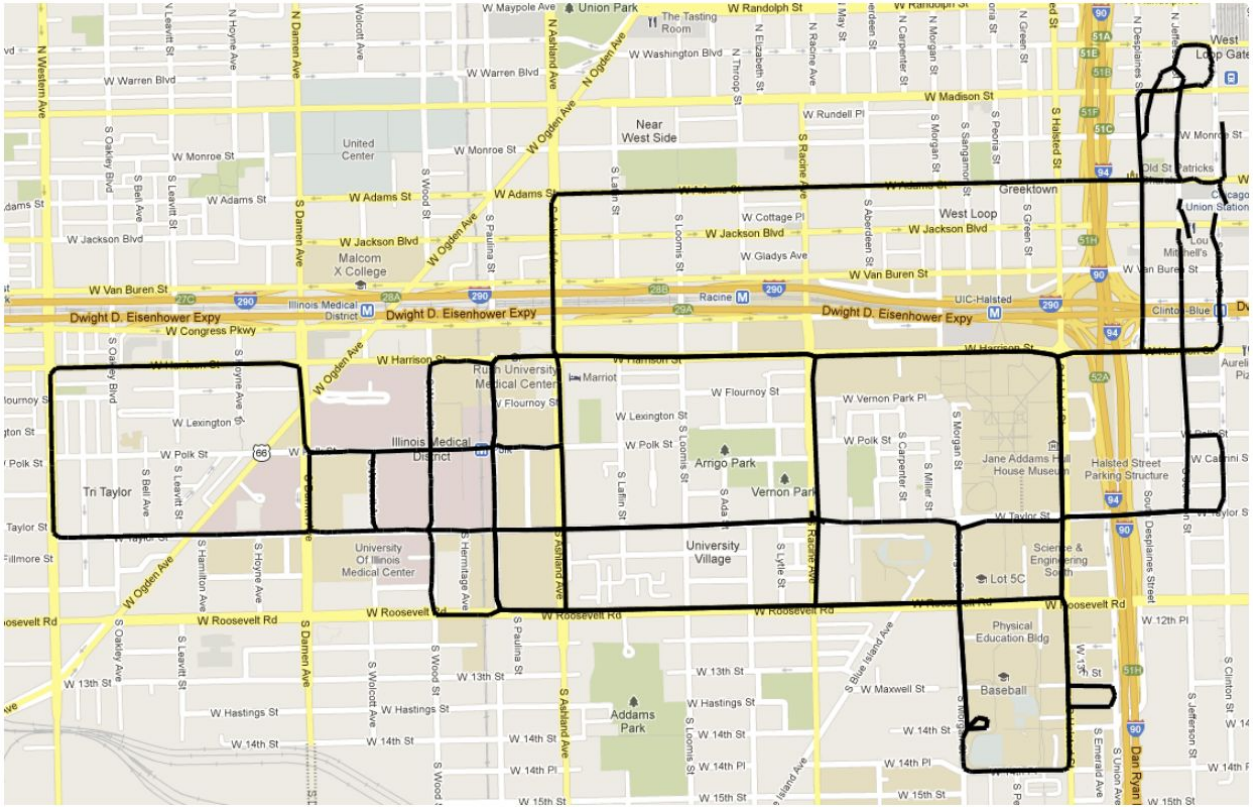
Topology Refinement - Pruning Again ...



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