

Inferring Road Maps from GPS Traces

Survey and Comparative Evaluation

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Road surveys



Rural/developing areas



New road construction



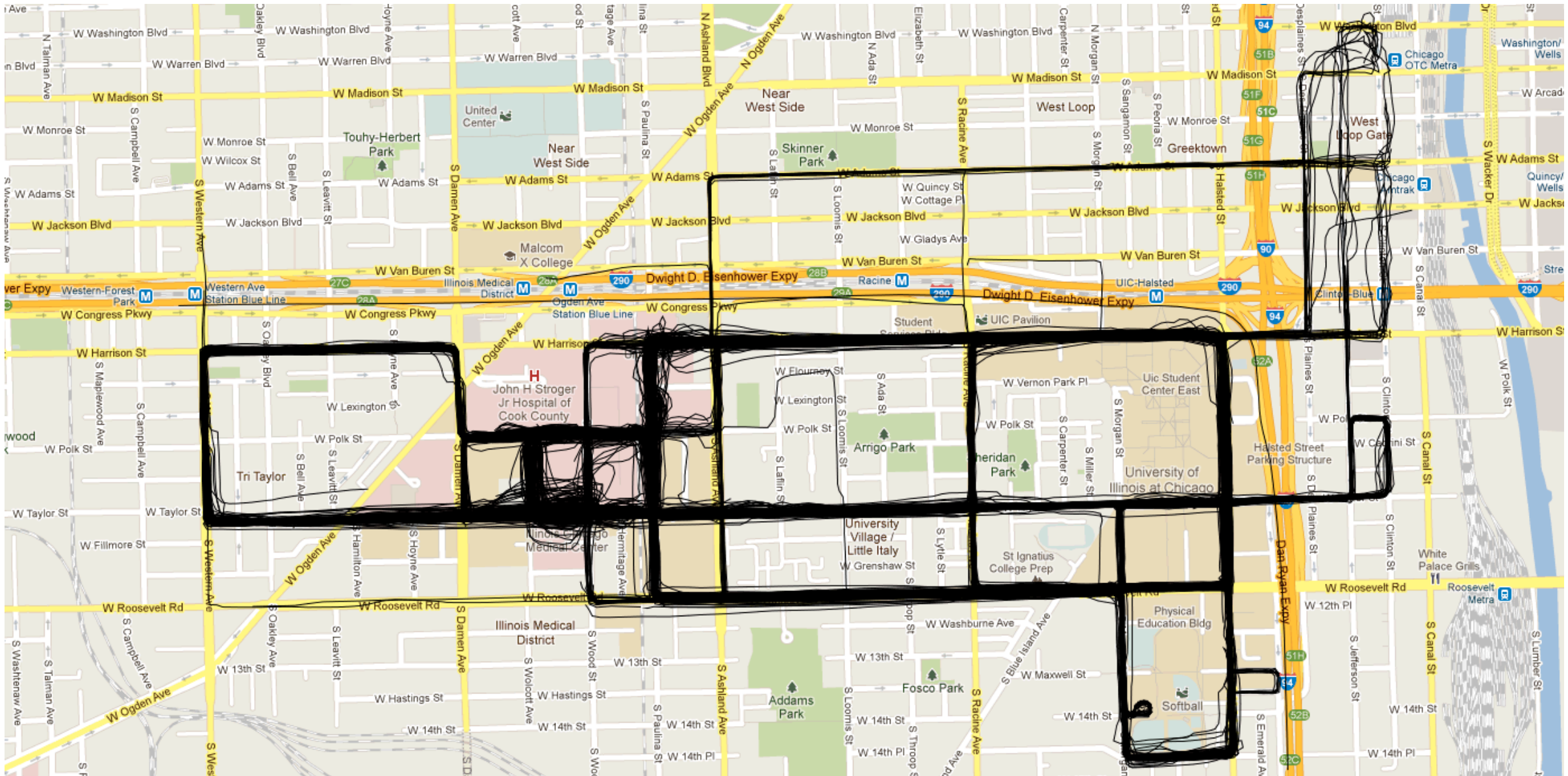
Road closures



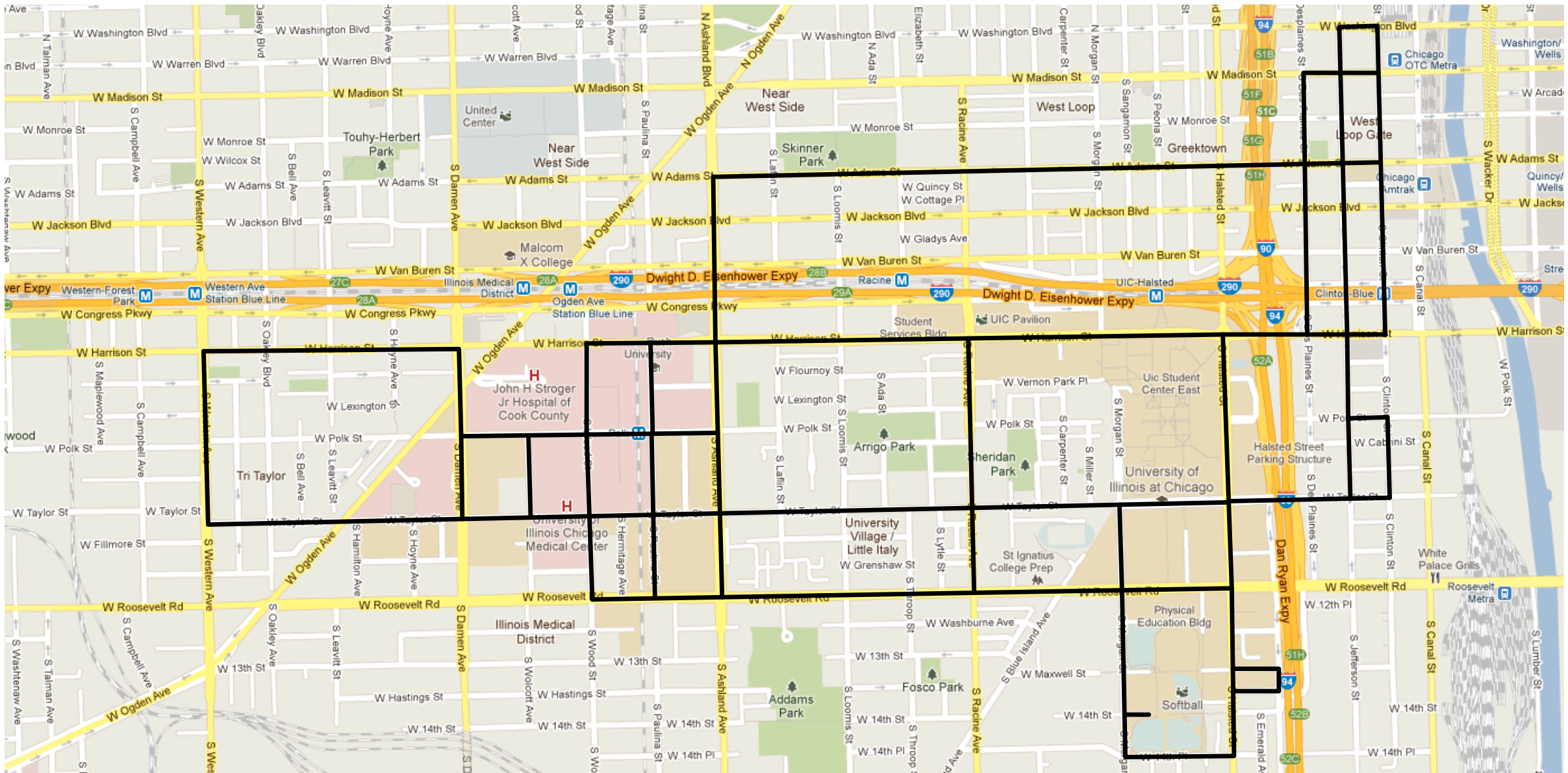
Crowd-sourced GPS data



GPS traces



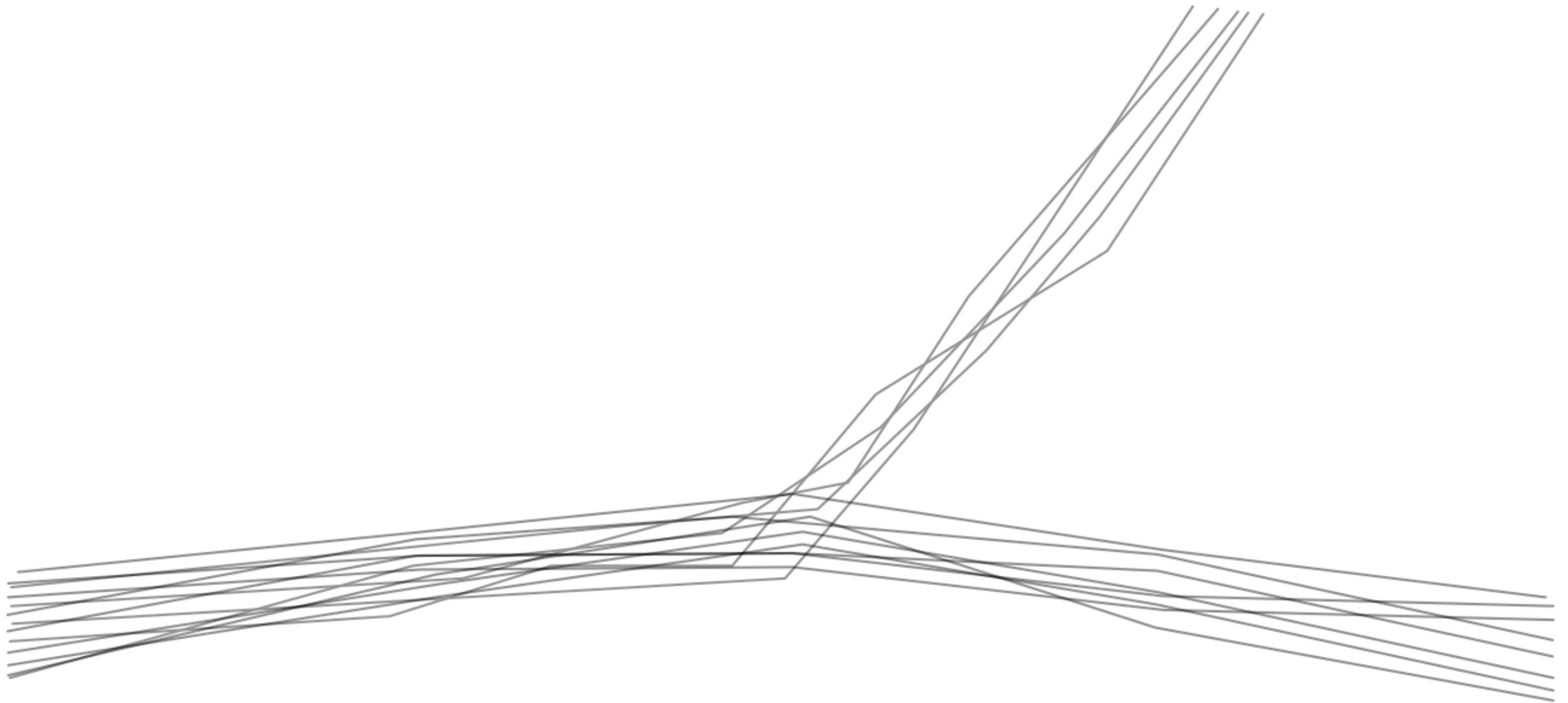
Inferred road map



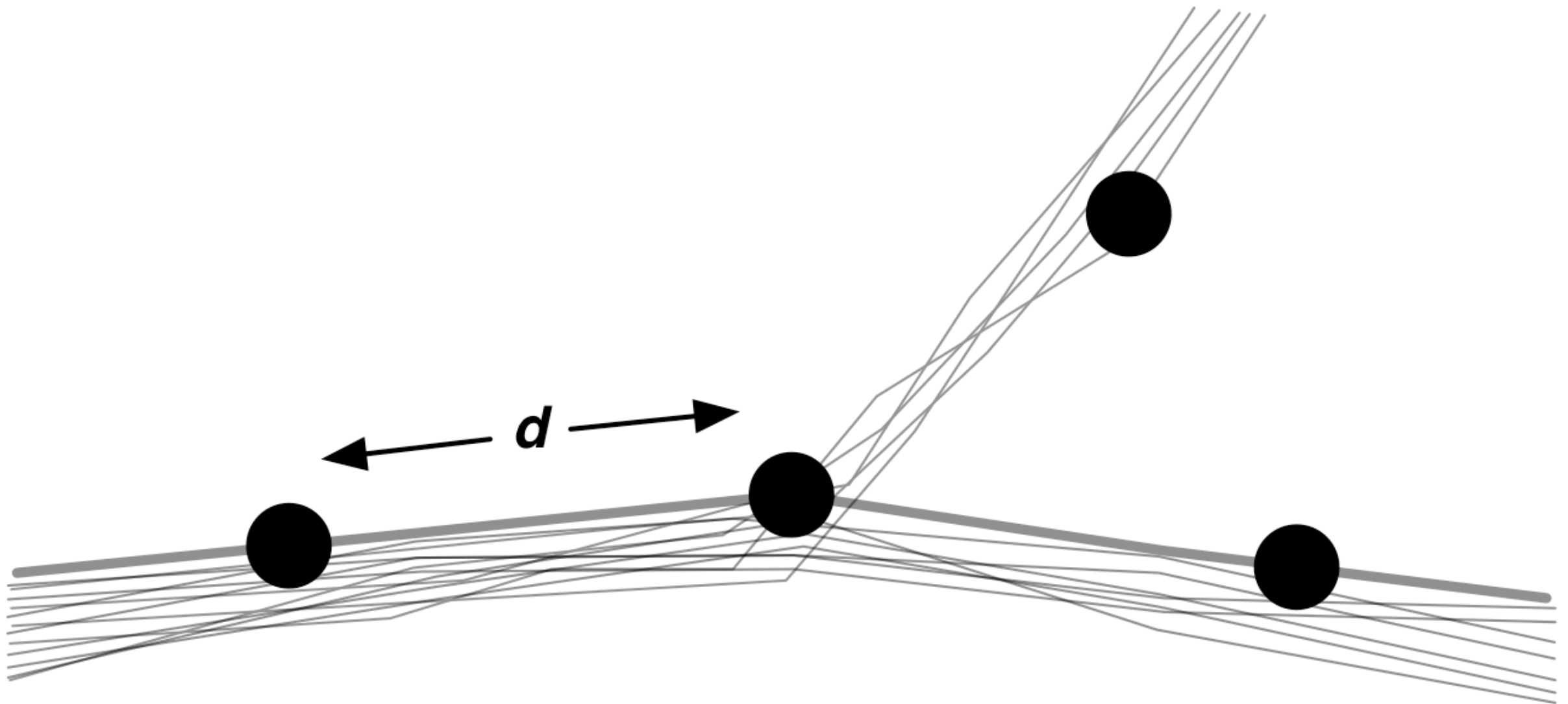
Contributions

- ▶ Quantitative evaluation method
- ▶ Survey of existing literature
- ▶ Comparative evaluation

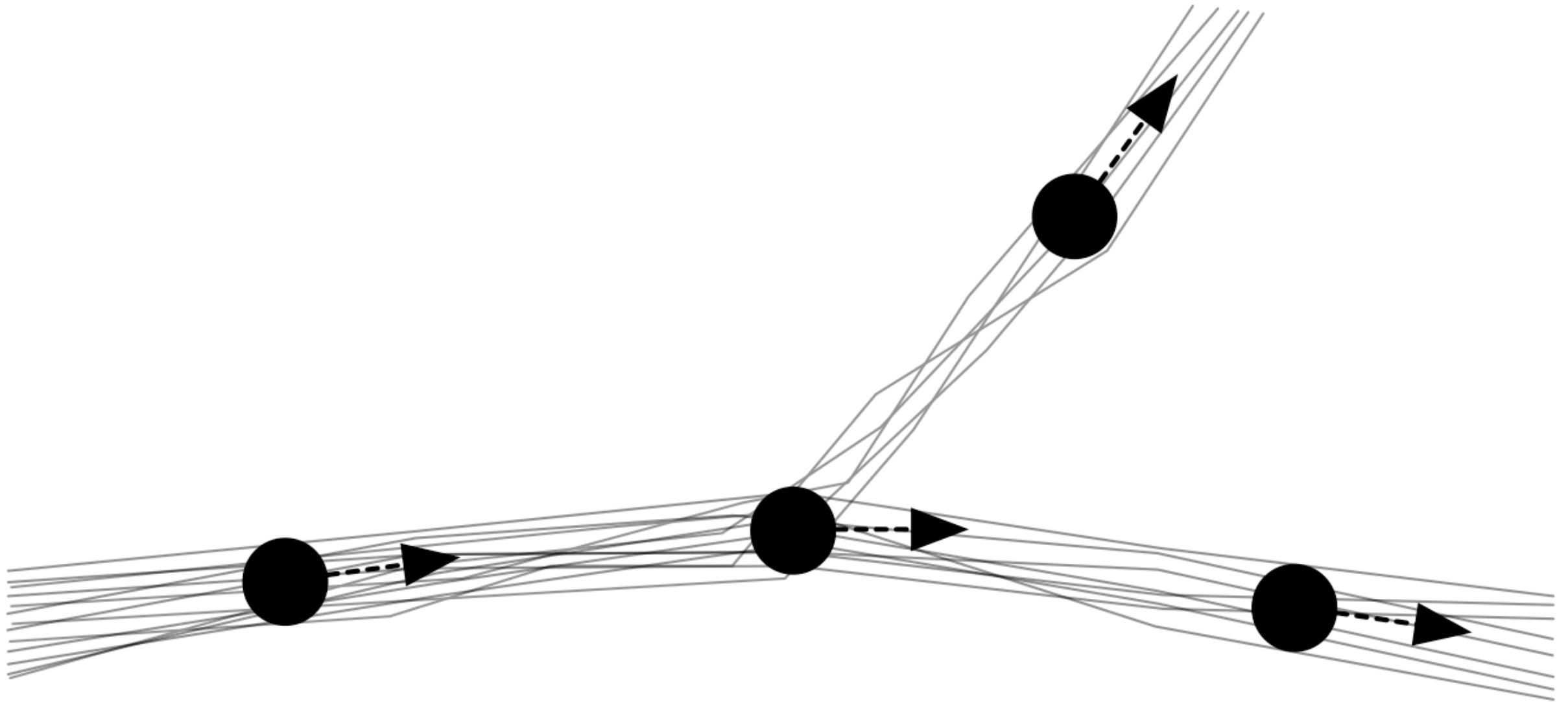
Edelkamp & Schrödl



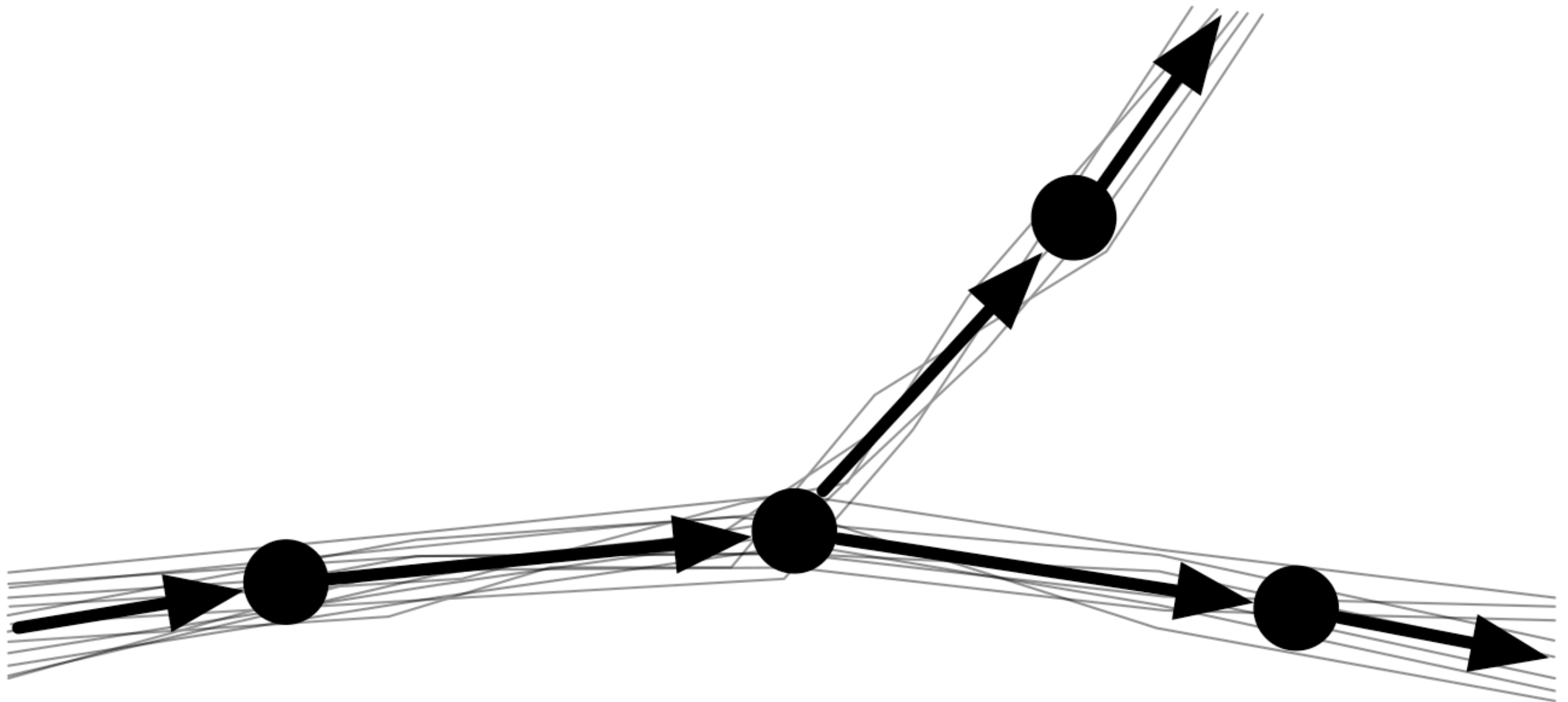
Drop seeds



Adjust seeds



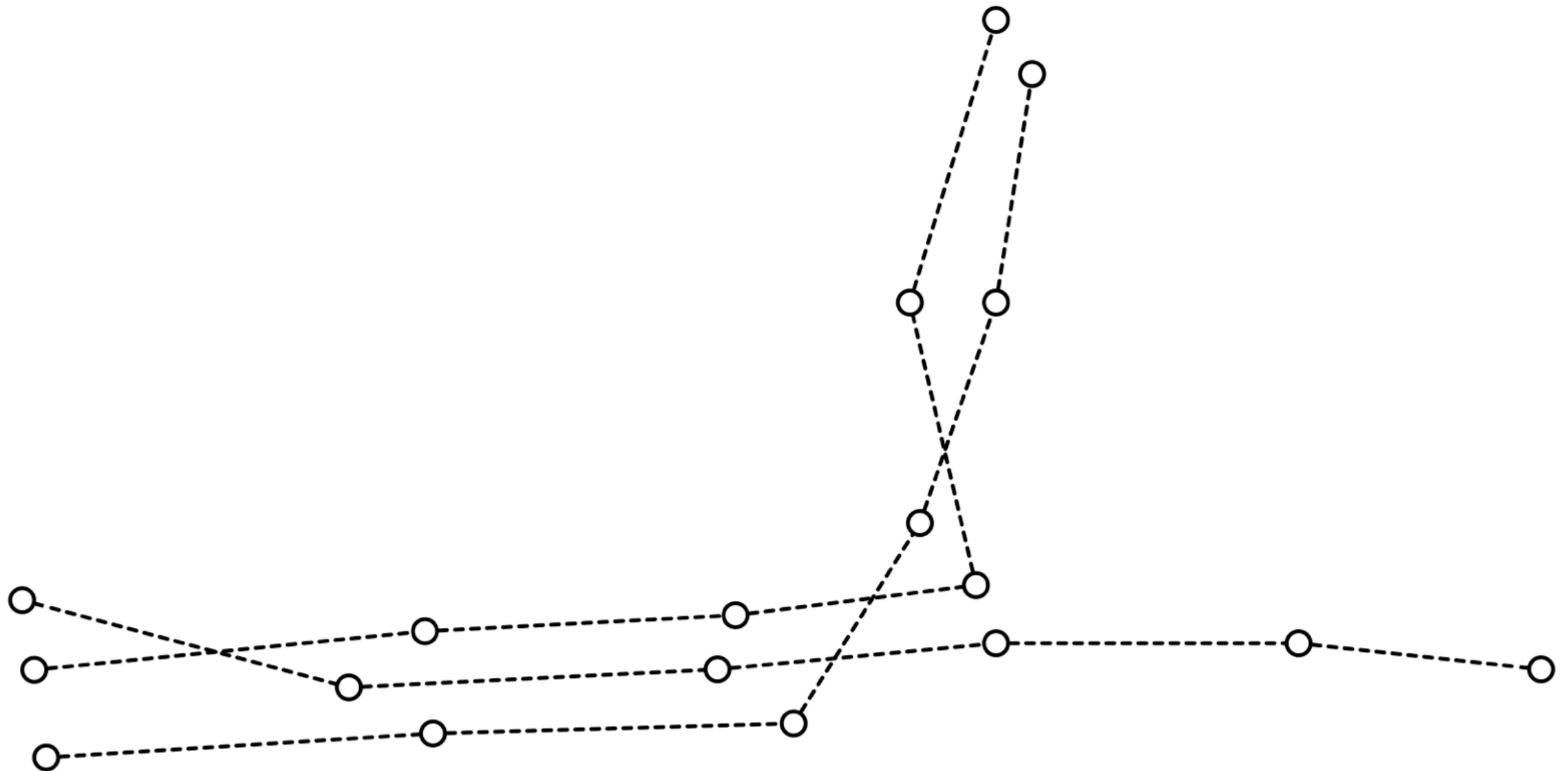
Link seeds



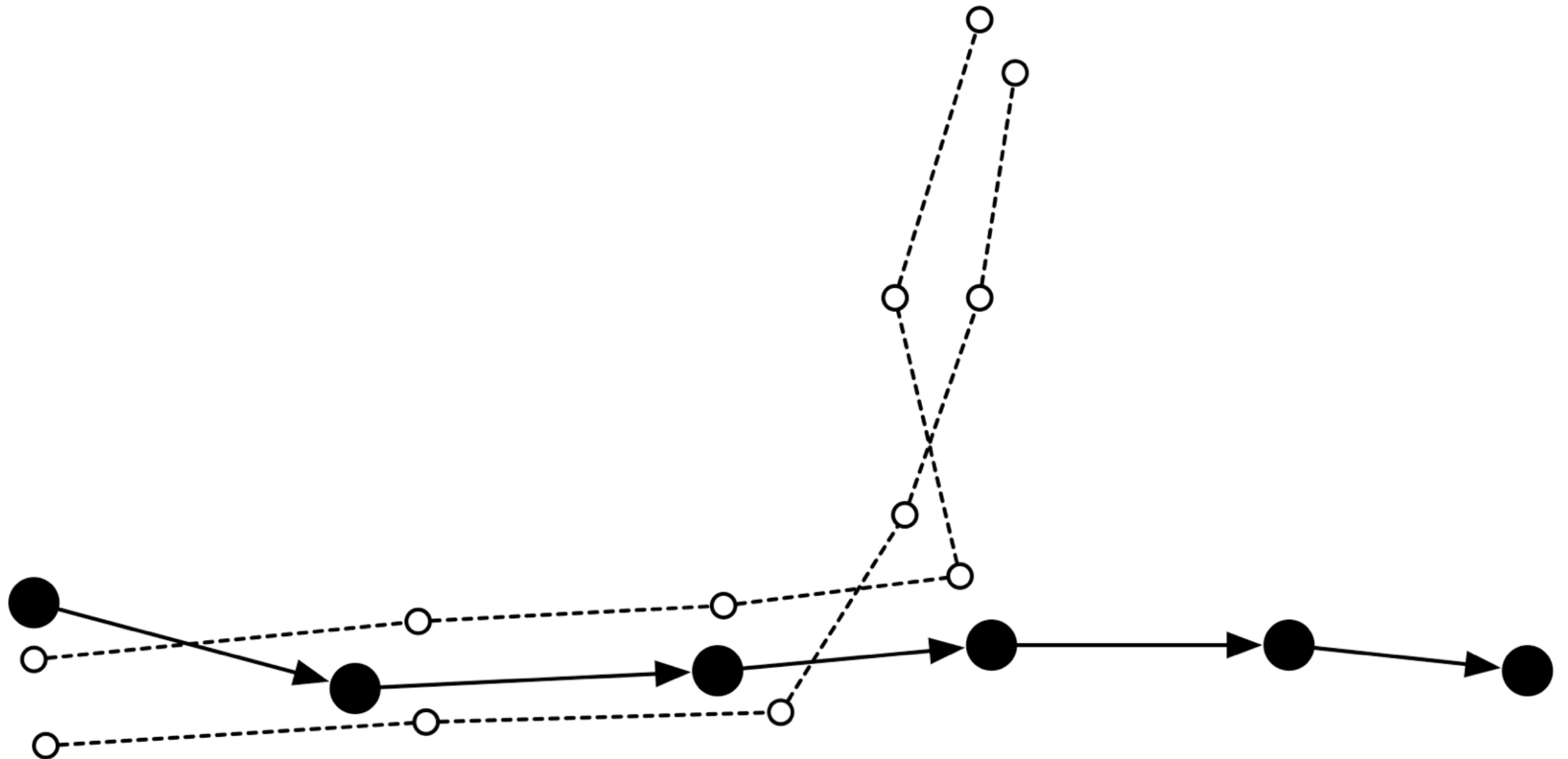
Cao & Krumm



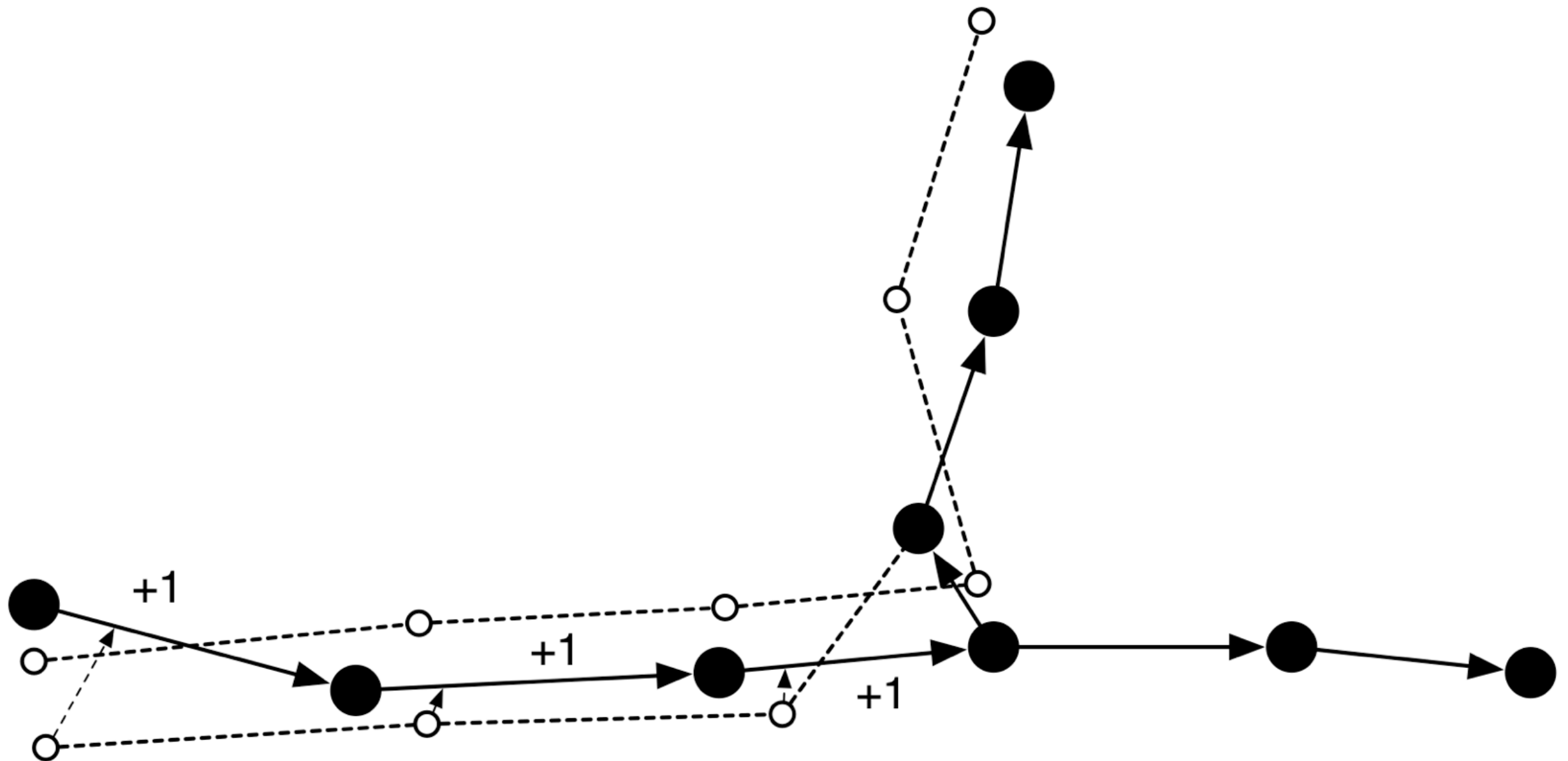
Pre-processing



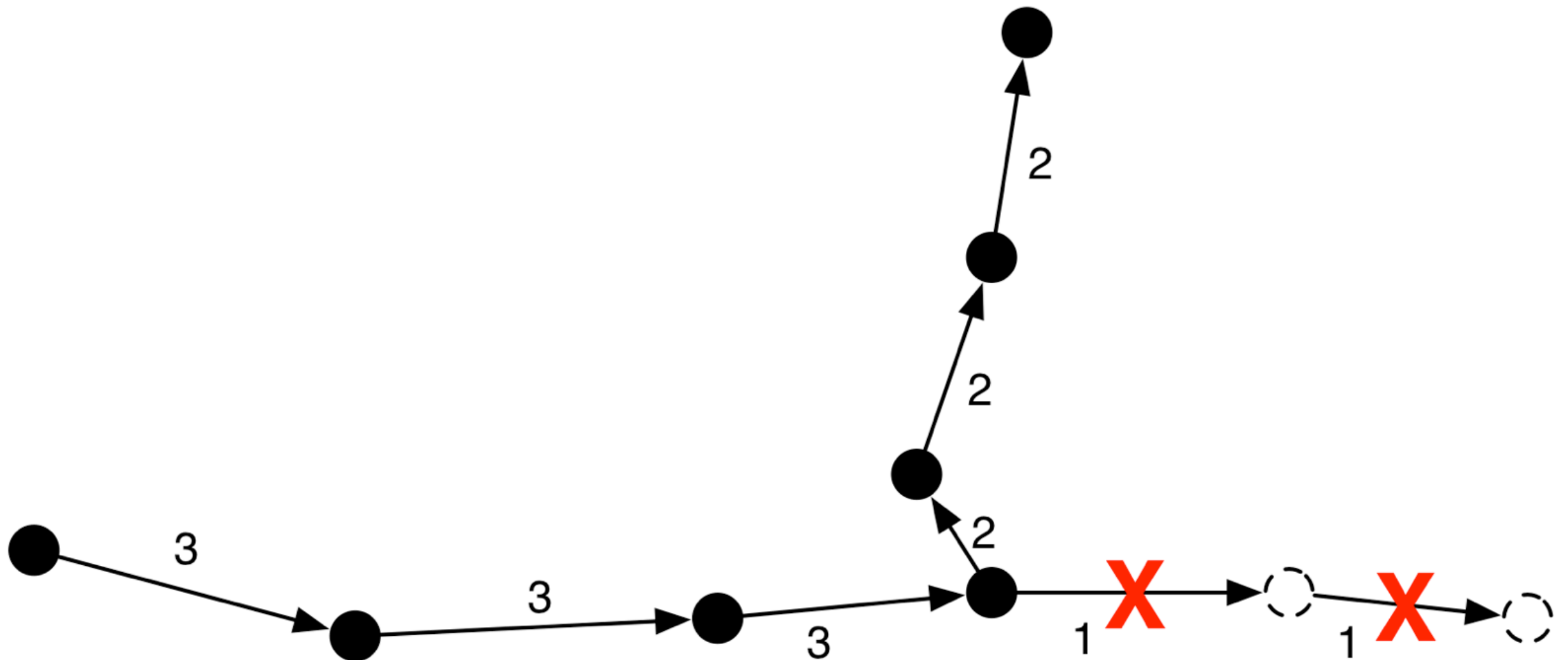
Add new edges



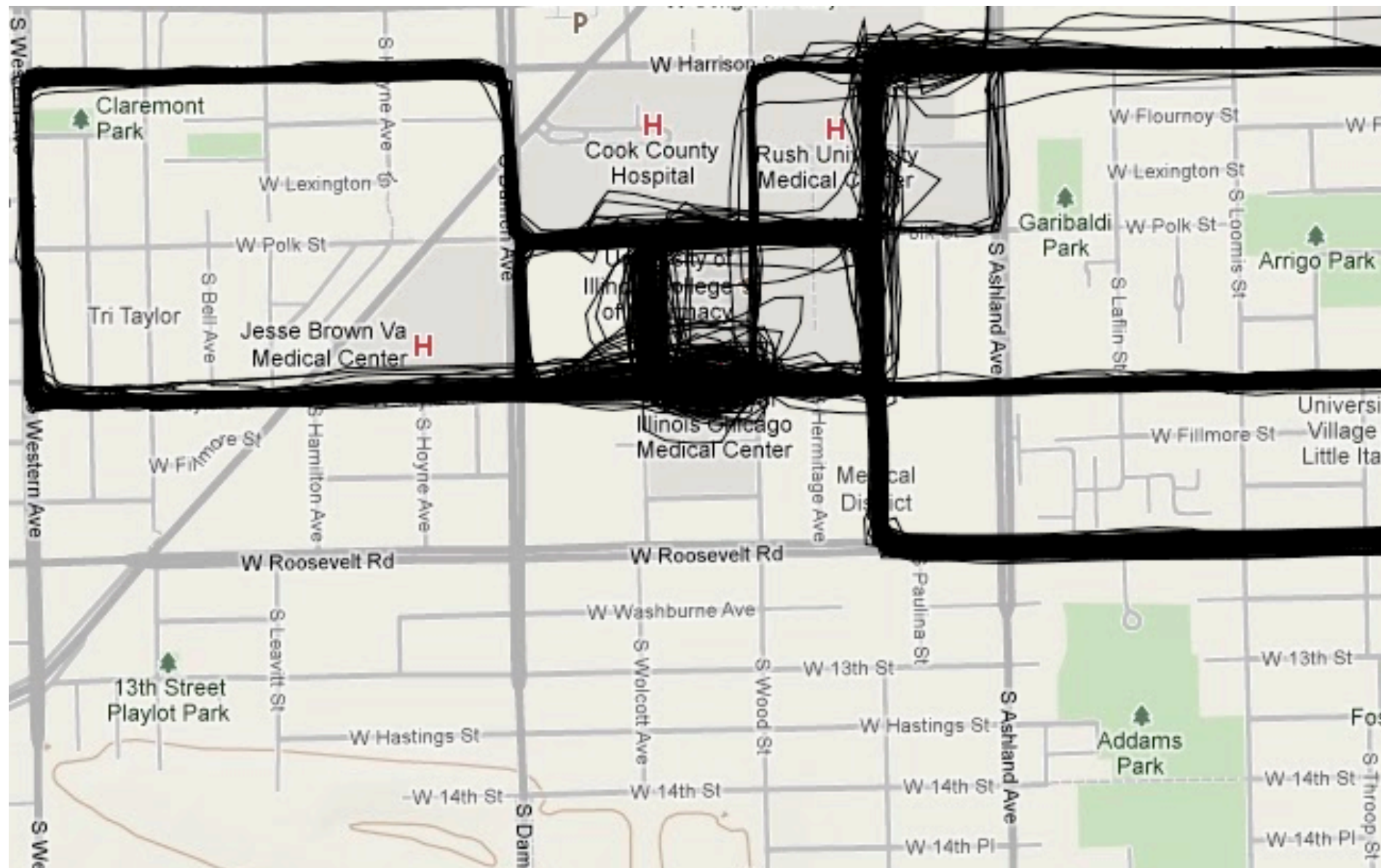
Match edges



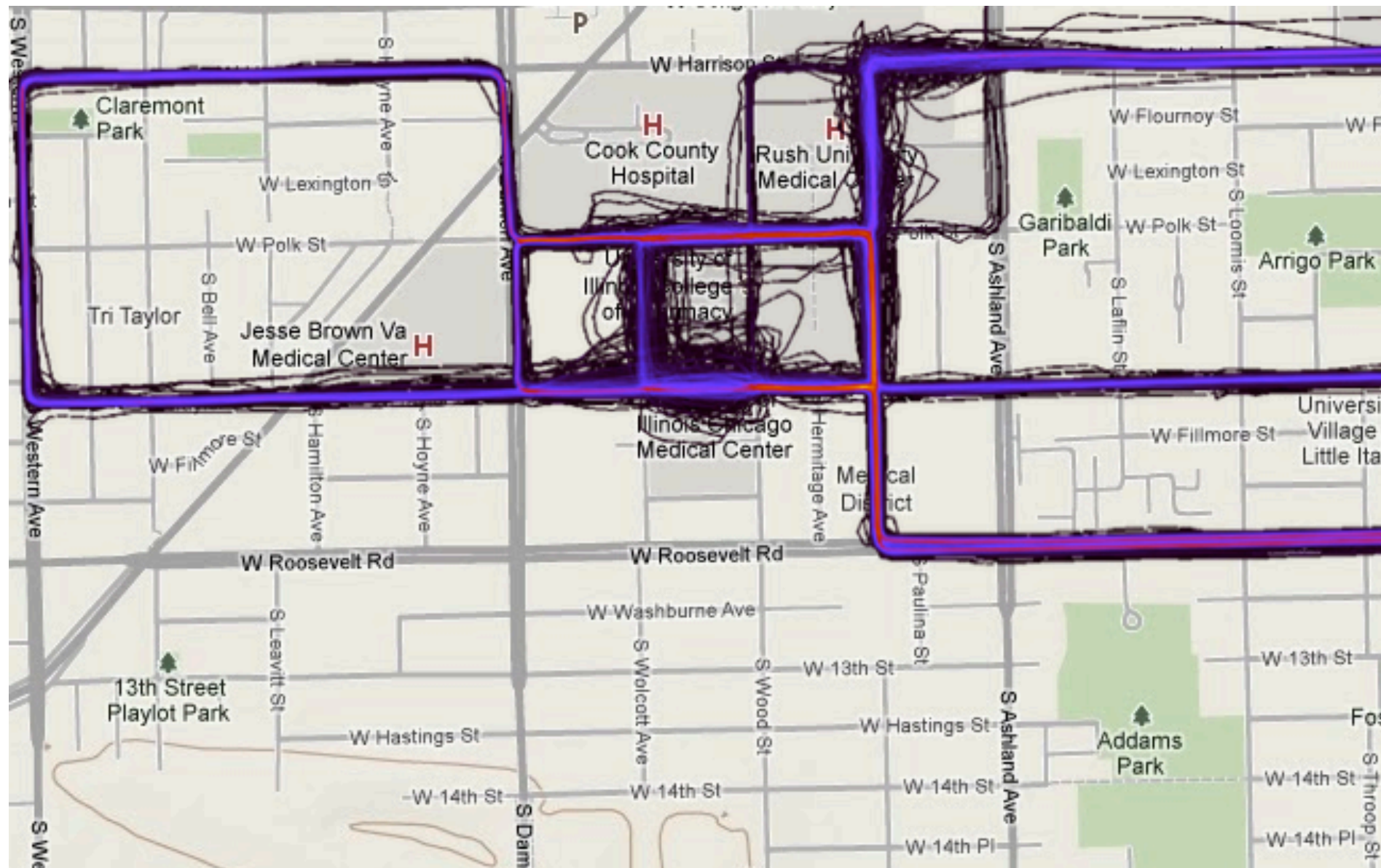
Prune spurious edges



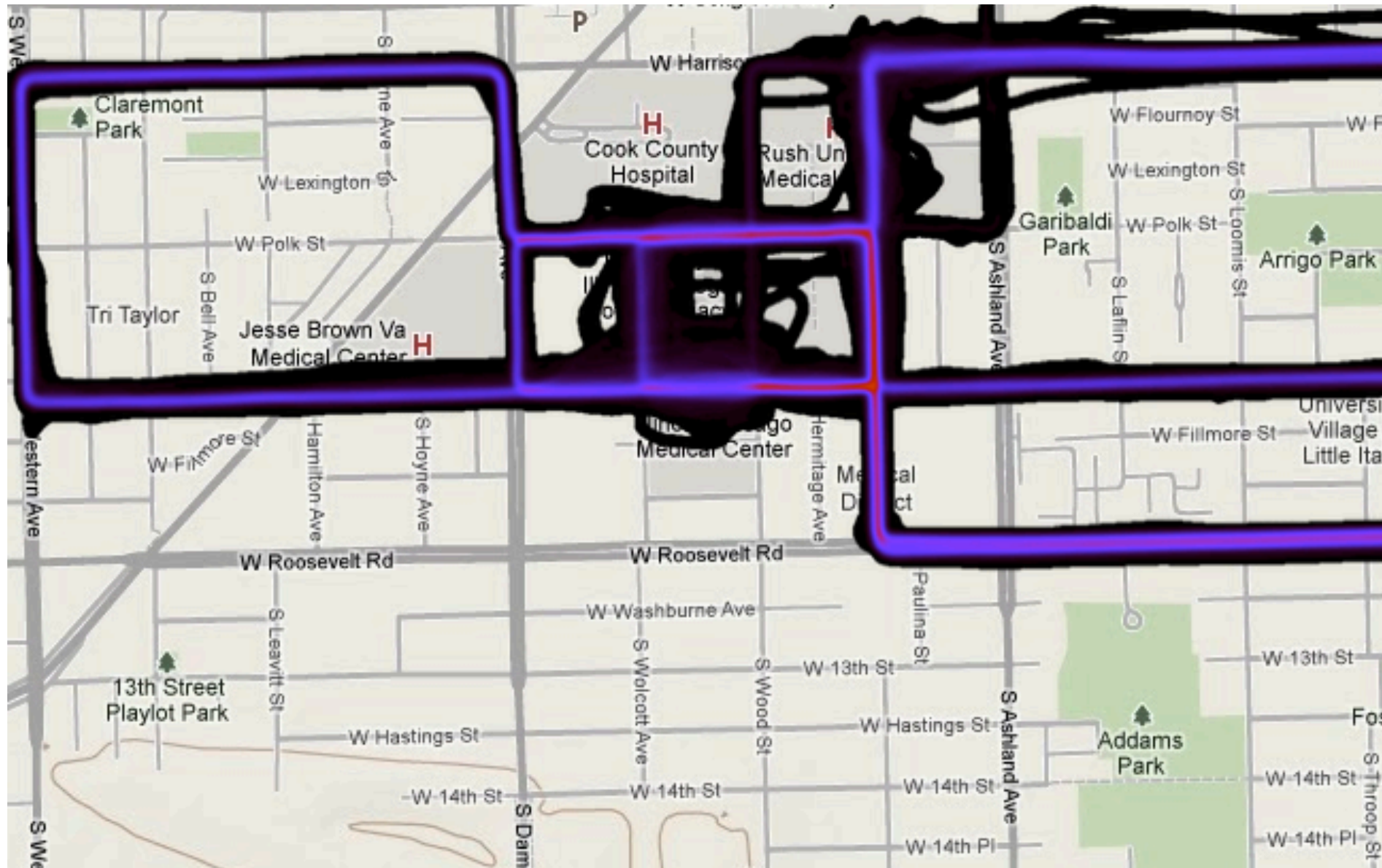
Davies, Beresford & Hopper



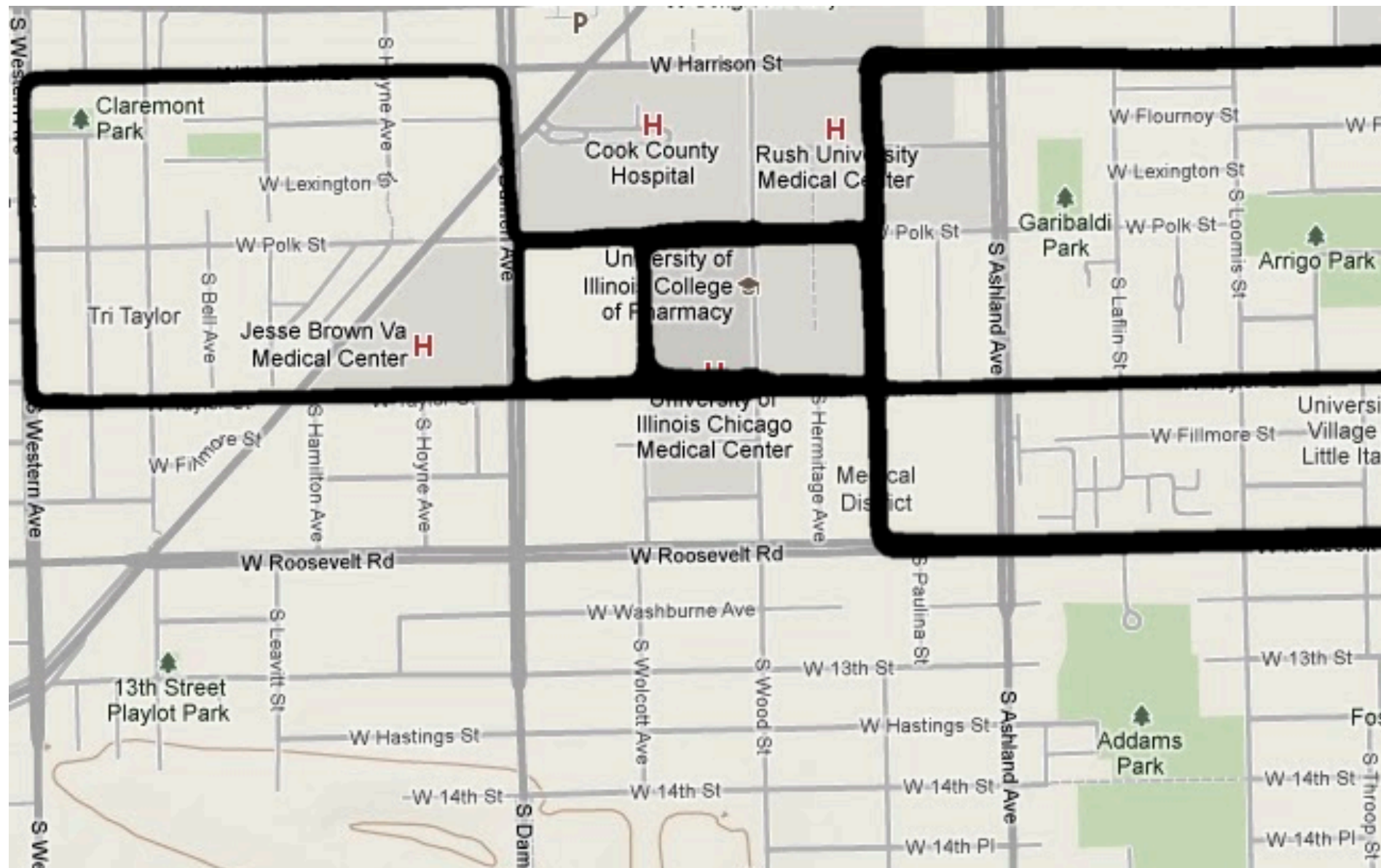
Create 2-D histogram



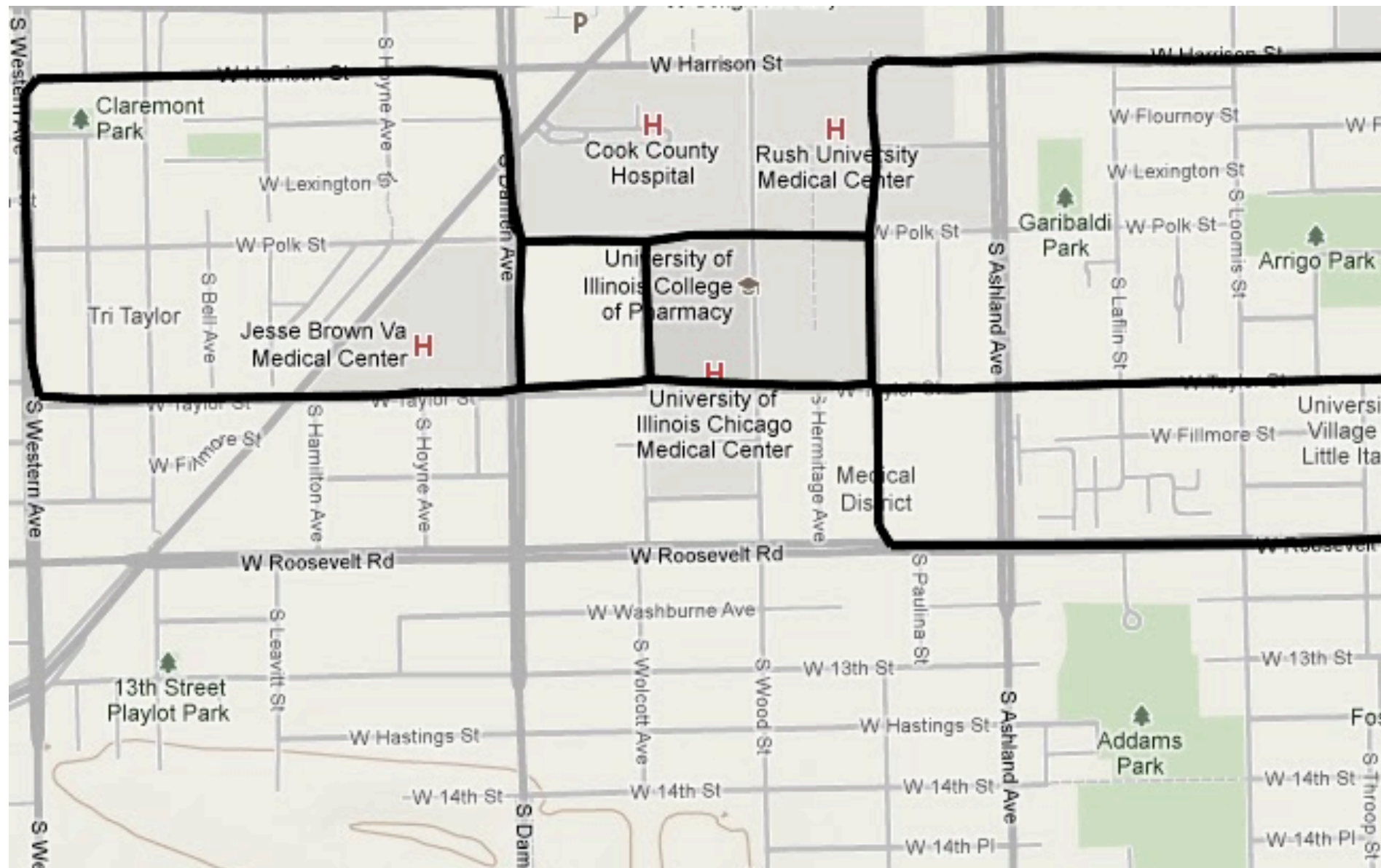
Density estimate



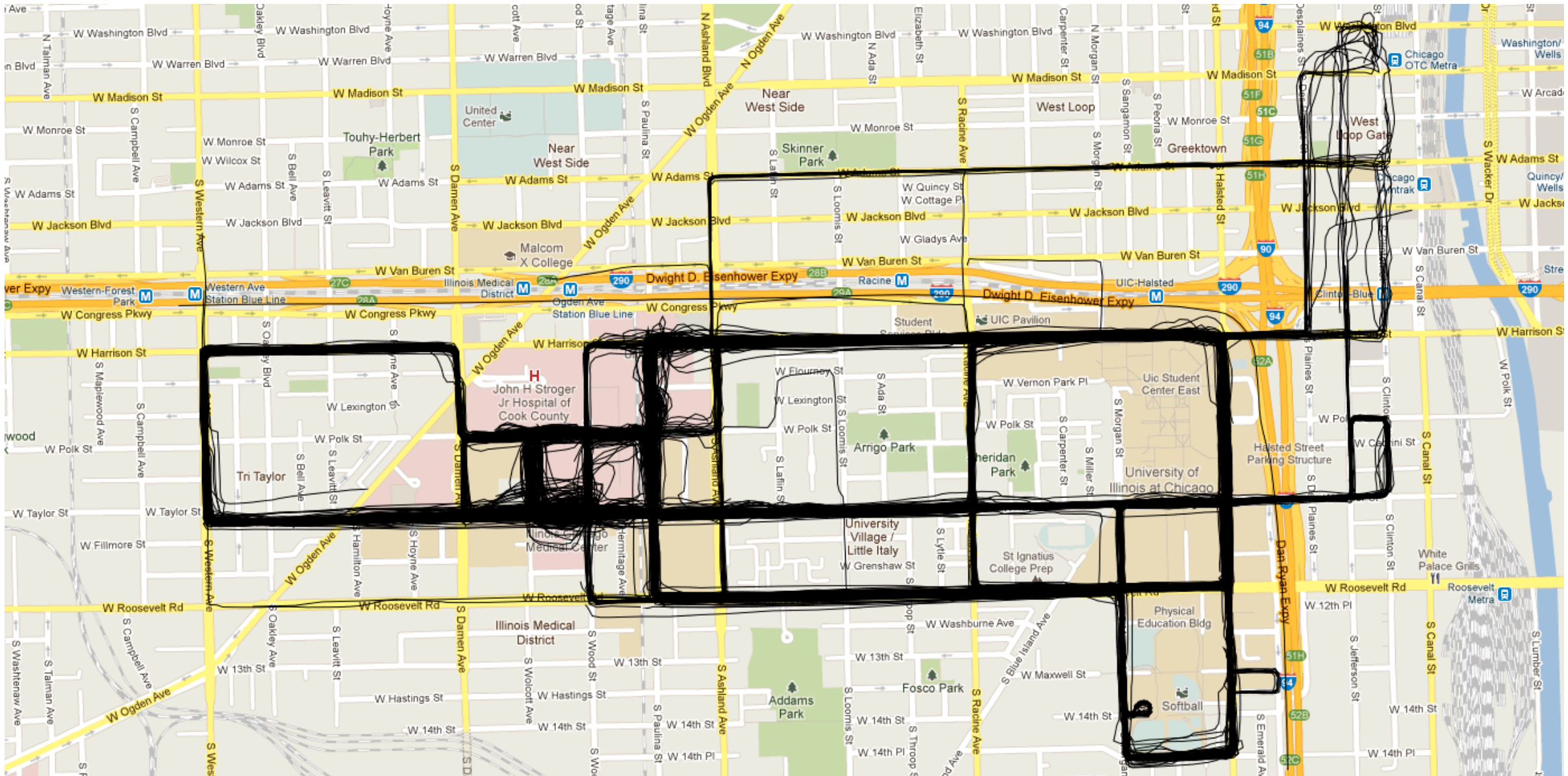
Apply threshold to image



Extract road centerline



Raw data



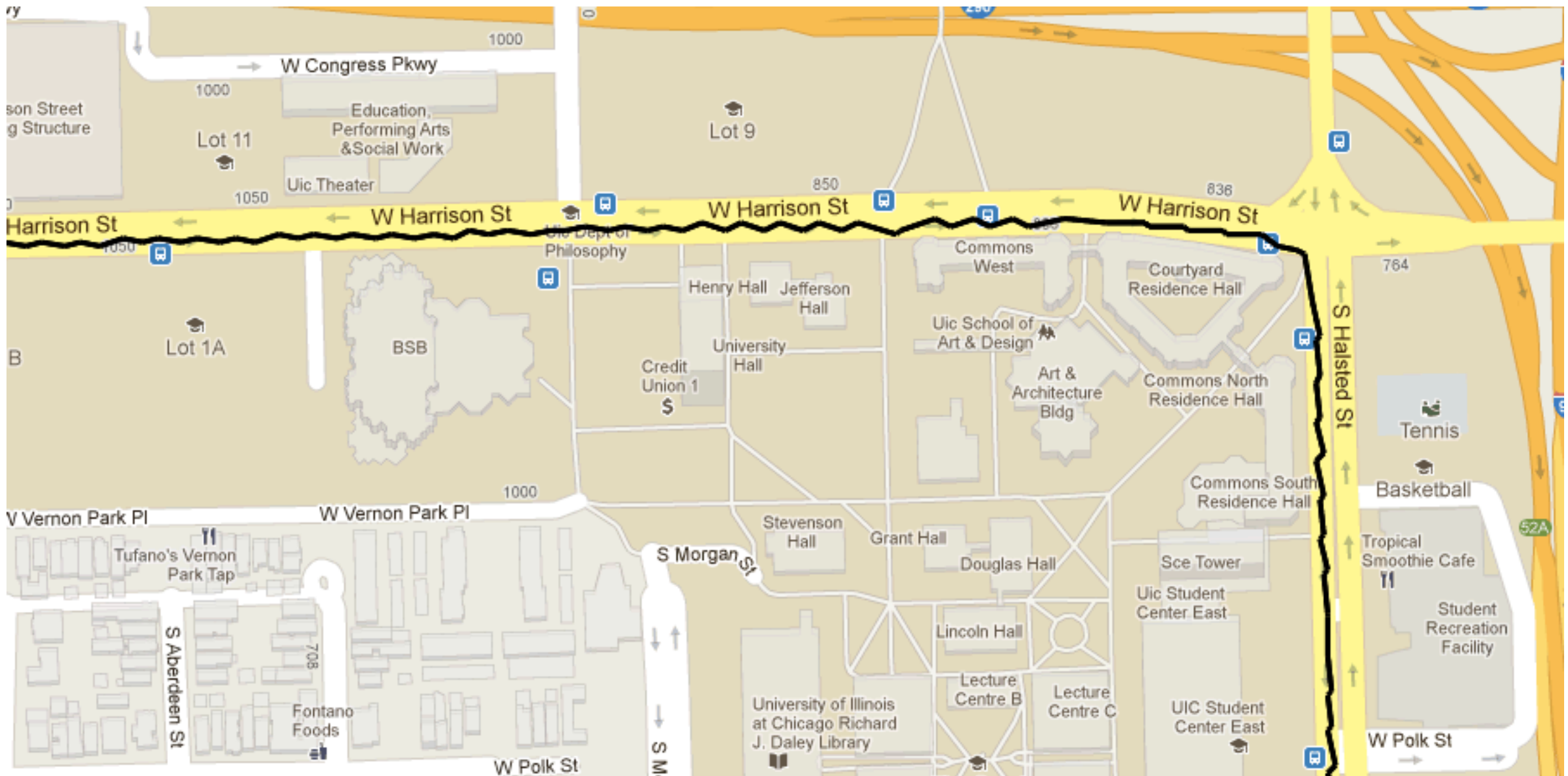
The map displays the University of Illinois at Chicago campus with the following labeled locations and features:

- Streets:** W Congress Pkwy, W Vernon Park Pl, W Polk St, S Morgan St, S Aberdeen St.
- Buildings and Landmarks:** Education, Performing Arts & Social Work, Uic Theater, Lot 11, Lot 9, Lot 1A, BSB, Henry Hall, Jefferson Hall, University Hall, Credit Union 1, Uic School of Art & Design, Art & Architecture Bldg, Commons North Residence Hall, Commons South Residence Hall, Stevenson Hall, Grant Hall, Douglas Hall, Lincoln Hall, Lecture Centre B, Lecture Centre C, UIC Student Center East, UIC Student Center East, UIC Student Center East, Tropical Smoothie Cafe, Student Recreation Facility, Tennis, Basketball.
- Other Labels:** 1000, 1050, 850, 650, 764, 52A, 708, Fontano Foods, Tufano's Vernon Park Tap, University of Illinois at Chicago Richard J. Daley Library, S M.

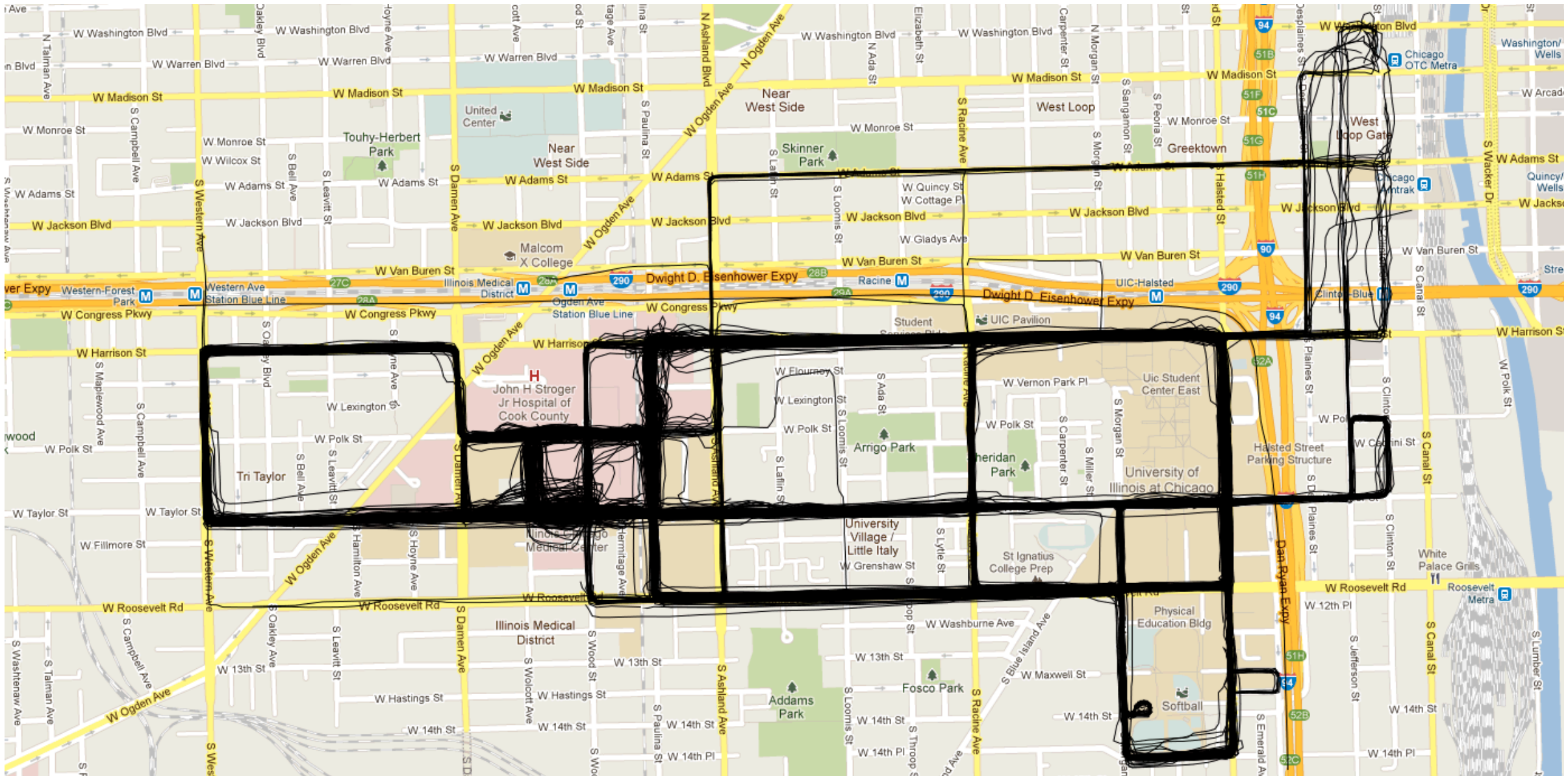
This map provides a detailed view of the University of Illinois at Chicago campus. Key streets include W Congress Pkwy, W Harrison St, W Vernon Park Pl, W Polk St, S Morgan St, and S Halsted St. The map identifies numerous academic and student buildings, such as the Uic Theater, Uic Dept of Philosophy, Commons West, Commons North Residence Hall, Commons South Residence Hall, Uic School of Art & Design, Art & Architecture Bldg, University Hall, Credit Union 1, Henry Hall, Jefferson Hall, Stevenson Hall, Grant Hall, Douglas Hall, Lincoln Hall, Lecture Centre B, Lecture Centre C, Uic Student Center East, and the University of Illinois at Chicago Richard J. Daley Library. Other landmarks include Lot 11, Lot 9, Lot 1A, BSB, Tufano's Vernon Park Tap, Fontano Foods, Tennis, Basketball, Tropical Smoothie Cafe, and the Student Recreation Facility. The map also shows the intersection of I-55 and I-90, and the location of the Uic Theater and Uic Student Center East.

This map illustrates the University of Illinois at Chicago campus. Key streets include W Congress Pkwy, W Harrison St, W Vernon Park Pl, W Polk St, S Morgan St, S Halsted St, and S Aberdeen St. Major landmarks and buildings shown are the Uic Theater, Education, Performing Arts & Social Work, Uic Dept of Philosophy, Commons West, Commons North Residence Hall, Commons South Residence Hall, Uic School of Art & Design, Art & Architecture Bldg, Commons West, Courtyard Residence Hall, Tennis, Basketball, Tropical Smoothie Cafe, Student Recreation Facility, UIC Student Center East, Uic Student Center West, Uic School of Art & Design, Art & Architecture Bldg, Commons North Residence Hall, Commons South Residence Hall, Stevenson Hall, Grant Hall, Douglas Hall, Lincoln Hall, Lecture Centre B, Lecture Centre C, University of Illinois at Chicago Richard J. Daley Library, Fontano Foods, Tufano's Vernon Park Tap, and BSB. The map also shows various lots (Lot 9, Lot 11, Lot 1A) and a large green area labeled 'BSB'. A yellow line indicates a major transit route along W Harrison St and S Halsted St.

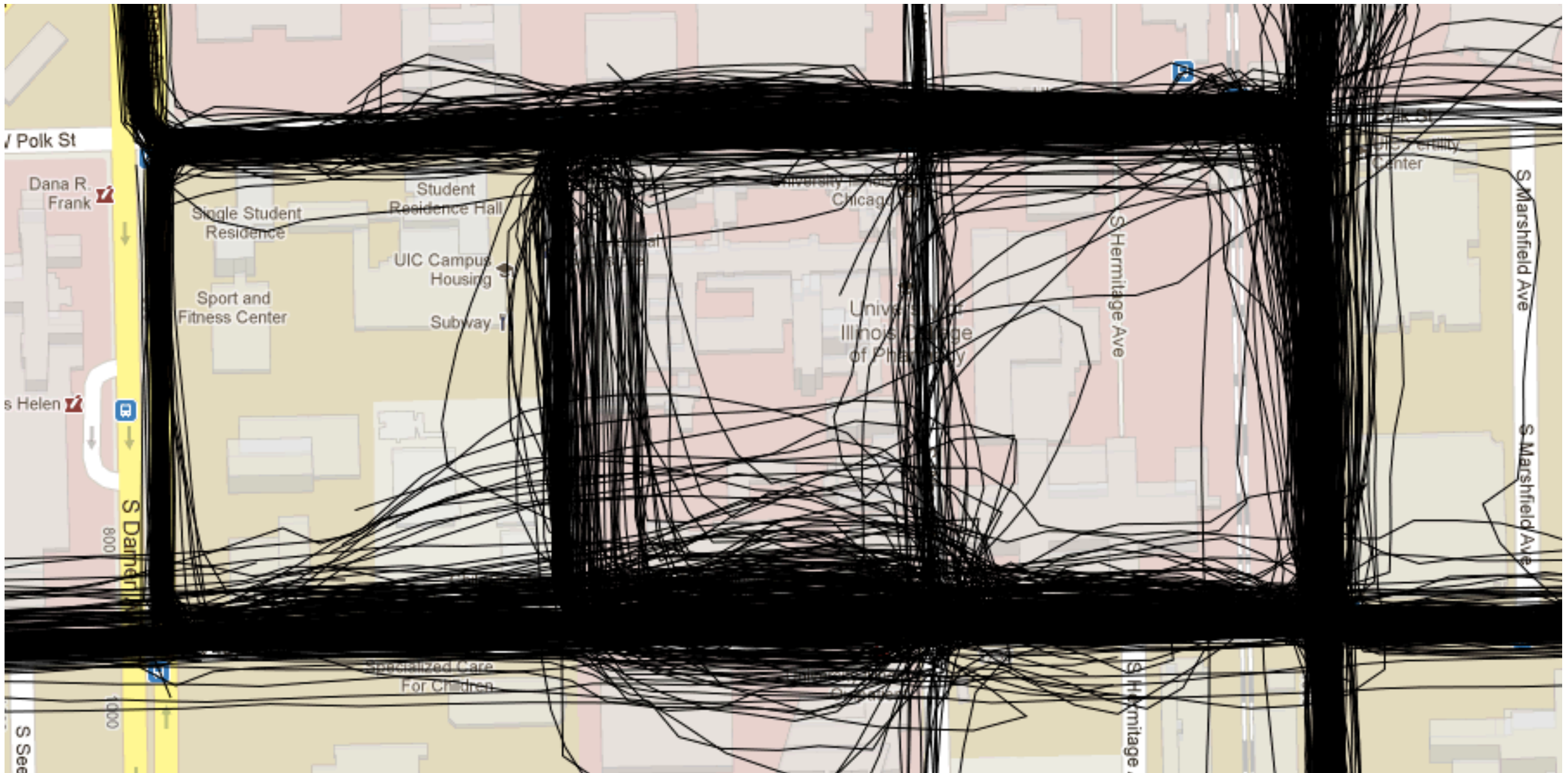
Davies (low-error)



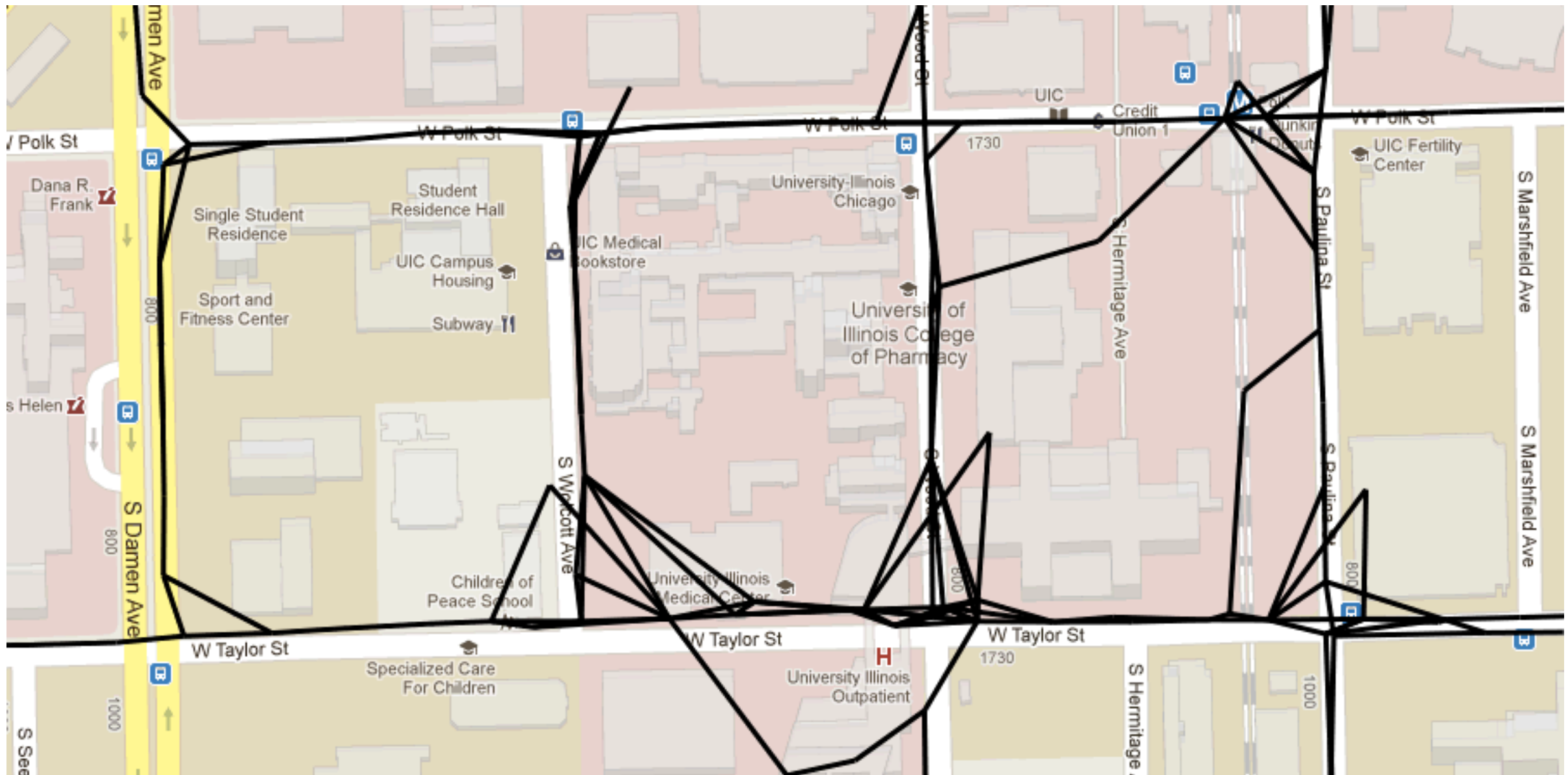
Raw data



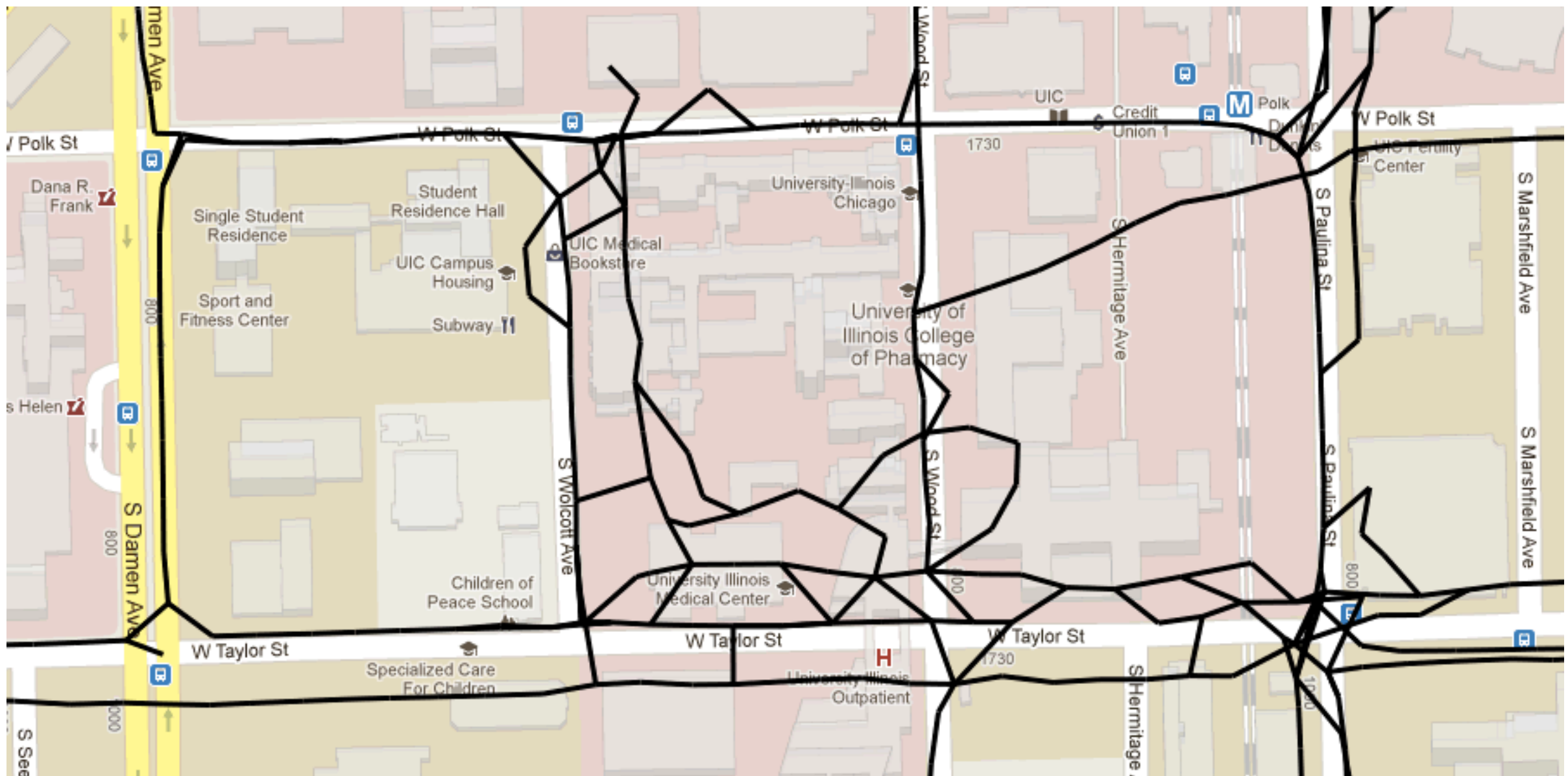
Raw data (high-error)



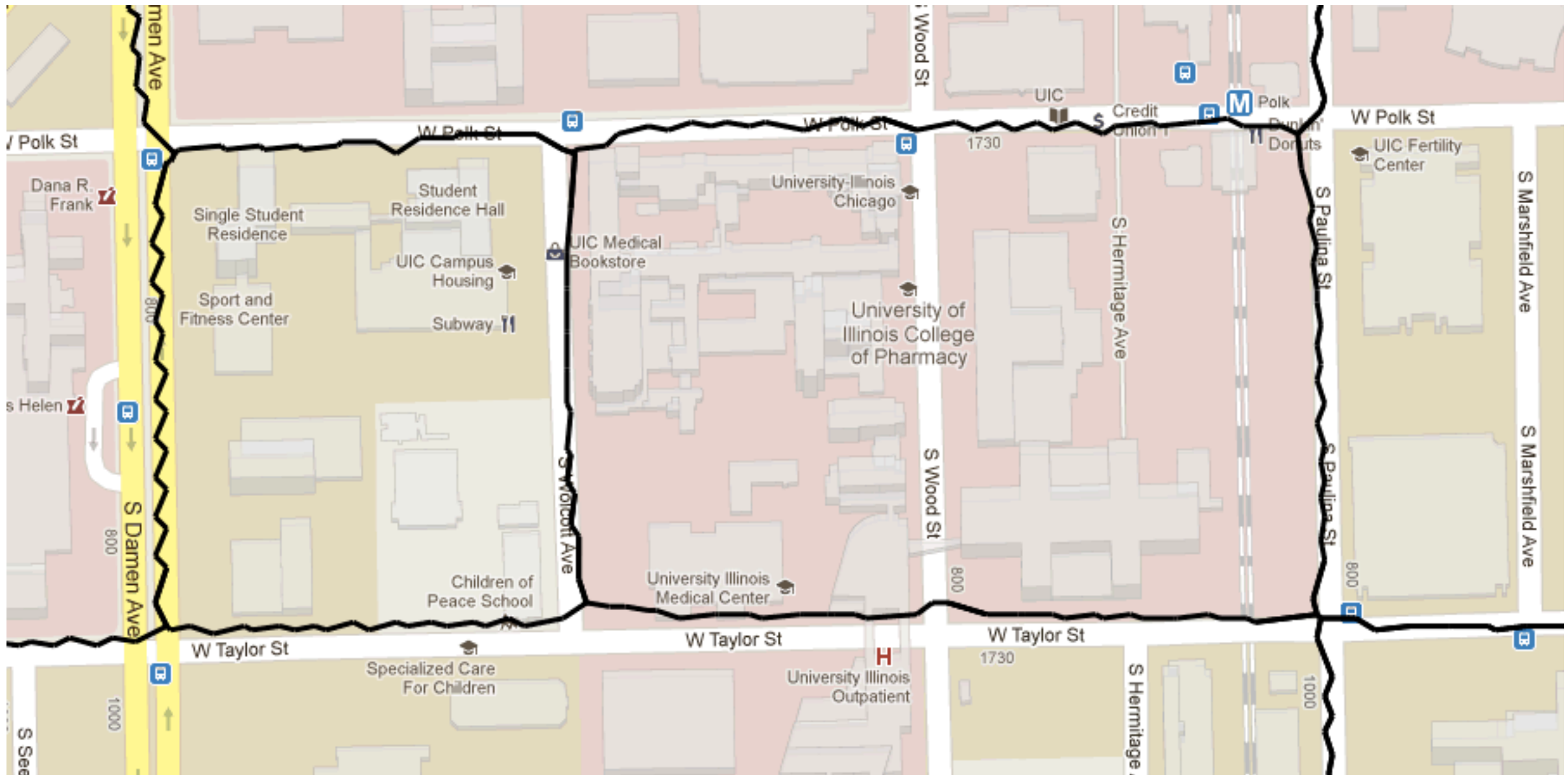
Edelkamp (high-error)



Cao (high-error)

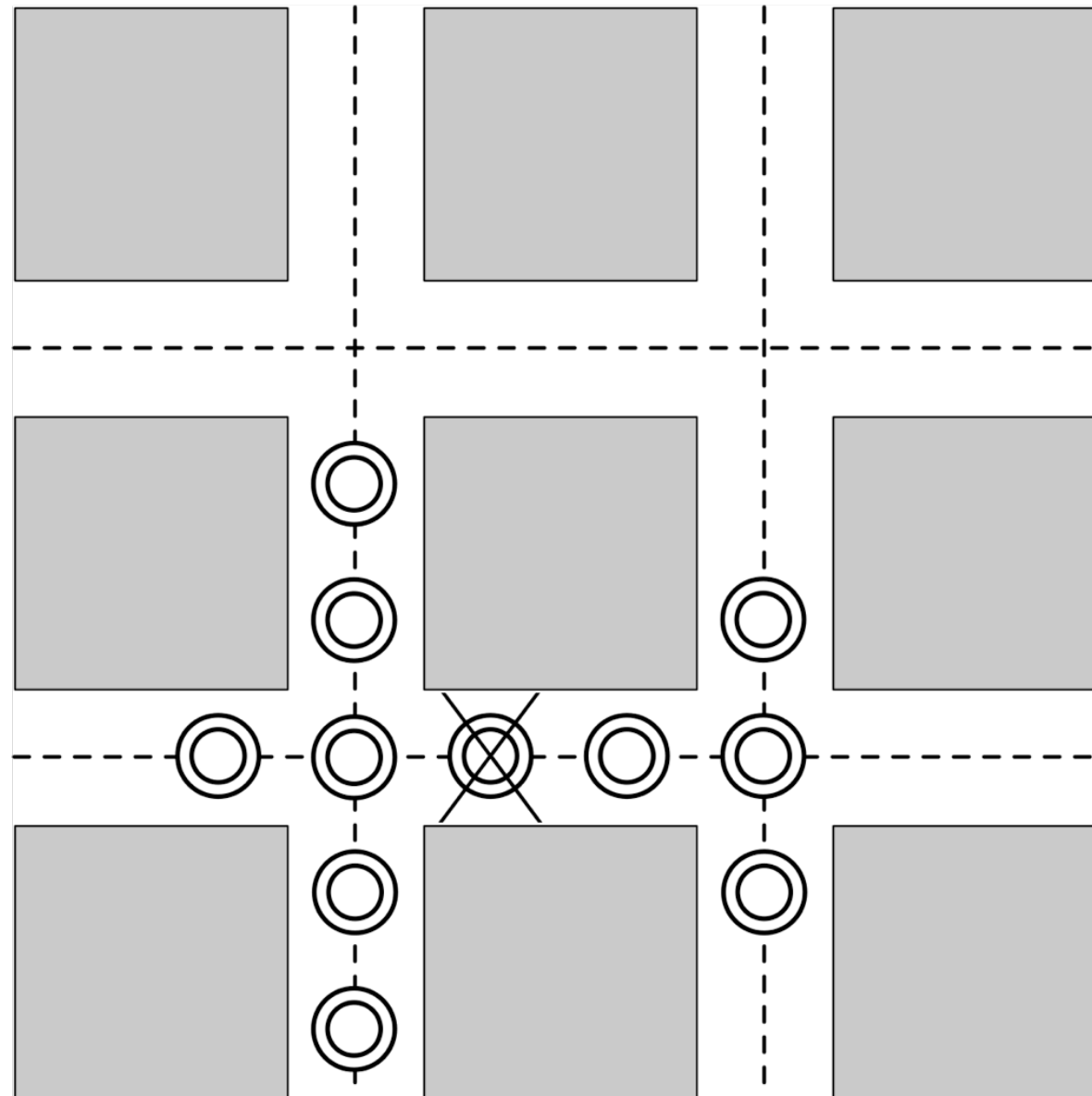


Davies (high-error)

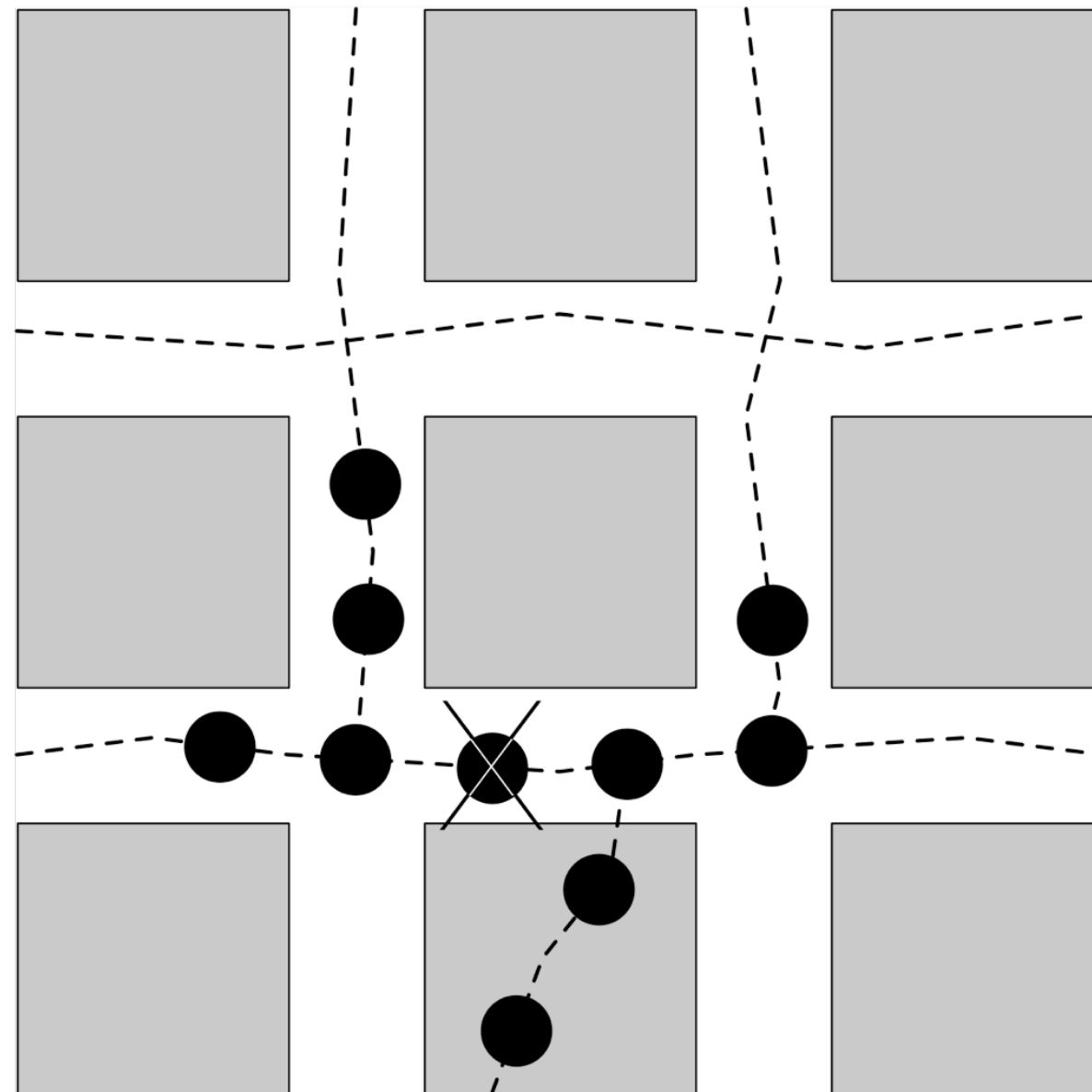


Quantitative Evaluation

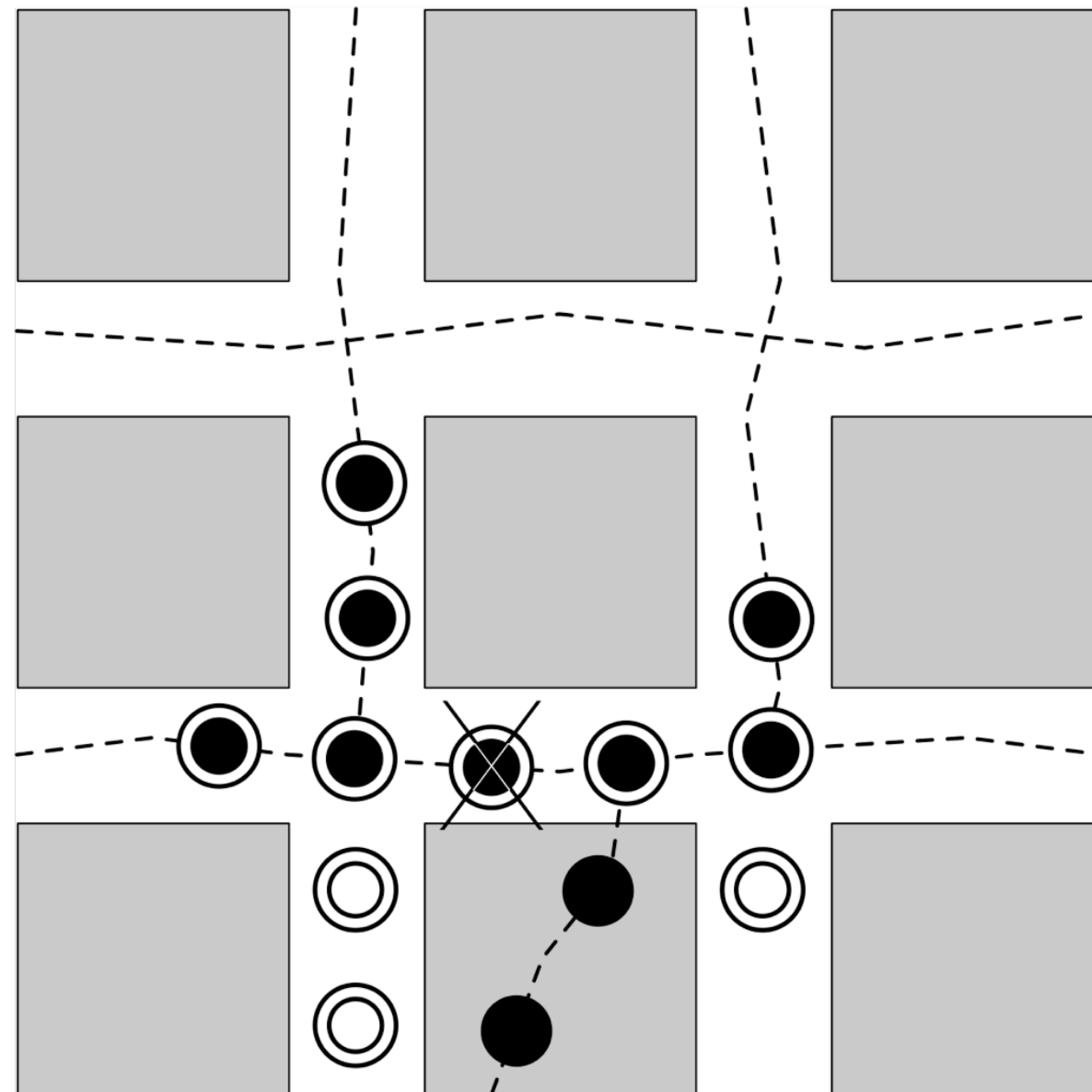
Ground truth map “holes”



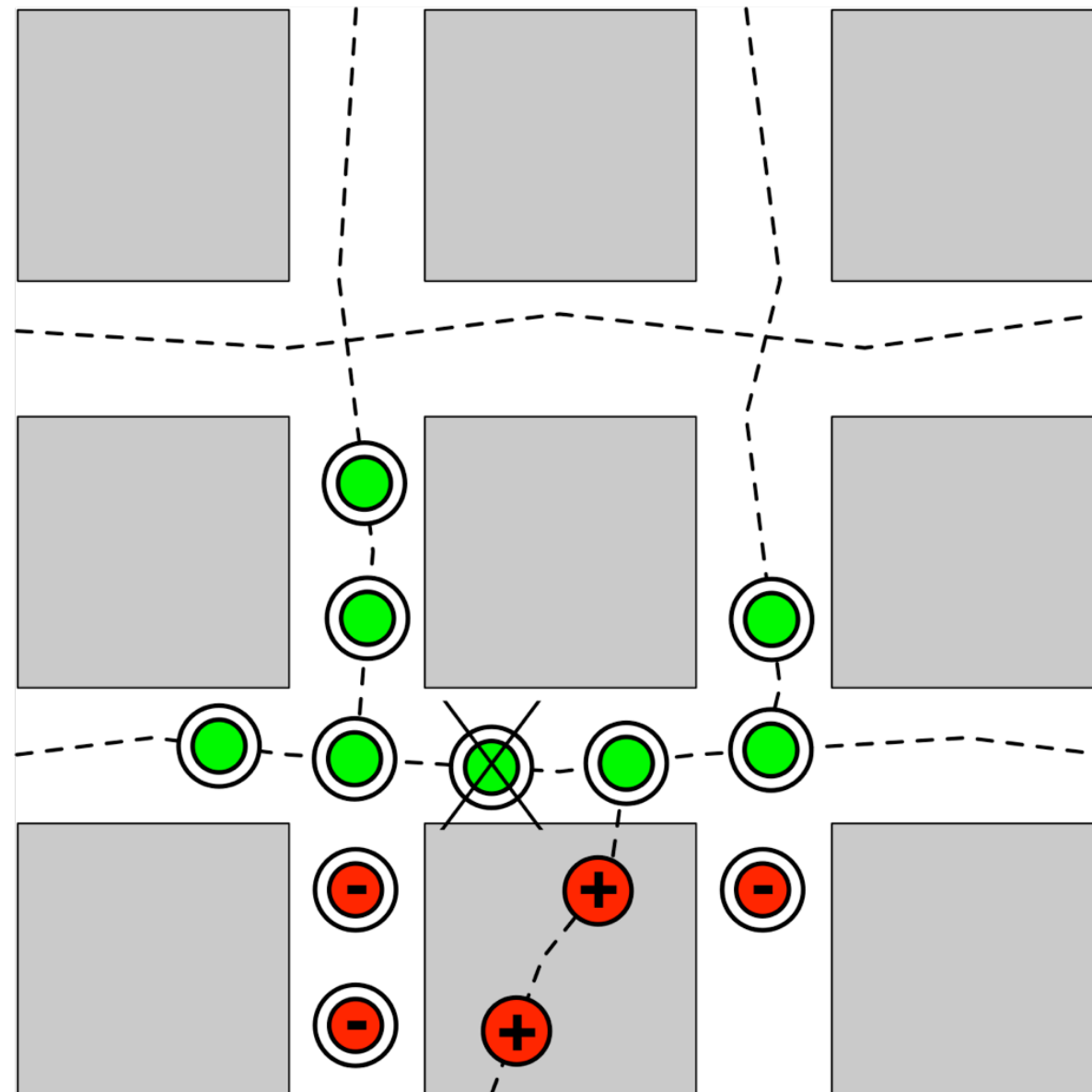
Generated map “marbles”



Marbles fall into holes



Marbles vs. holes



Map comparison metrics

$$\textit{spurious} = \frac{\textit{spurious_marbles}}{\textit{spurious_marbles} + \textit{matched_marbles}}$$

$$\textit{missing} = \frac{\textit{empty_holes}}{\textit{empty_holes} + \textit{matched_holes}}$$

Overall performance

$$F = 2 \cdot \frac{\textit{precision} \cdot \textit{recall}}{\textit{precision} + \textit{recall}}$$

$$\textit{precision} = 1 - \textit{spurious}$$

$$\textit{recall} = 1 - \textit{missing}$$

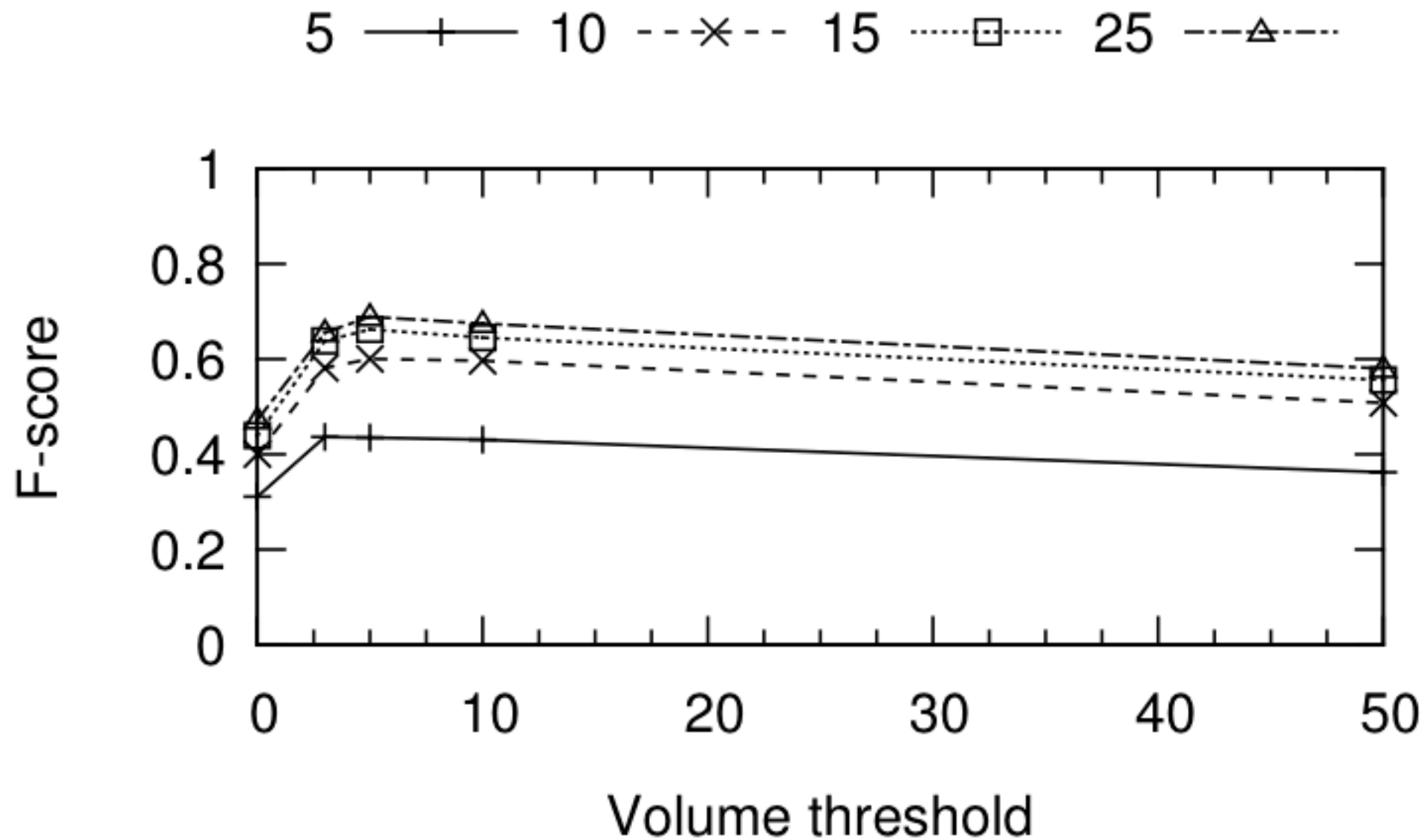
Overall performance

$$F = 2 \cdot \frac{(1 - \textit{spurious}) \cdot (1 - \textit{missing})}{(1 - \textit{spurious}) + (1 - \textit{missing})}$$

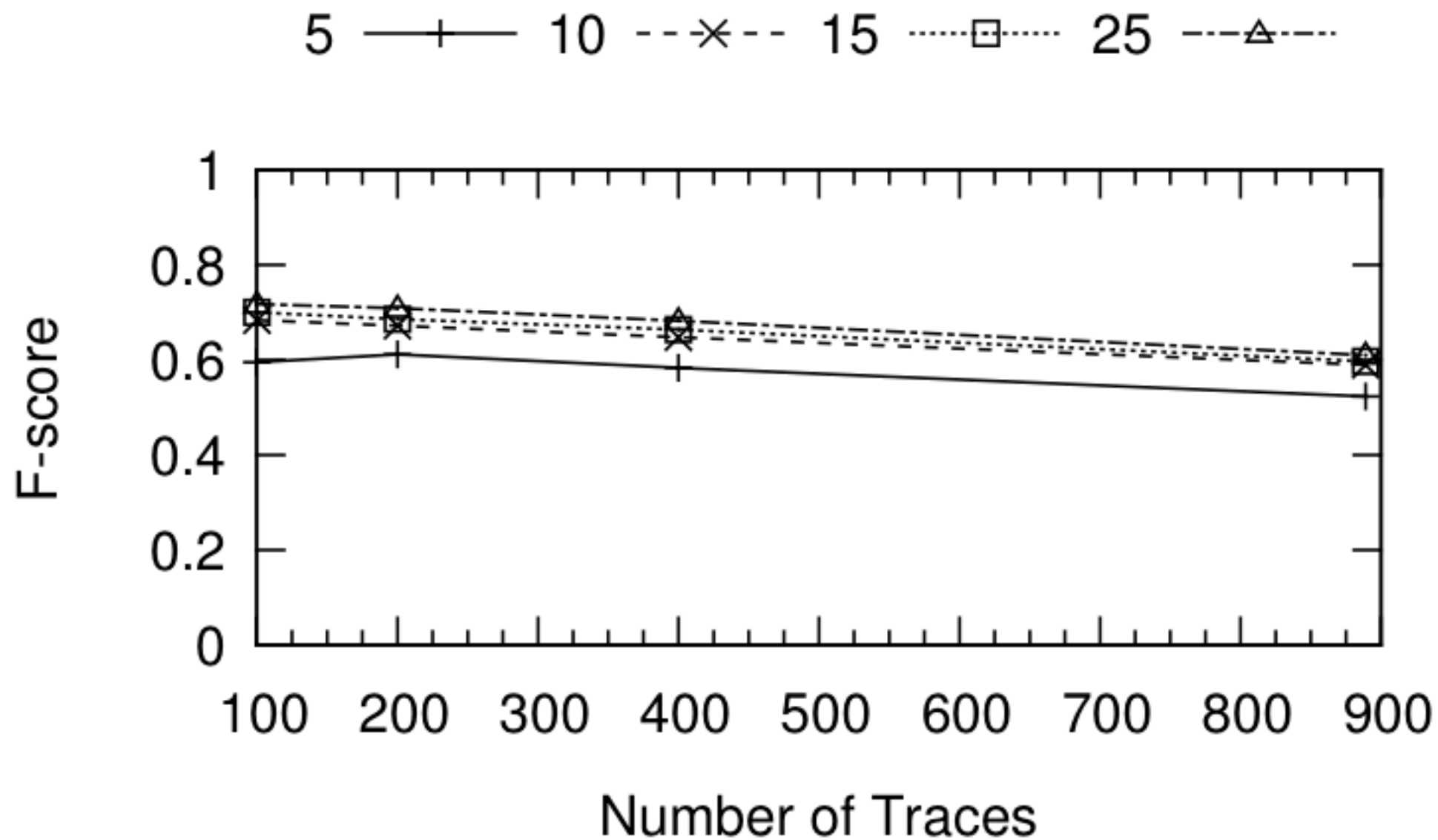
$$\textit{precision} = 1 - \textit{spurious}$$

$$\textit{recall} = 1 - \textit{missing}$$

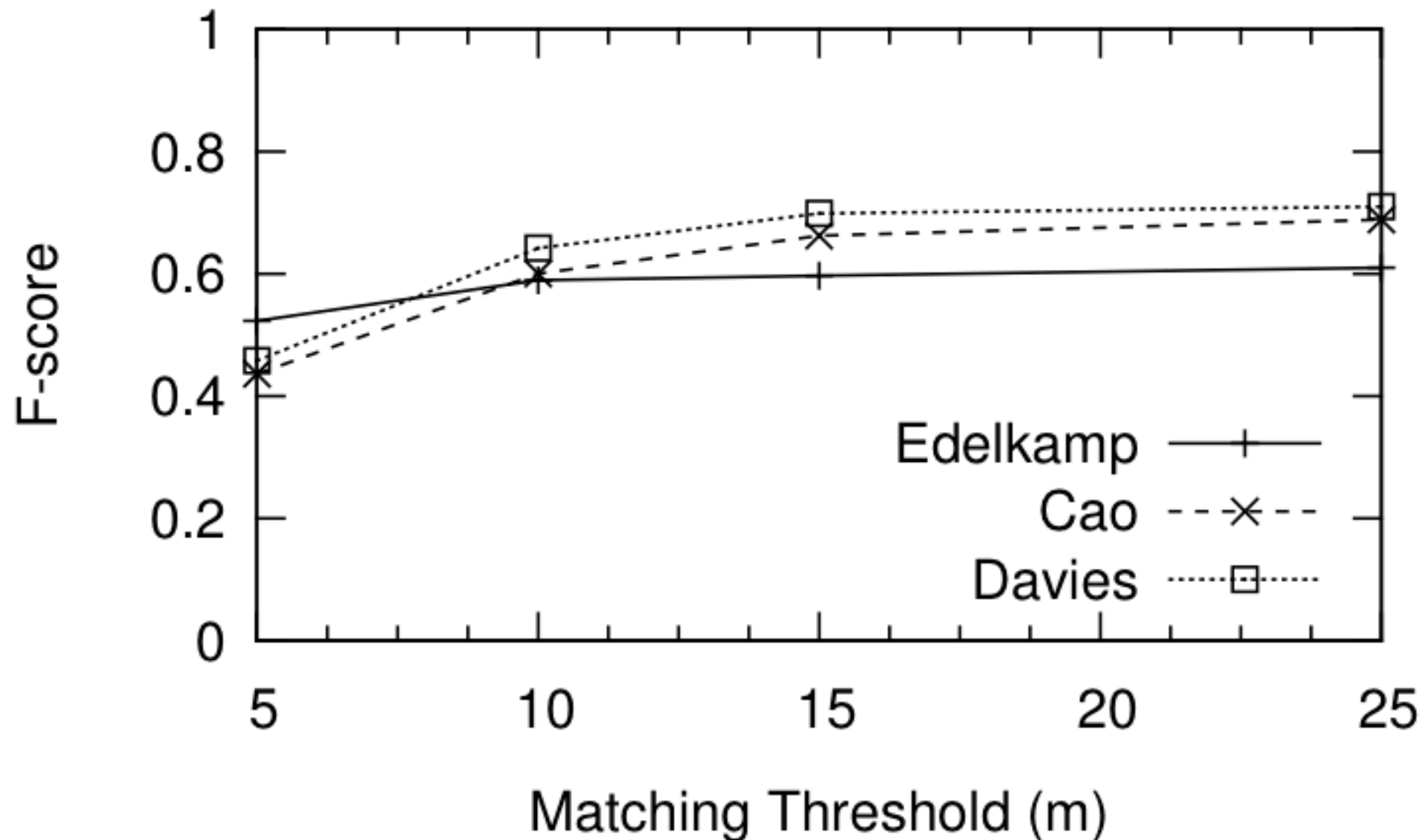
Parameter tuning



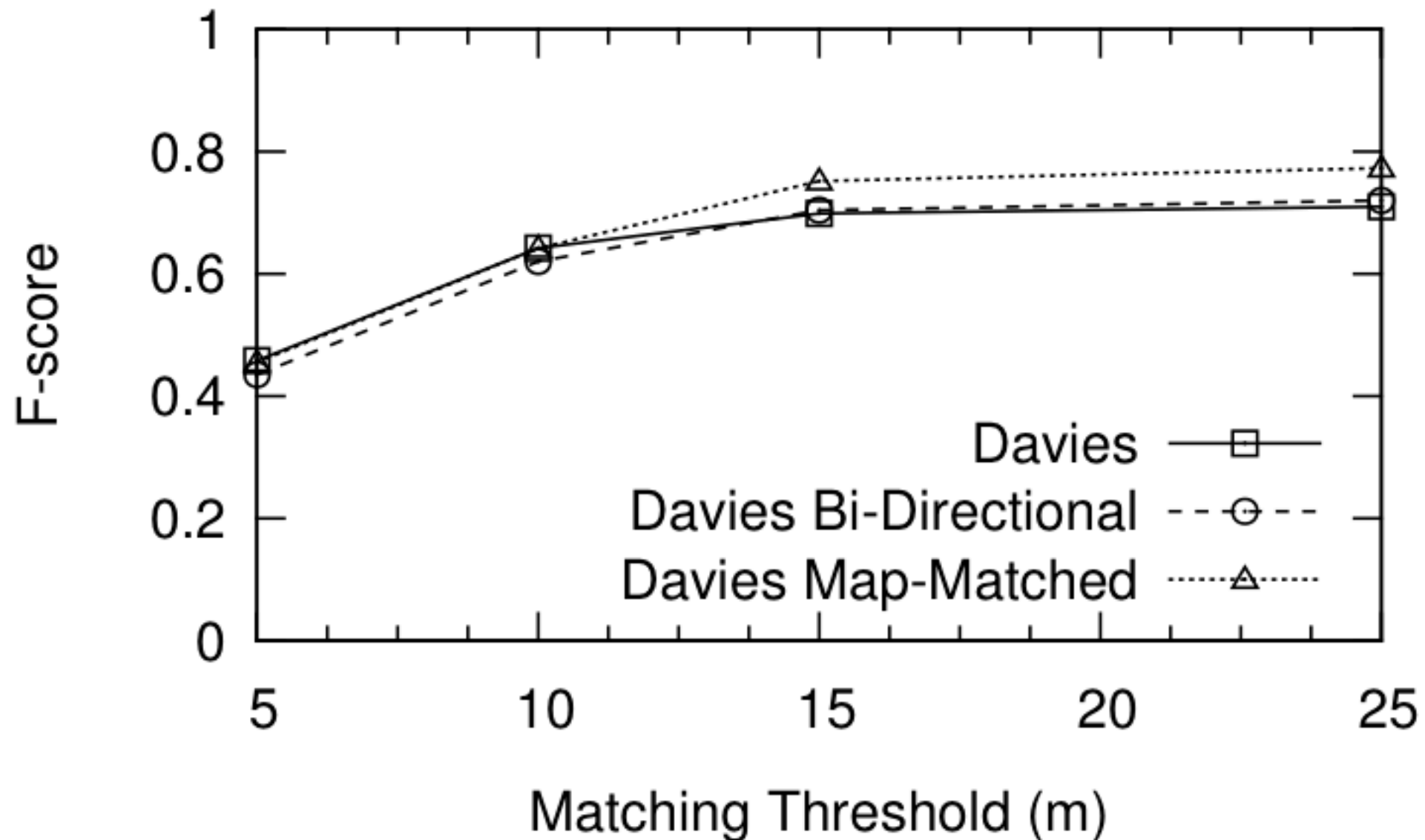
Observation validation



Quantitative results



Enhanced Davies



Performance summary

Algorithm	Full data set	Low-error data set
Edelkamp	0.60	0.75
Cao	0.65	0.70
Davies	0.70	0.80
Davies Enhanced	0.75	0.85

Summary

- ▶ Three representative algorithms
- ▶ Qualitative evaluation
- ▶ Quantitative evaluation method
- ▶ Quantitative results

Thanks!

Questions?

Dataset and implementations available at
bits.cs.uic.edu