

EasyTracker

Automatic Transit Tracking, Mapping, and
Arrival Time Prediction Using Smartphones

James Biagioni, Tomas Gerlich,
Timothy Merrifield and Jakob Eriksson

UIC Bits Networked
UNIVERSITY OF ILLINOIS
AT CHICAGO Systems Laboratory
COLLEGE OF ENGINEERING

We love bus trackers!



Winter in Chicago



Our shuttle web (before)



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Bus Service

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Intracampus Bus Service

 The **Intracampus Bus Service** provides free transportation for students, faculty, and staff to various points on campus. The routes are the **UIC Intracampus Route**, the **UIC East Side Route**, and the **Semester Express**. A valid UIC identification card ([i-card](#)) must be presented to the driver when boarding.

- For schedules and route maps, see the separate sections below.
- To see all the **weekday routes** on one map [Click Here](#).  (Adobe Reader required)

NEW Facilities Management, in collaboration with Jakob Eriksson, Assistant Professor of Computer Science, is pleased to announce the availability of the [UIC Shuttle Tracker](#), which provides real-time location of UIC buses as well as CTA buses within the UIC campus.

The UIC Shuttle Tracker is available at <http://bus.uic.edu/>. To learn more, [click here](#).

UIC Intracampus Route

The UIC Intracampus Route links the east and west sides of campus via Roosevelt Road or Taylor Street.

Hours of Operation

- **Monday - Friday:** 7:00 A.M. - 11:00 P.M. 20-Minute Service  [Map](#)
- **Weekend/Holiday:** 7:00 A.M. - 11:00 P.M. 30-Minute Service  [Map](#)

UIC East Side Route

The UIC East Side Route circles the east side including the south residence halls. The UIC East Side Route does not operate on the weekends or holidays.

Hours of Operation

- **Monday - Friday:** 7:00 A.M. - 11:00 P.M. 20-Minute Service  [Map](#)

Our shuttle web (before)



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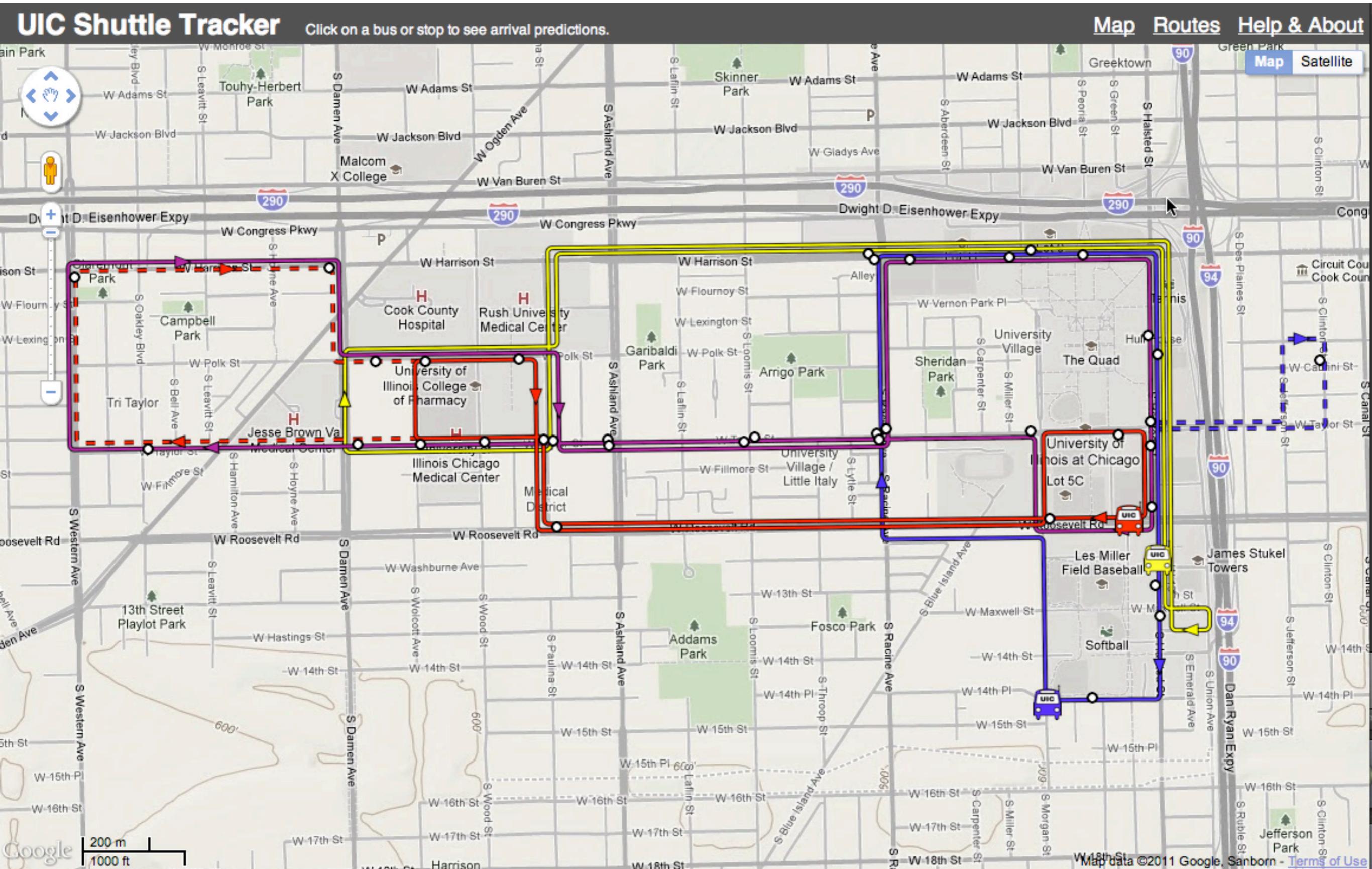
UIC East Side Route

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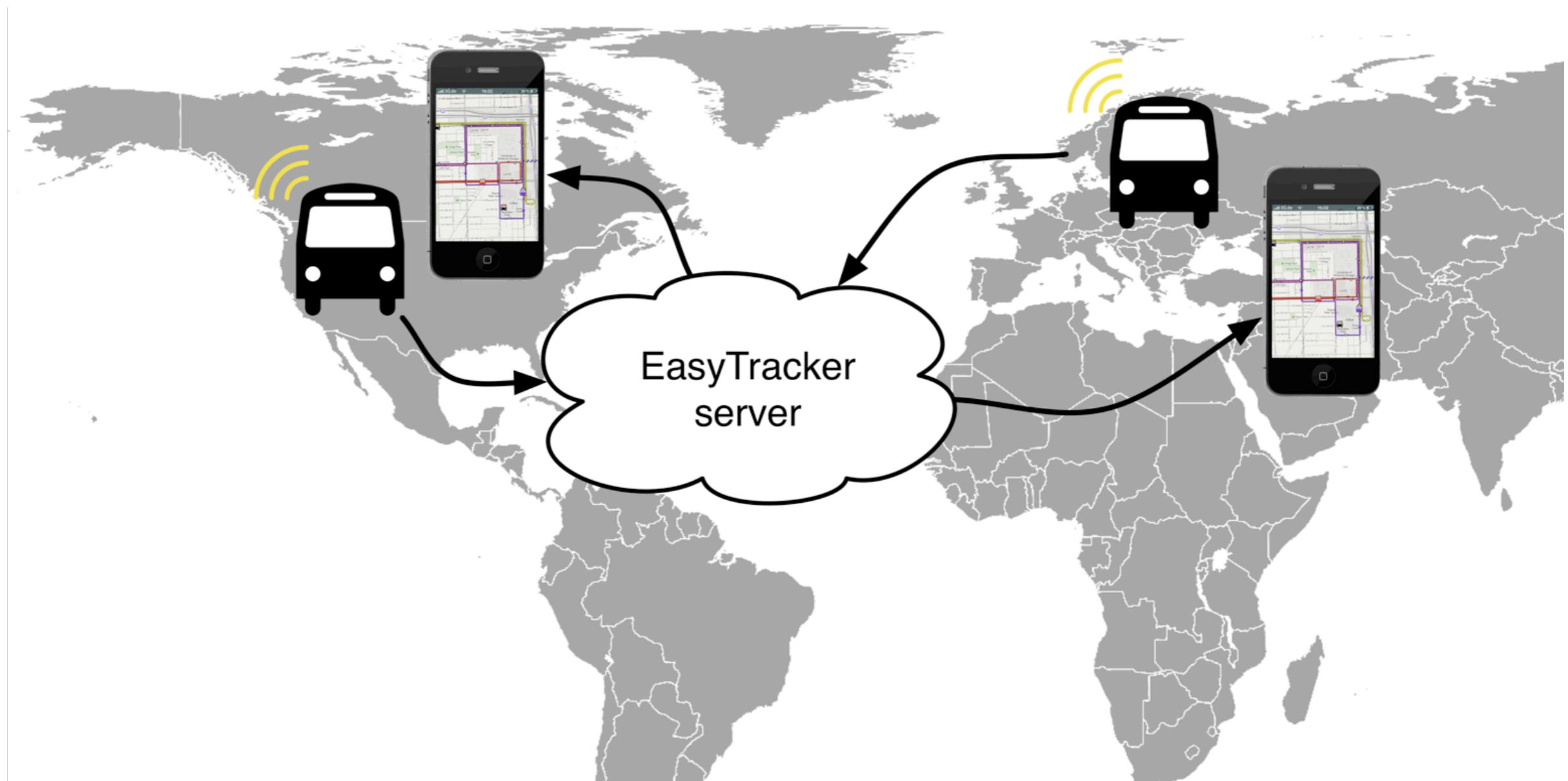
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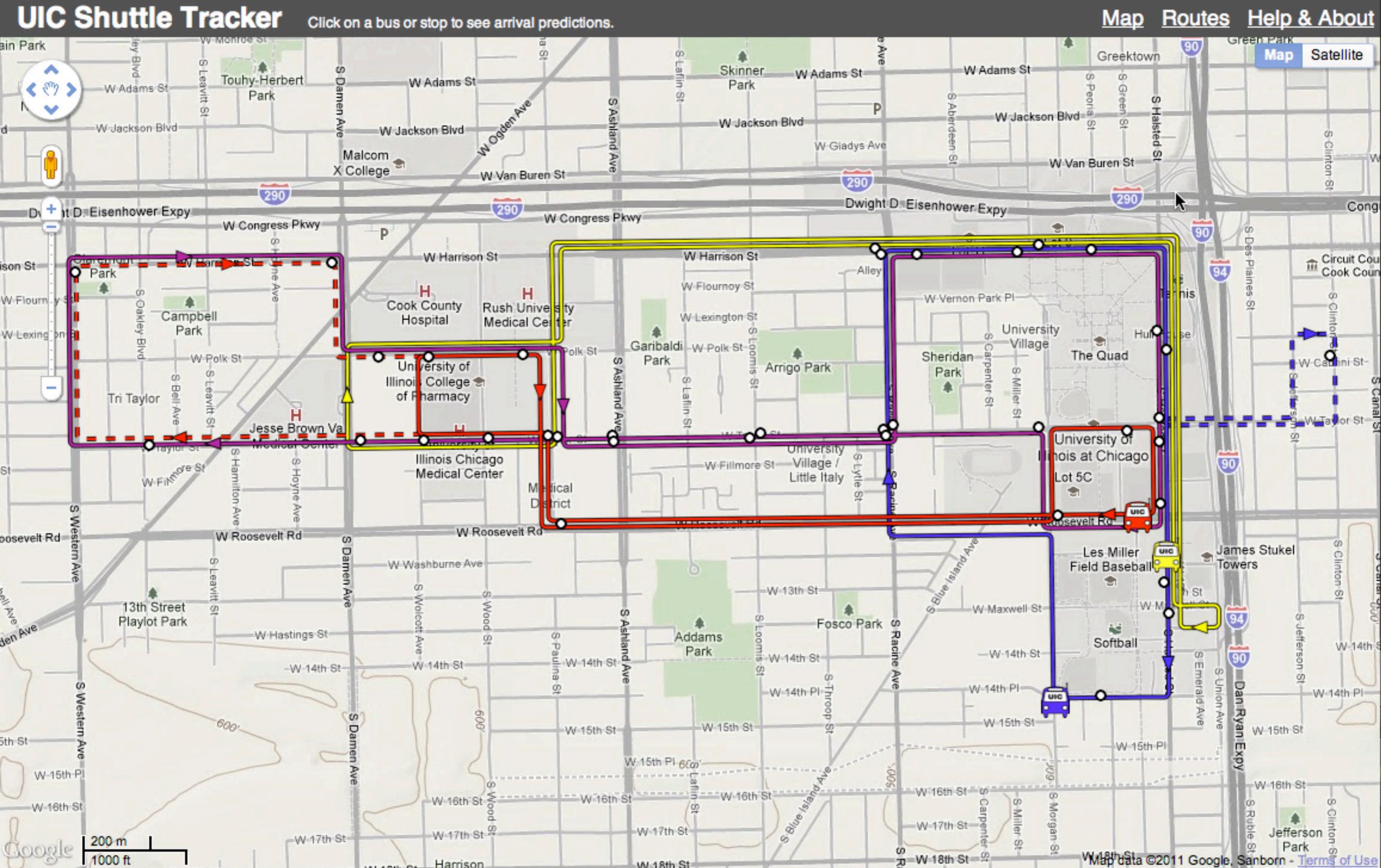
Our shuttle web (after)



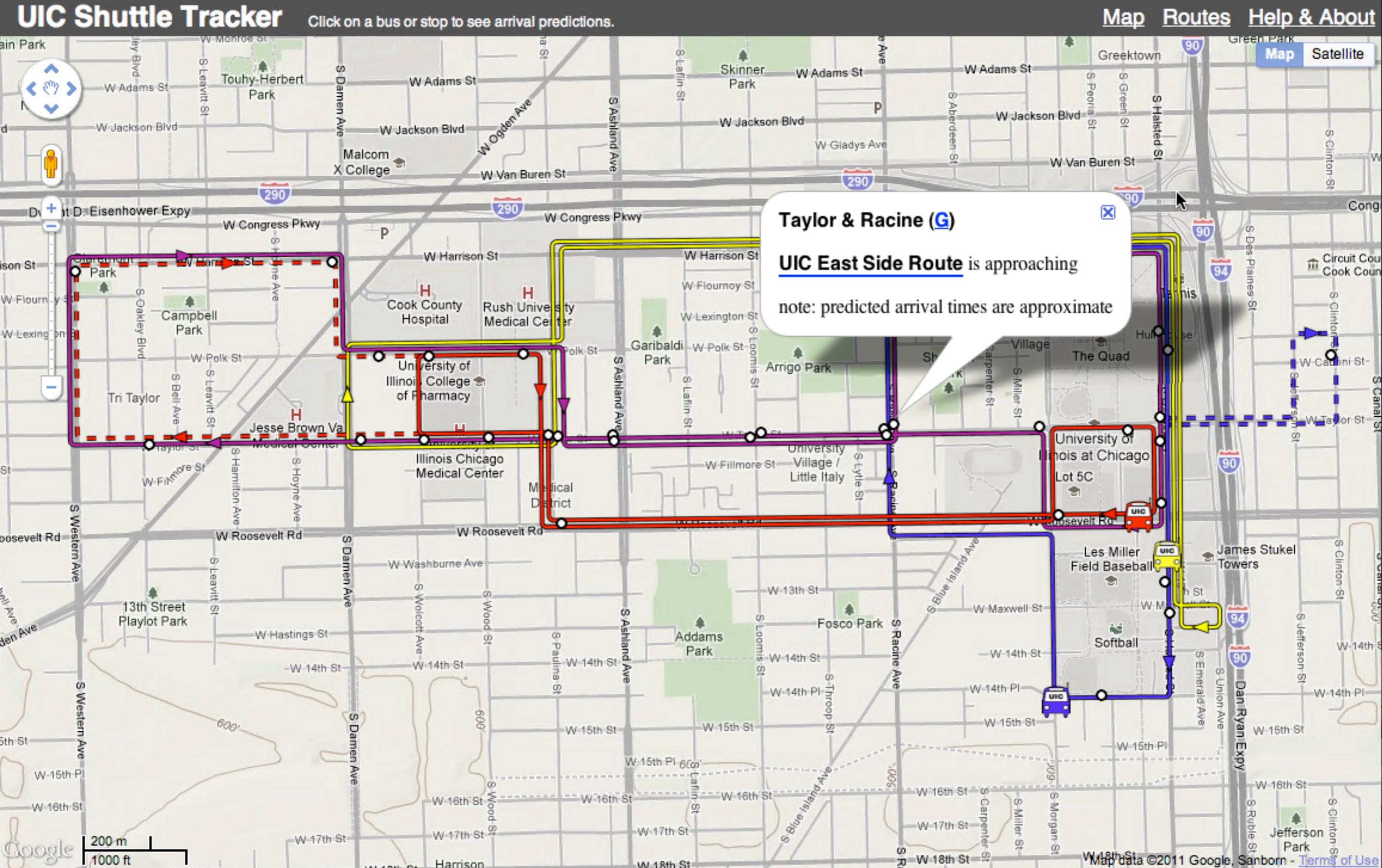
One service for everyone



Our shuttle web



Our shuttle web



This paper in a nutshell

- ▶ Automatic generation of
 - route shapes
 - stop locations
 - schedules
- ▶ Online processing for
 - vehicle-to-route classification
 - arrival-time prediction



EasyTracker installation

EasyTracker installation

1. Obtain smartphone



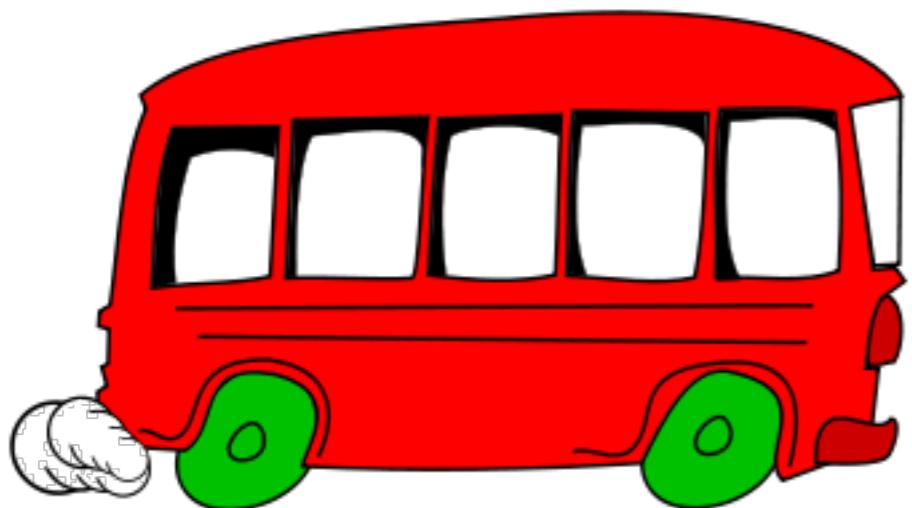
EasyTracker installation

1. Obtain smartphone
2. Install EasyTracker app



EasyTracker installation

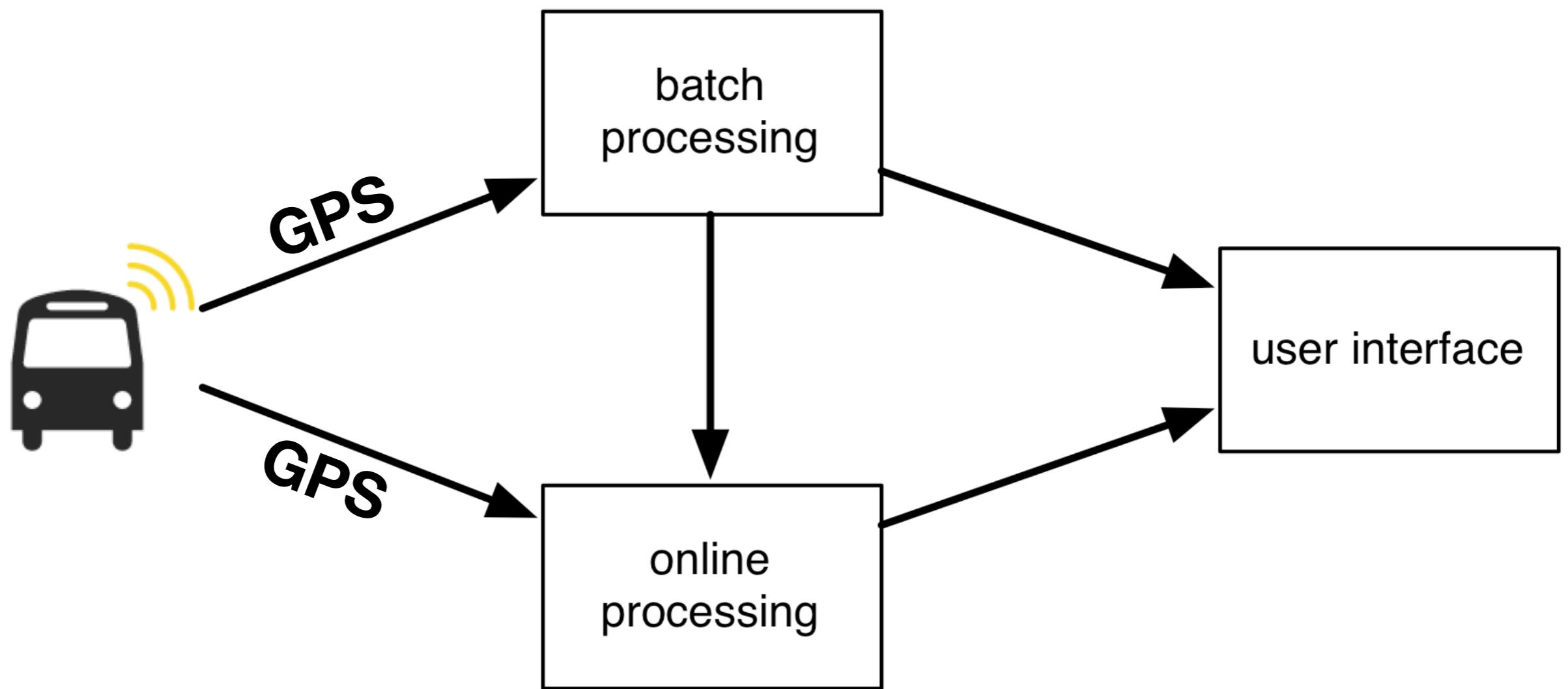
1. Obtain smartphone
2. Install EasyTracker app
3. Stick phone in bus



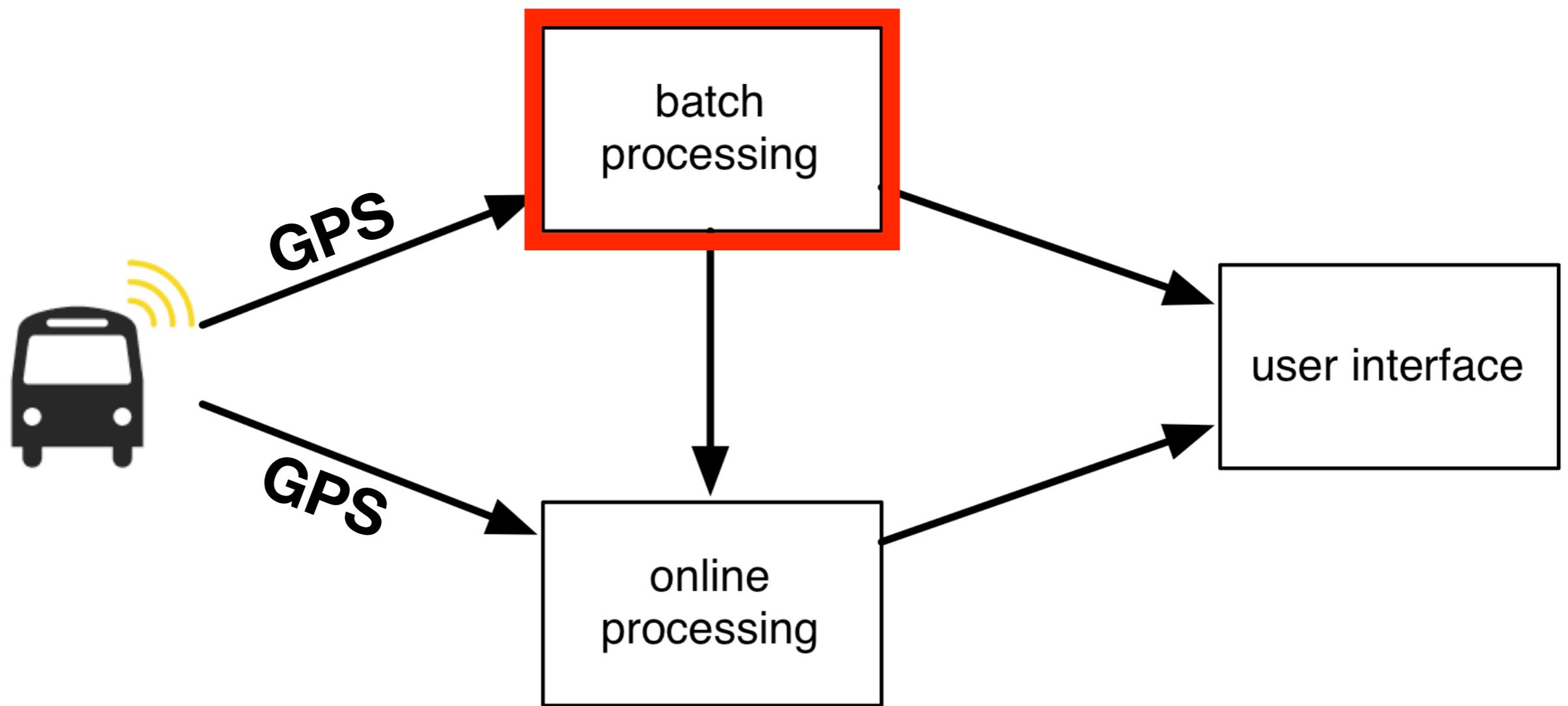
4. Relax



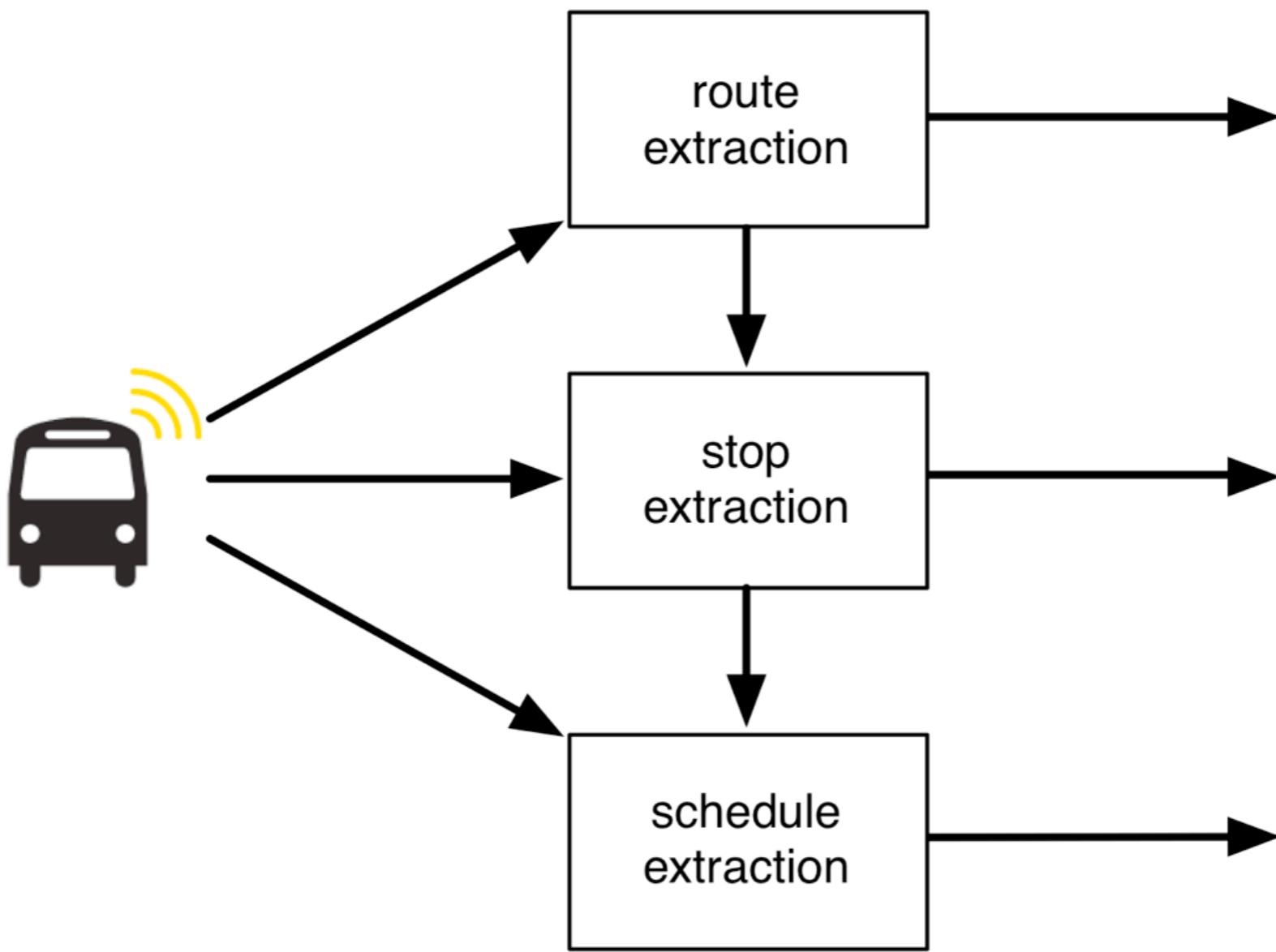
System overview



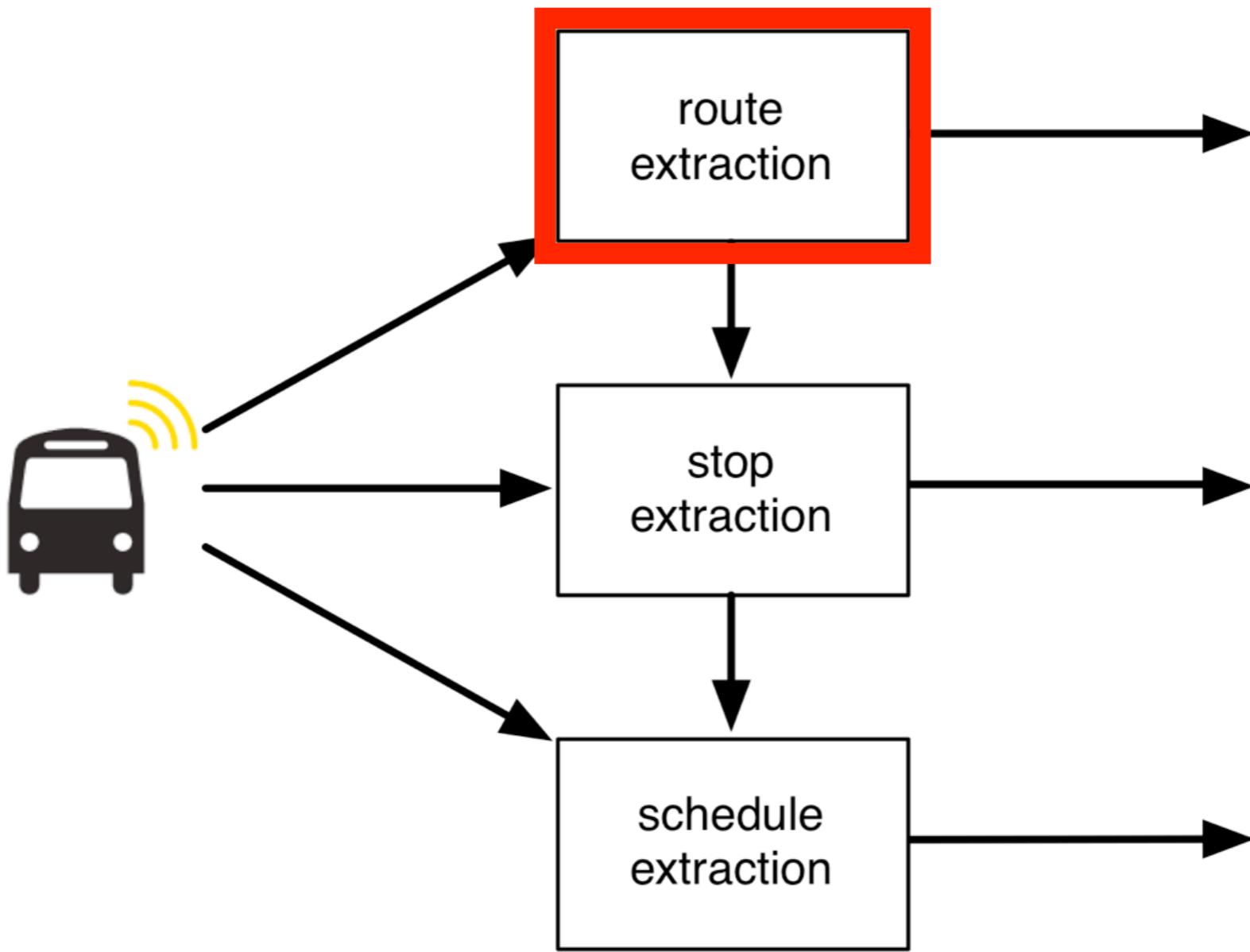
System overview



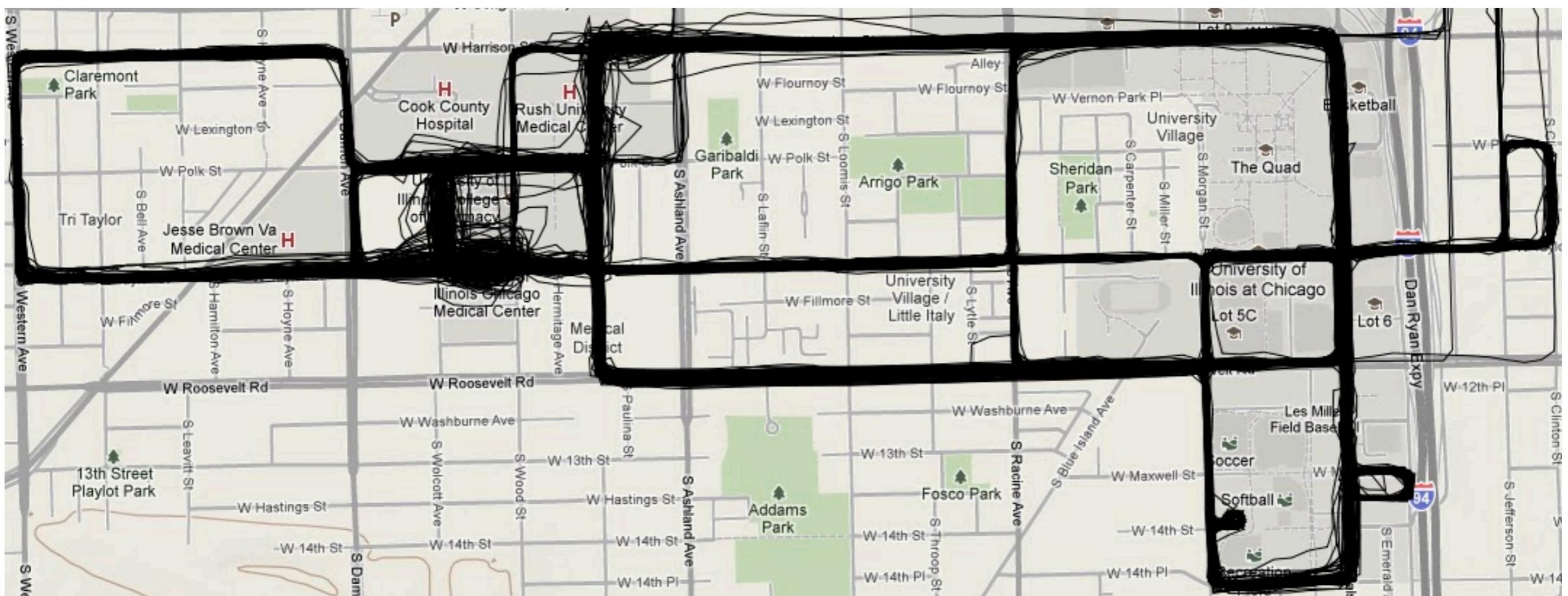
Batch processing



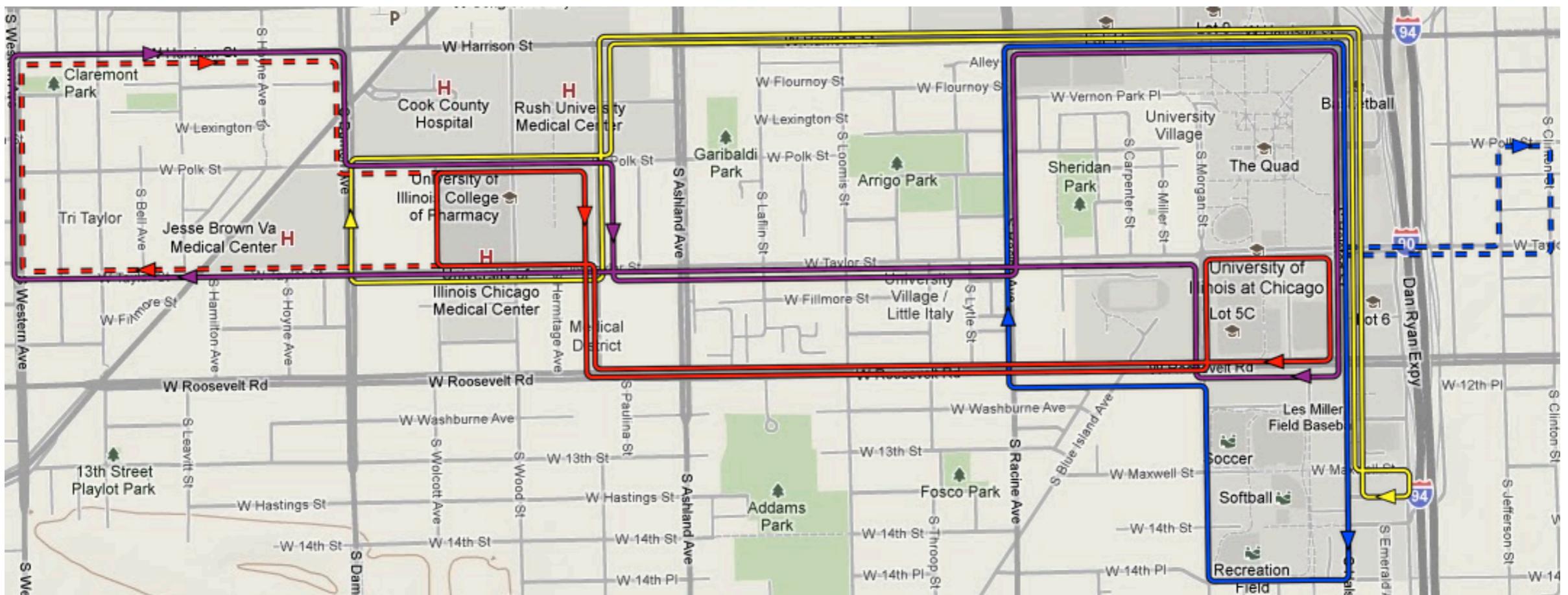
Batch processing



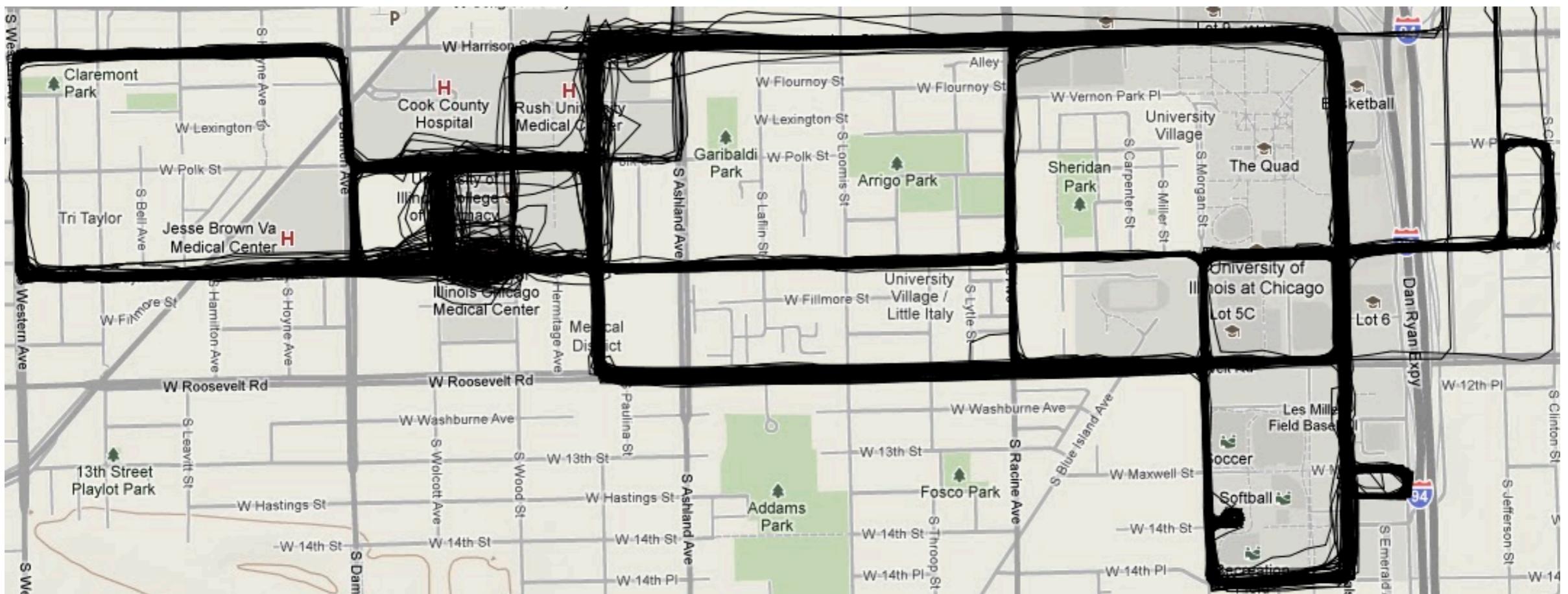
Raw GPS traces



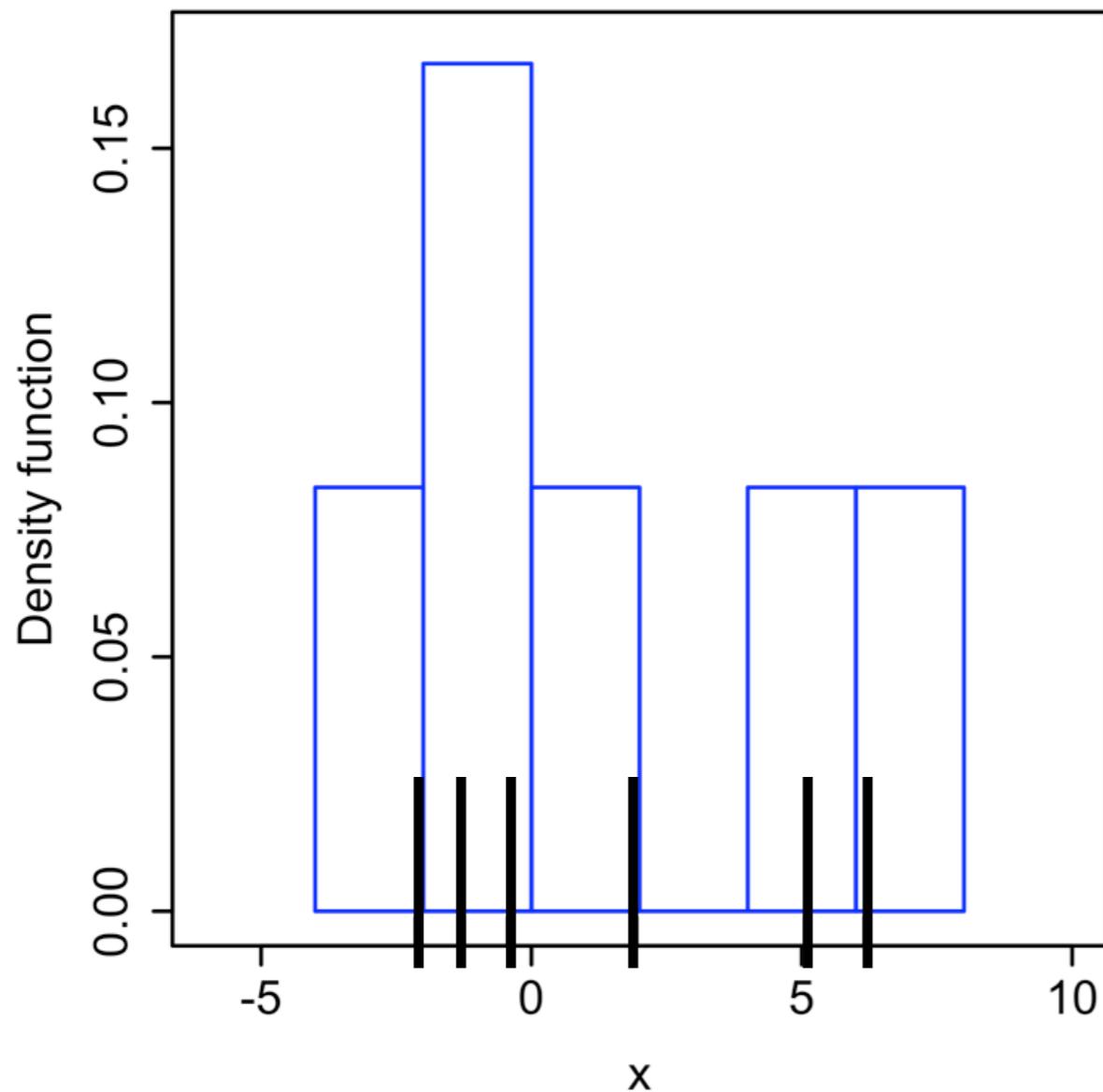
Route map



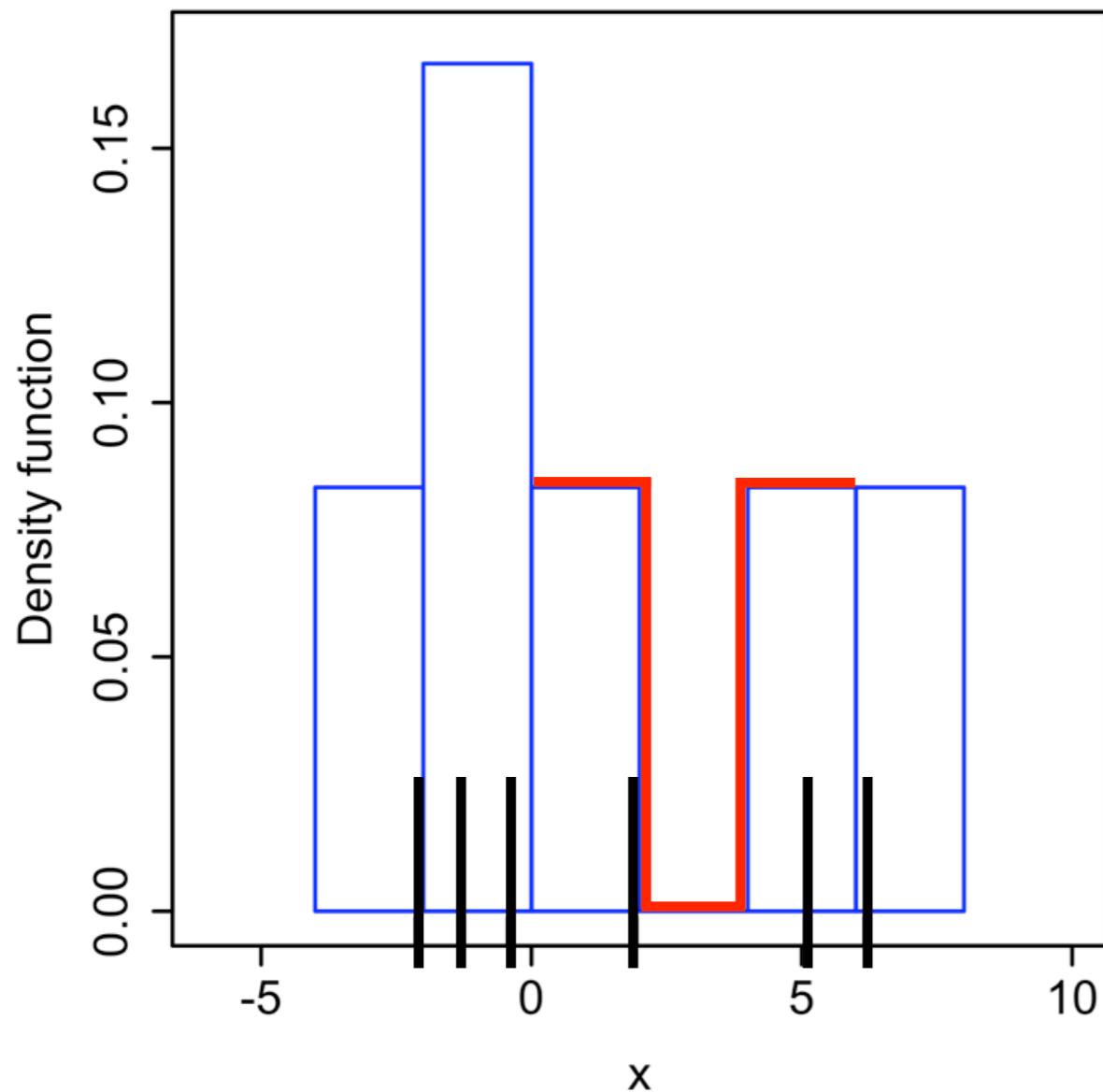
Raw GPS traces



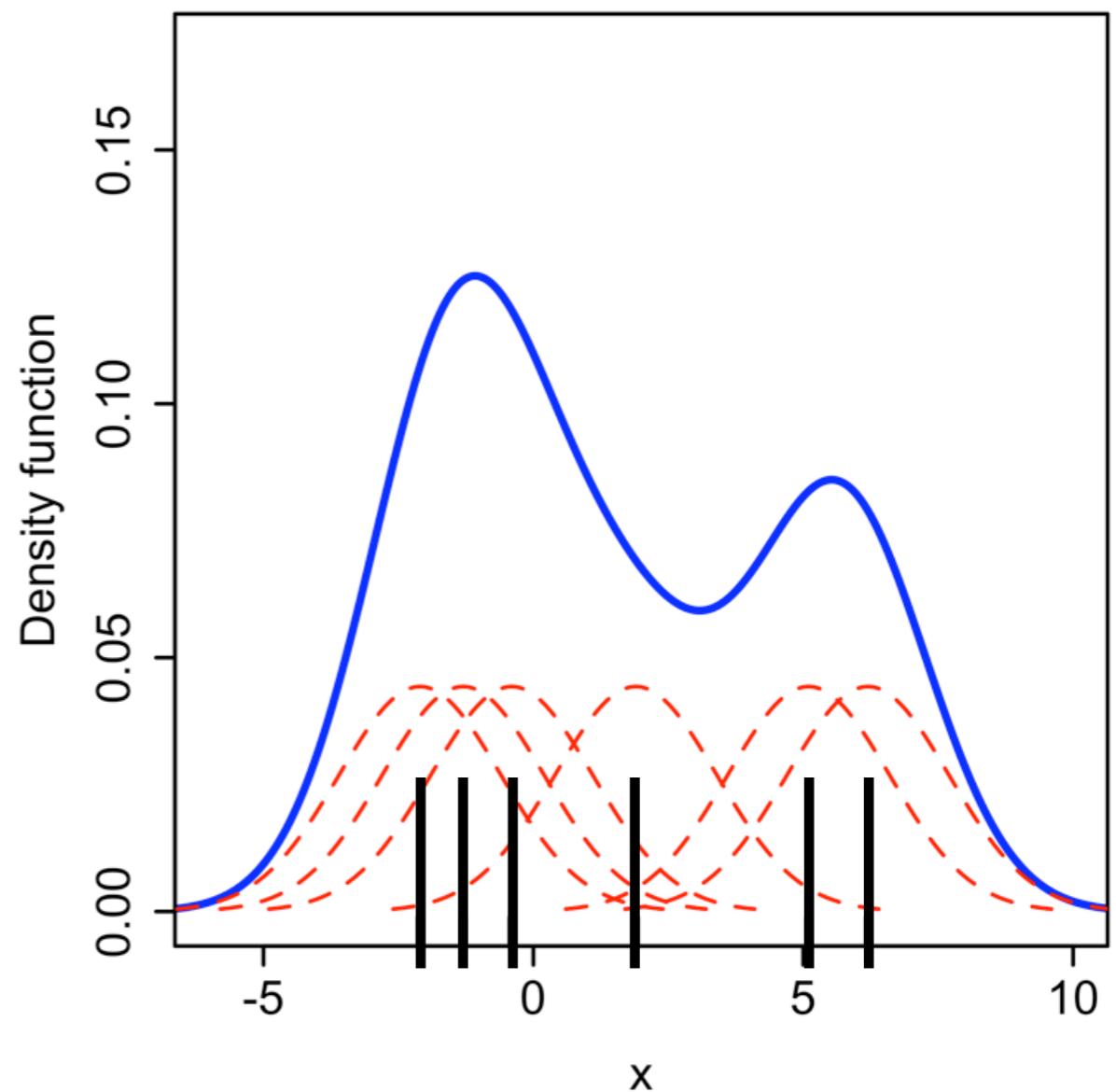
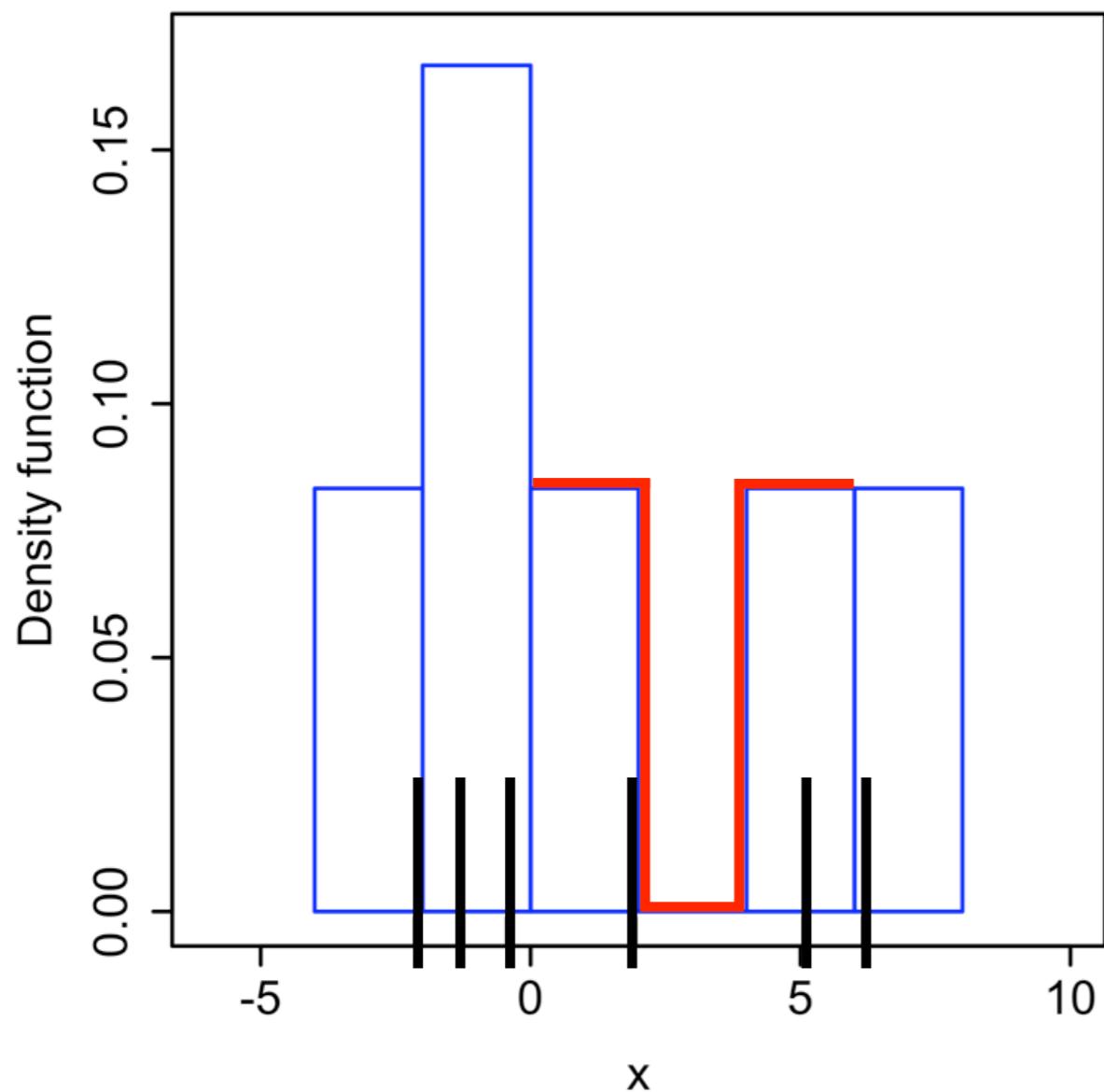
Kernel Density Estimation



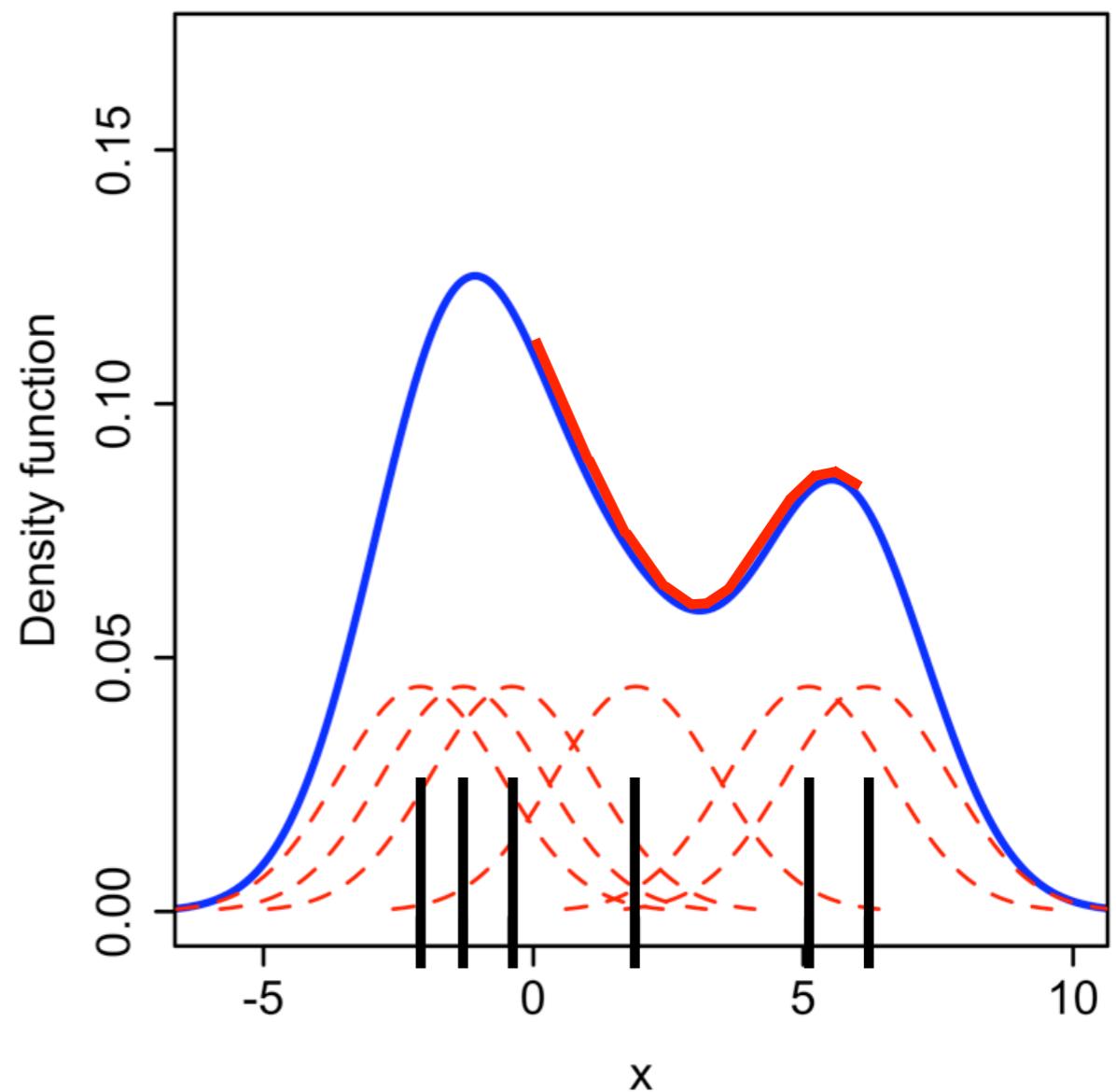
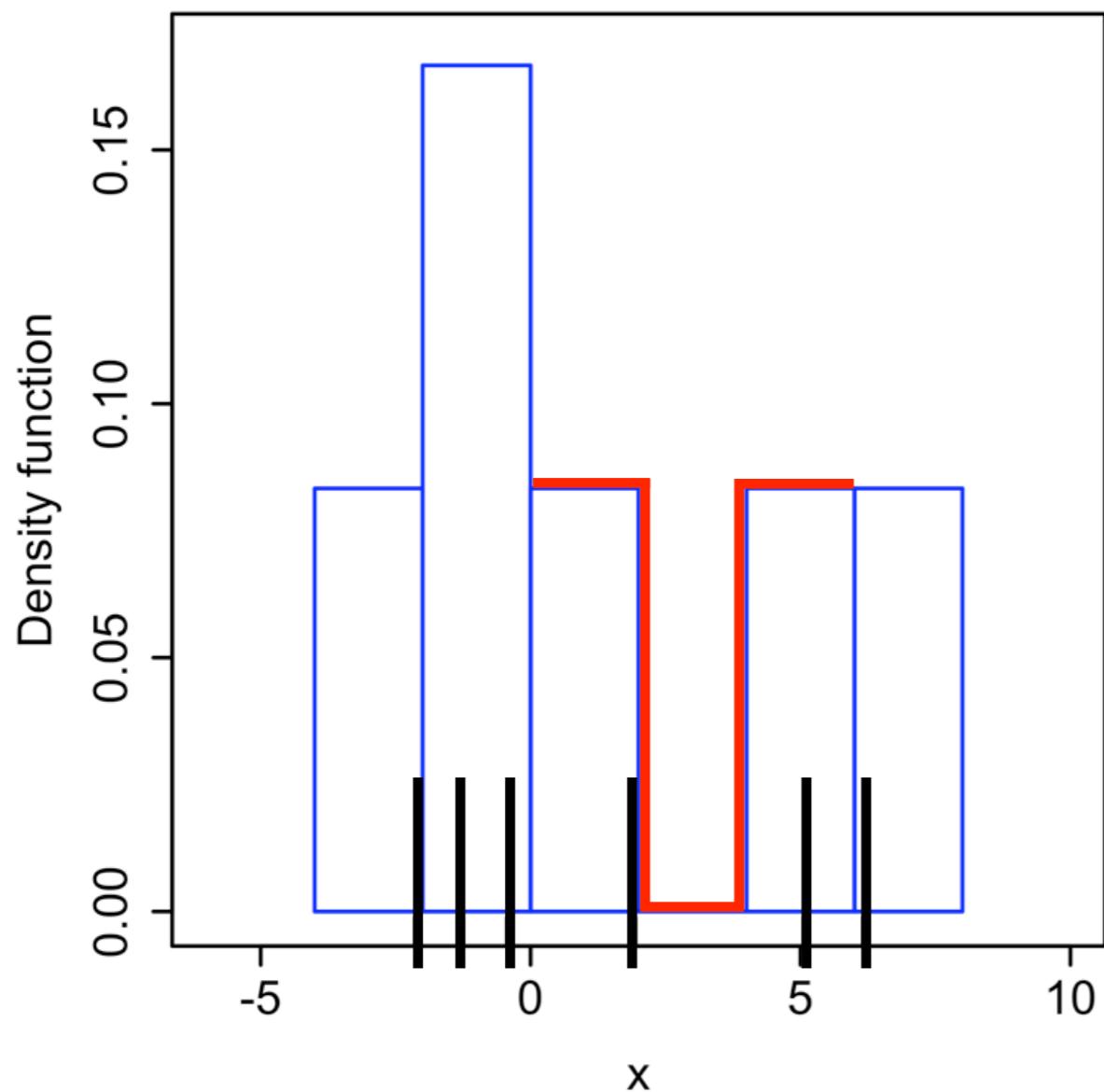
Kernel Density Estimation



Kernel Density Estimation



Kernel Density Estimation

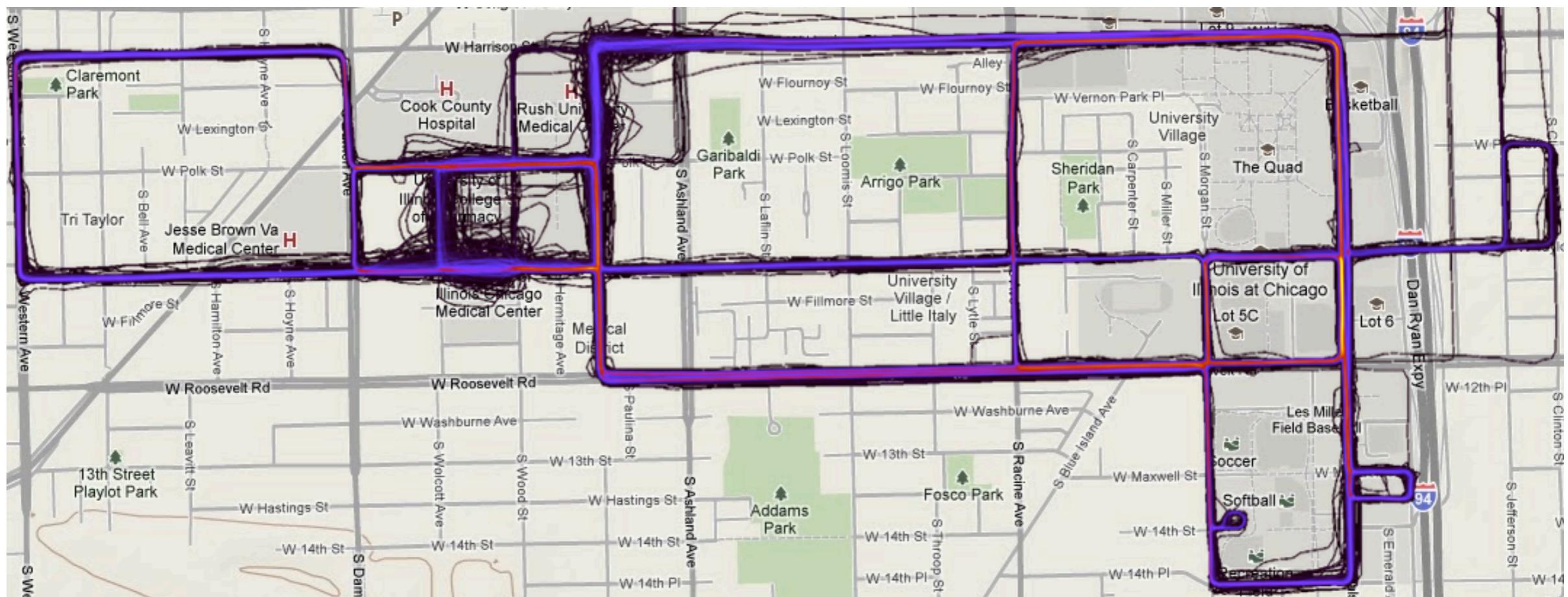


Kernel density estimation

$$\hat{f}(x) = \frac{1}{n} \sum_{i=1}^n K(x - x_i)$$

$$K(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$

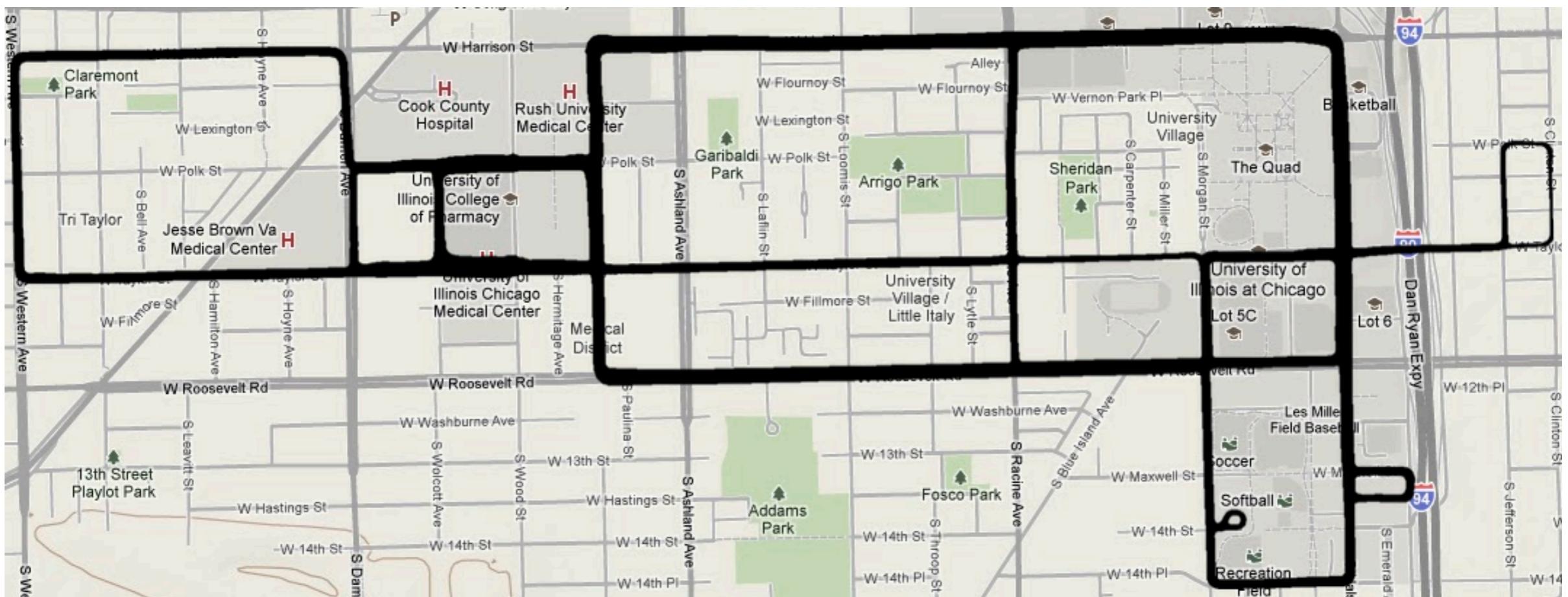
2-D histogram



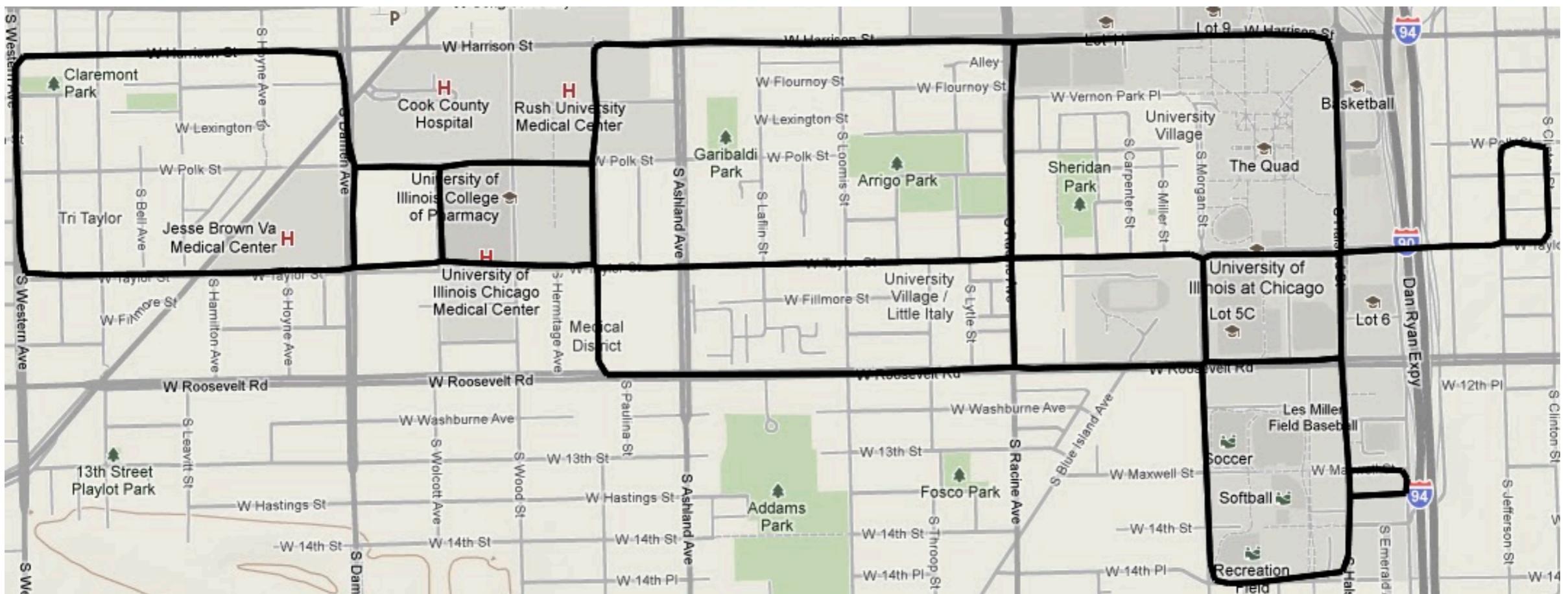
Trajectory density estimate



Thresholded image



Map extraction

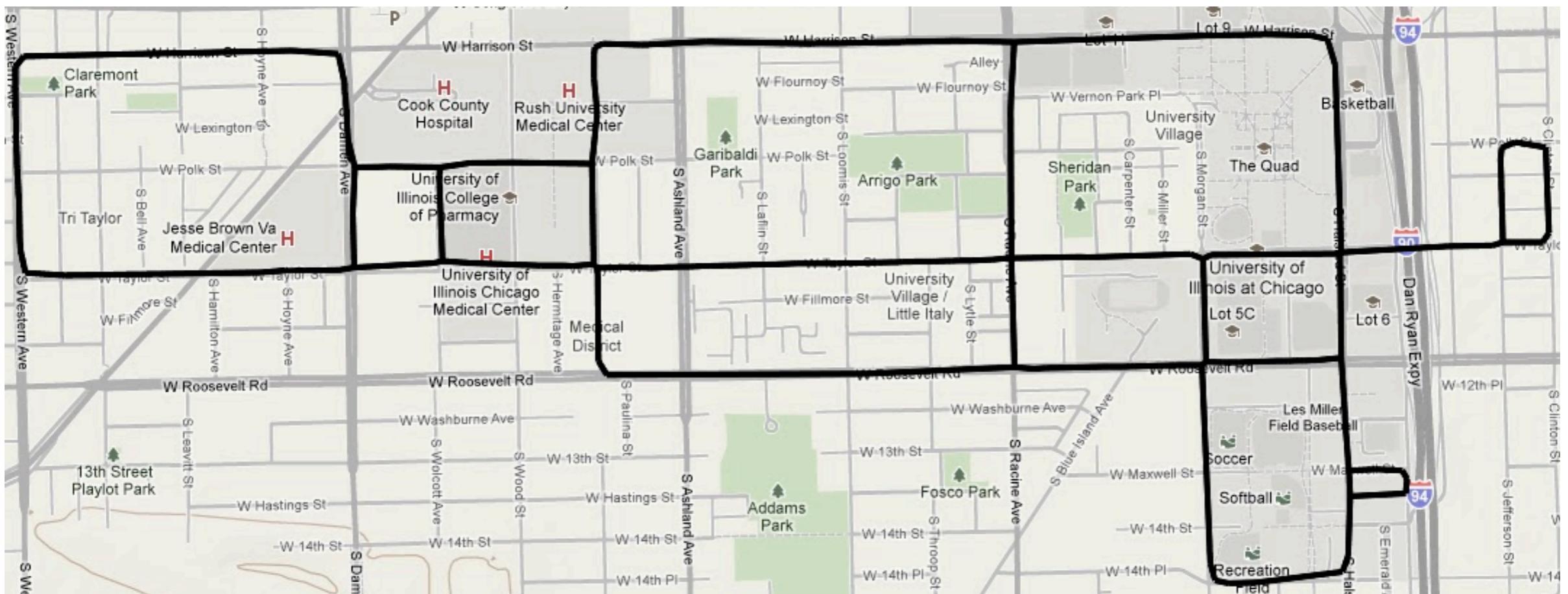


- ▶ Davies et al., 2006

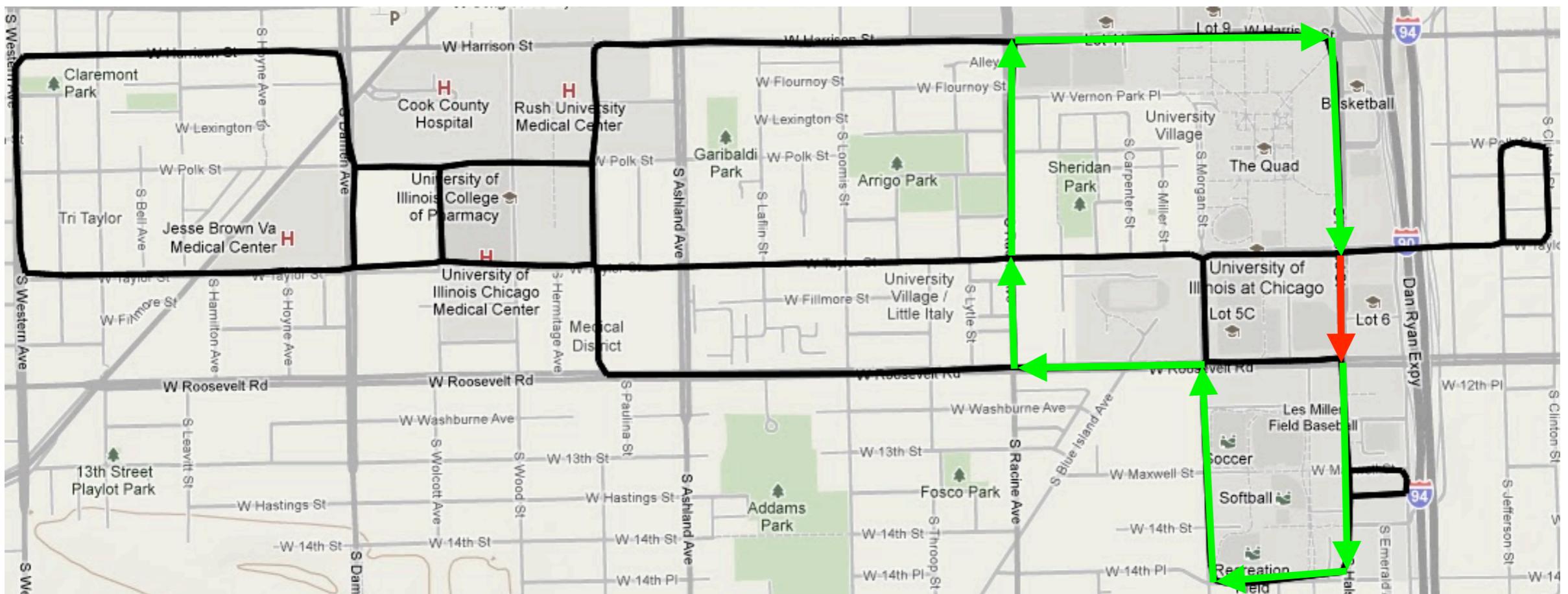
Route extraction

- ▶ Map match GPS traces
 - Viterbi-based map matching
 - based on Thiagarajan, et al. 2009
- ▶ Extract common routes
 - edge subsequence matching
 - statistical test removes spurious results

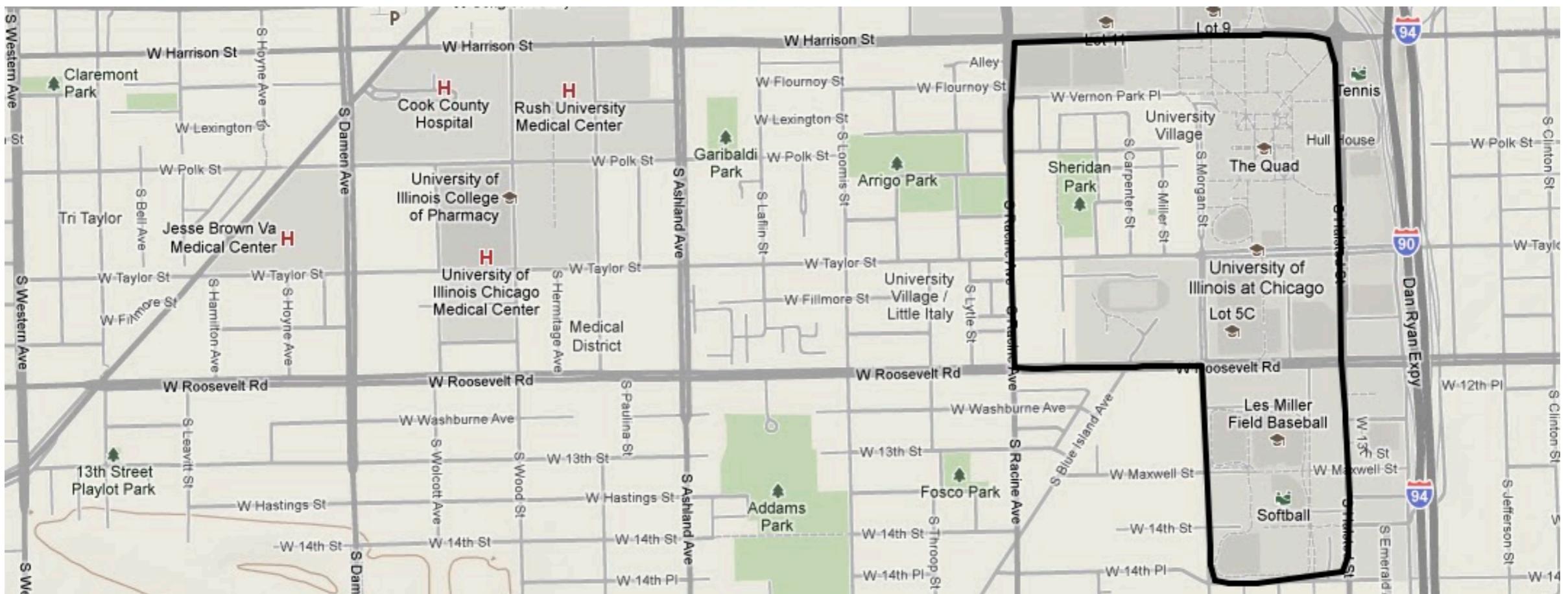
Route extraction



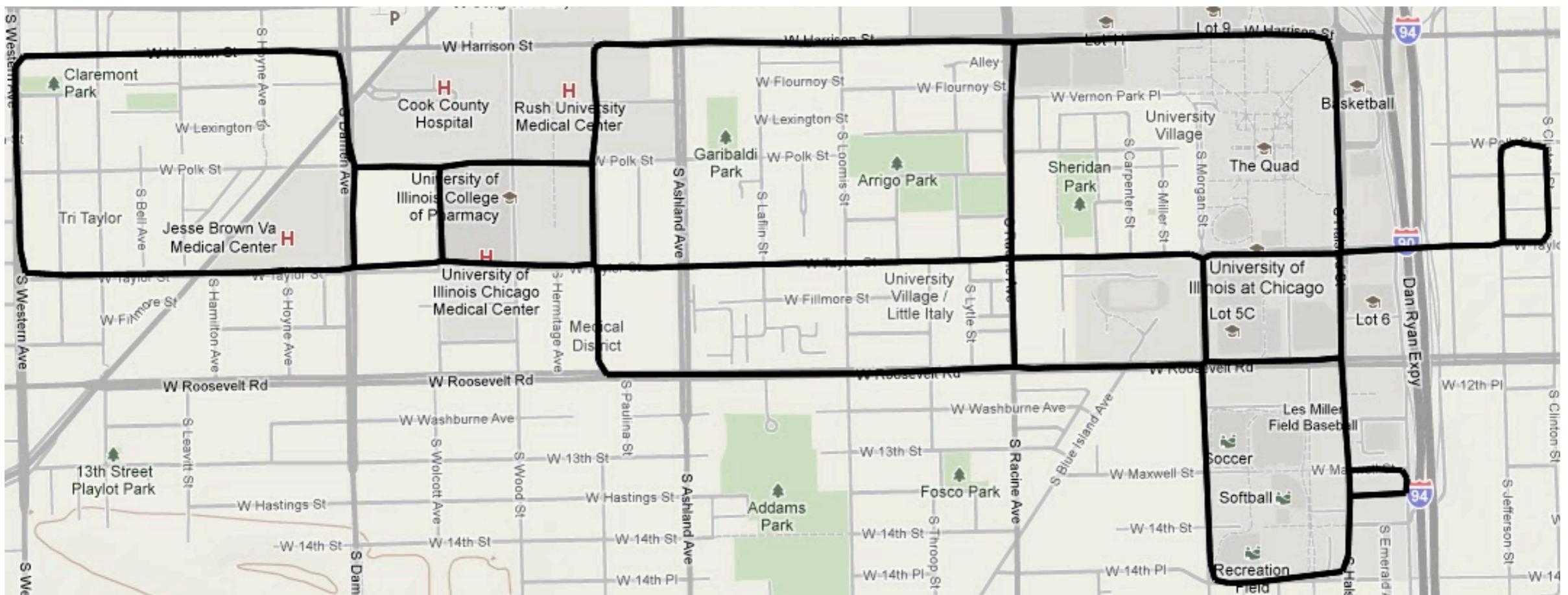
Route extraction



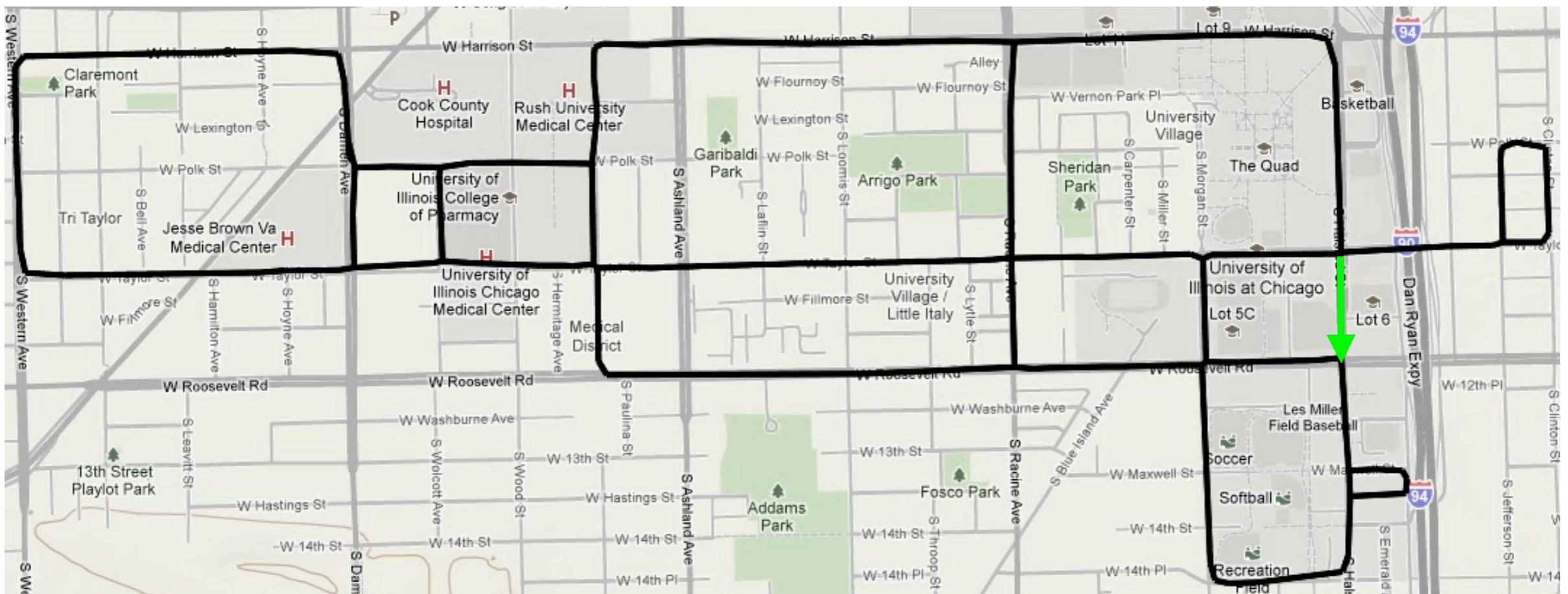
Route extraction



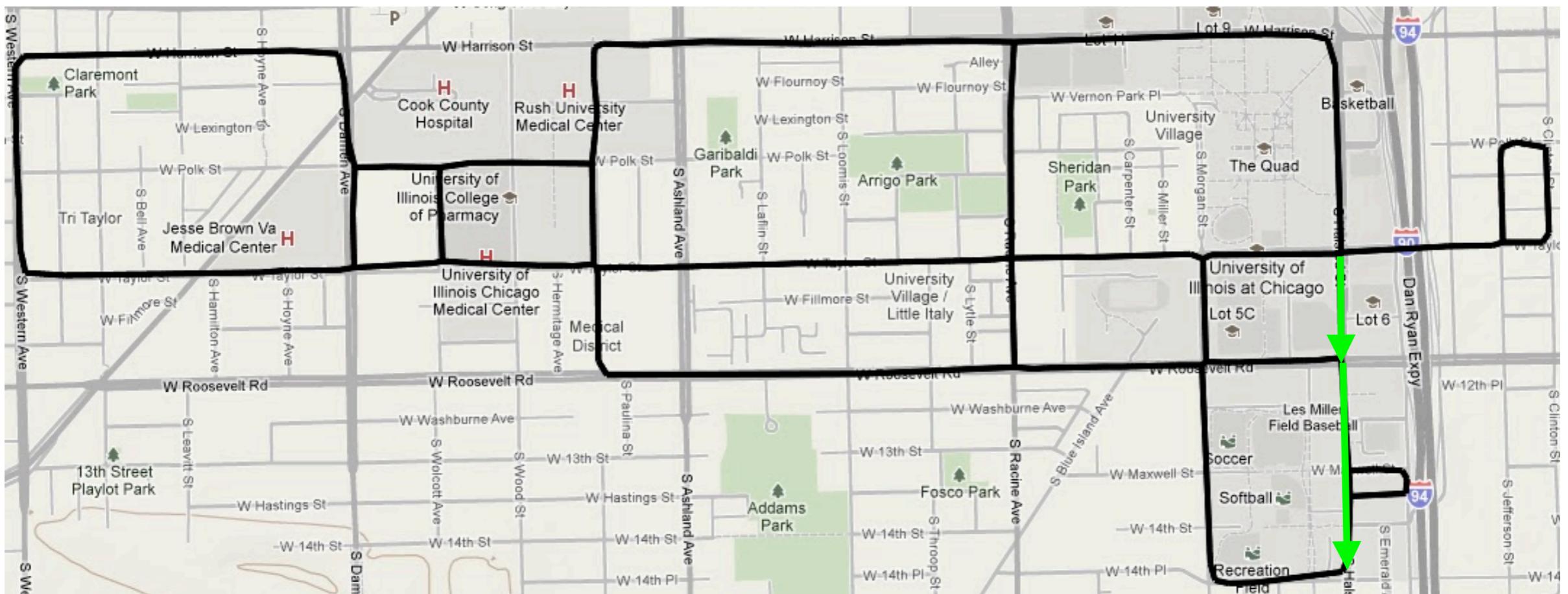
Route extraction



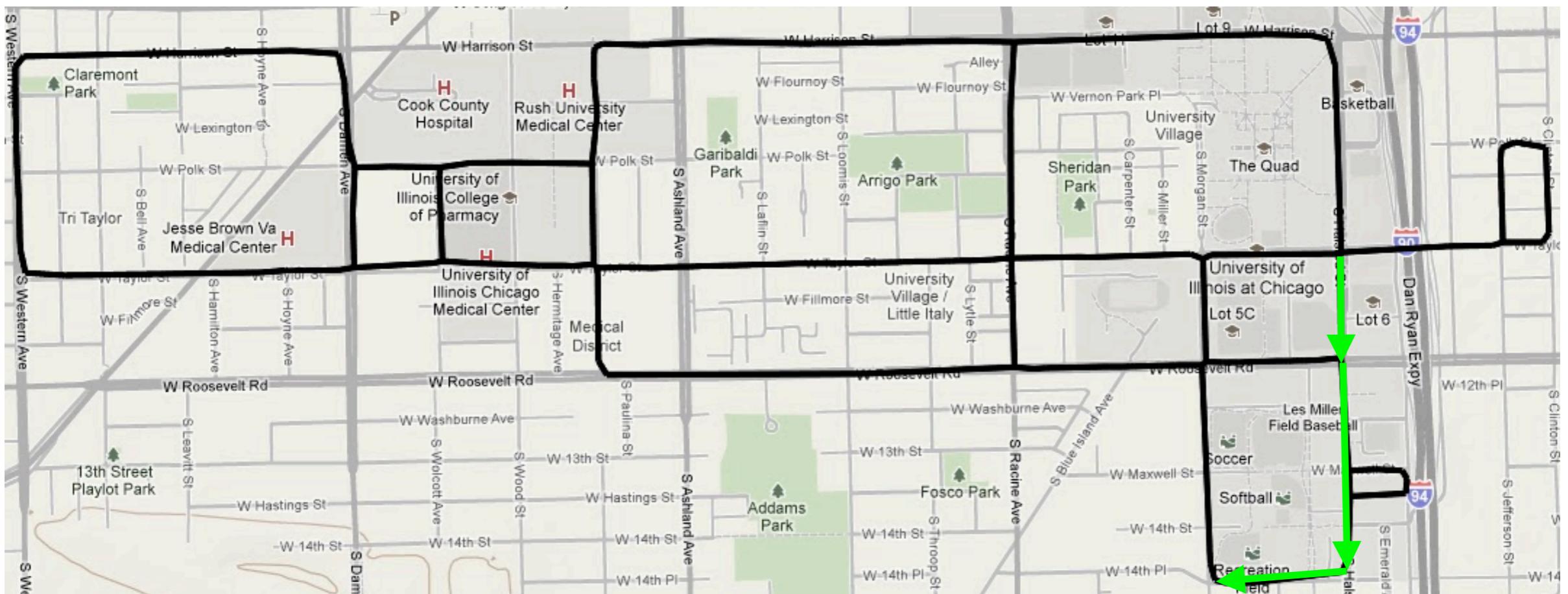
Route extraction



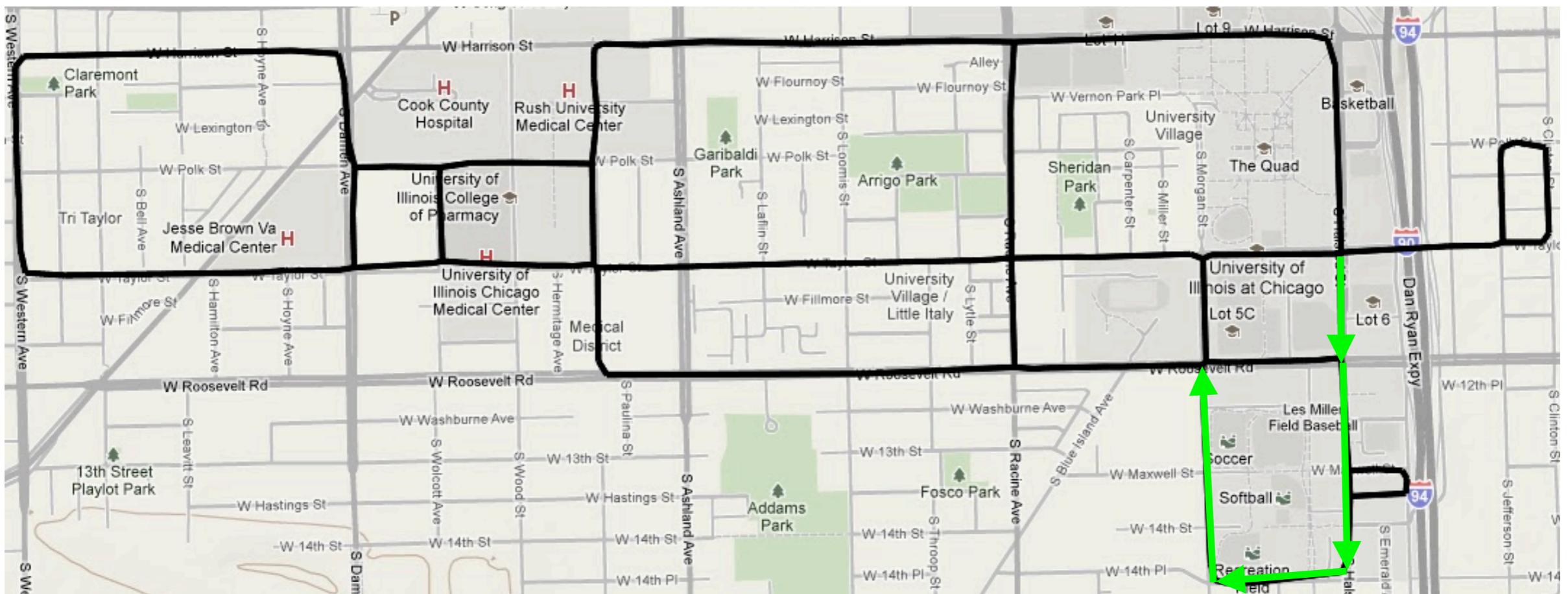
Route extraction



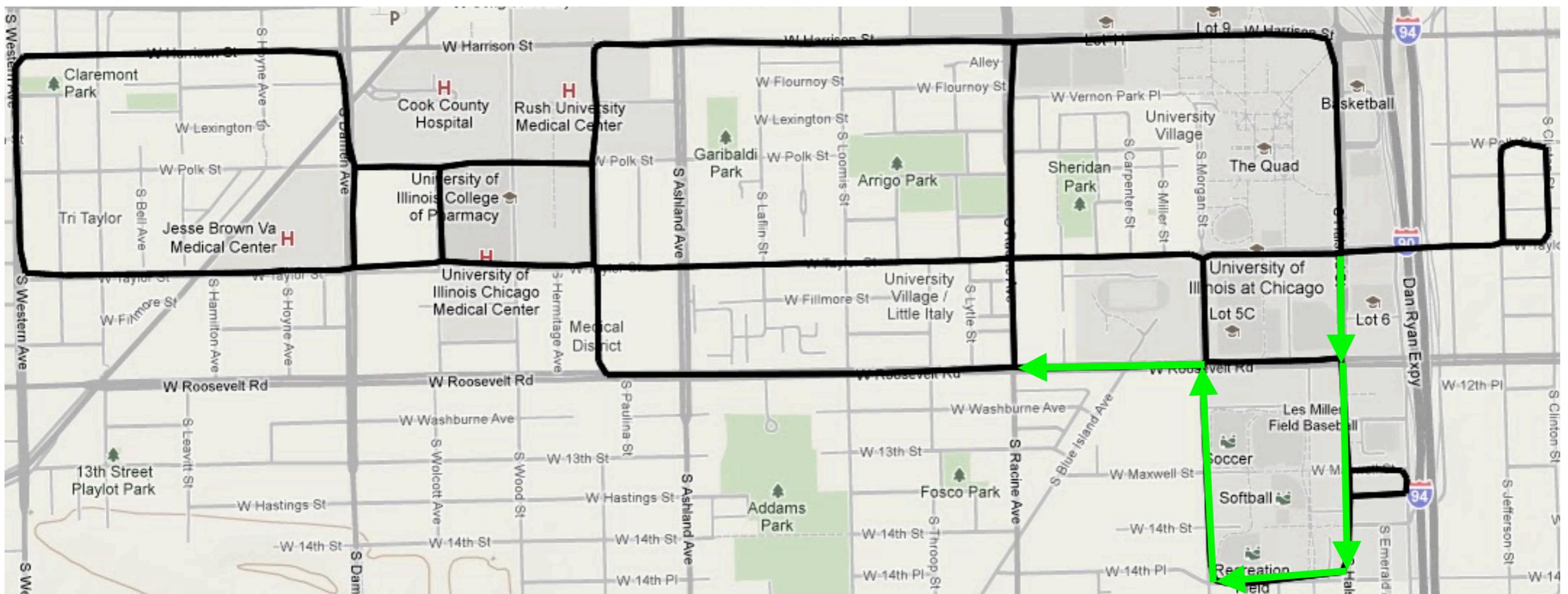
Route extraction



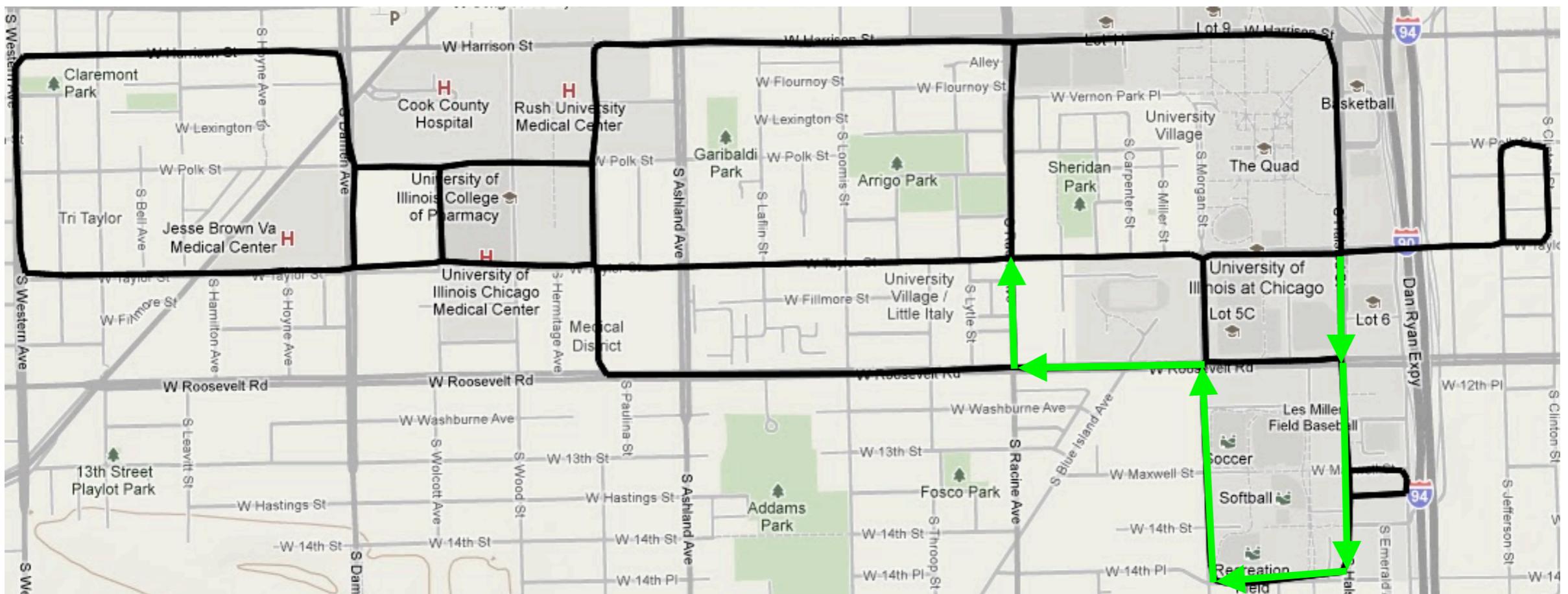
Route extraction



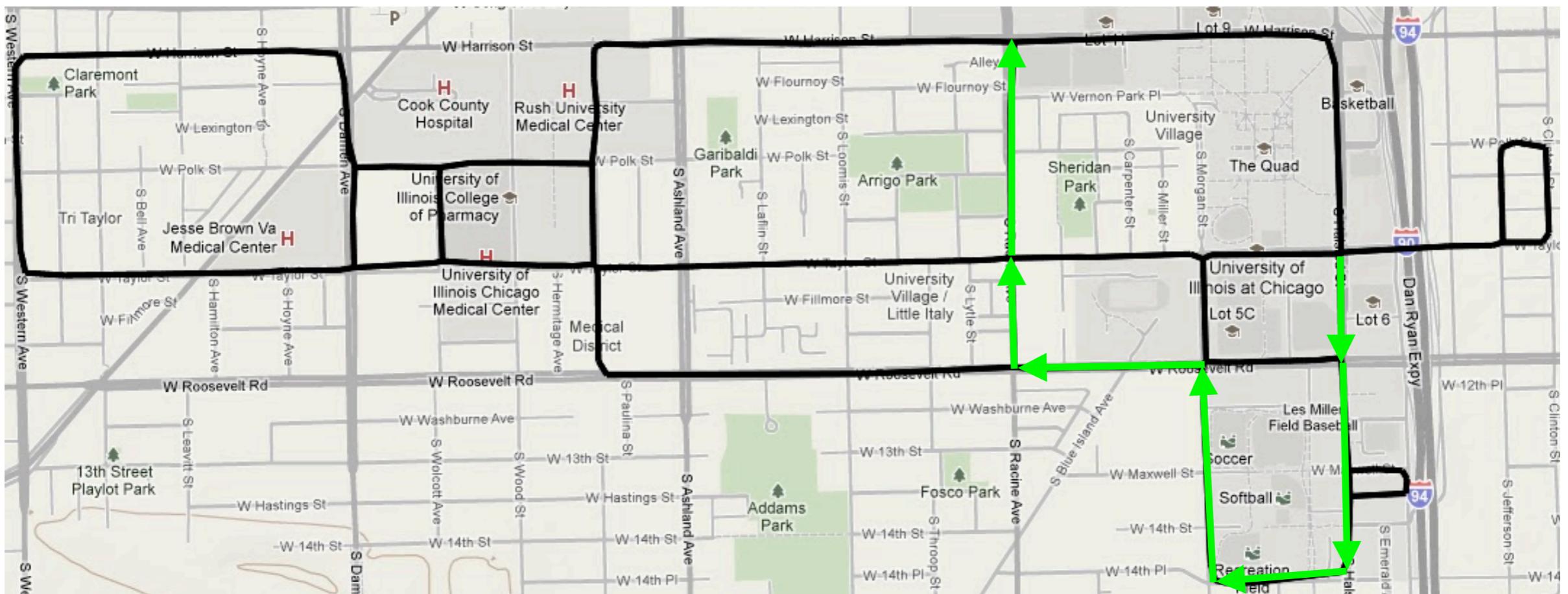
Route extraction



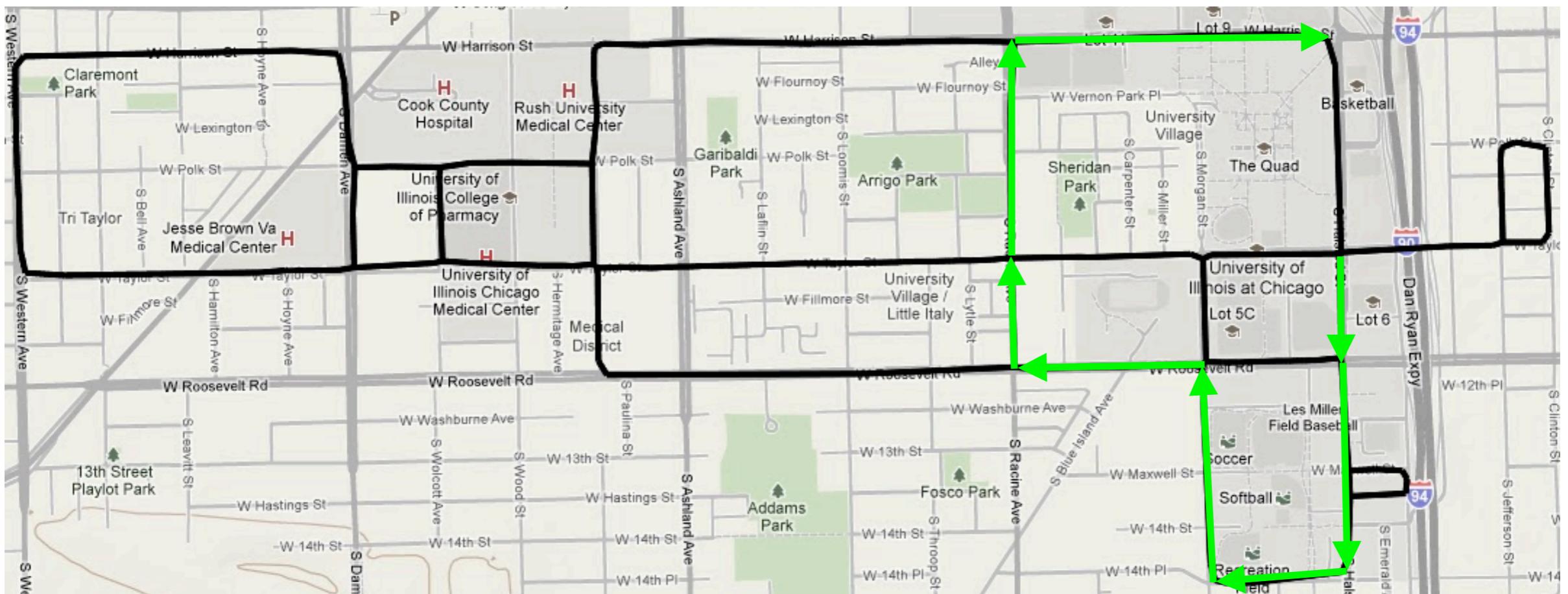
Route extraction



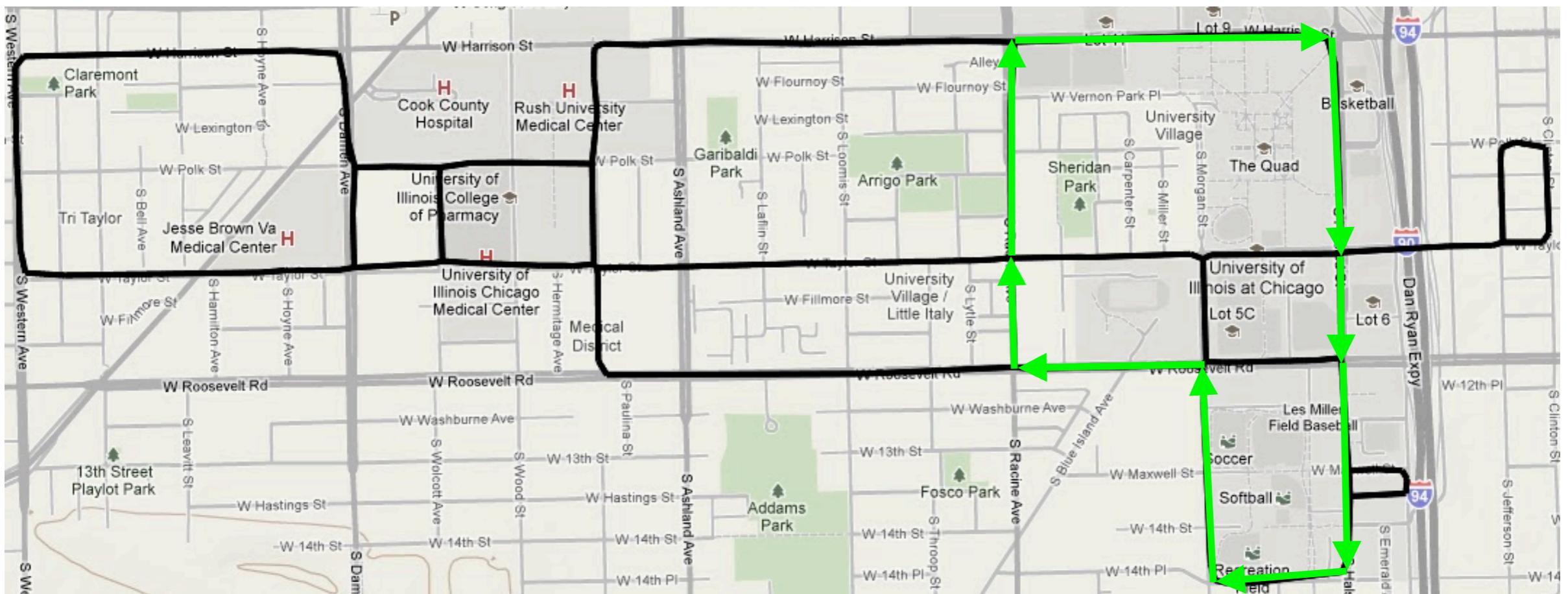
Route extraction



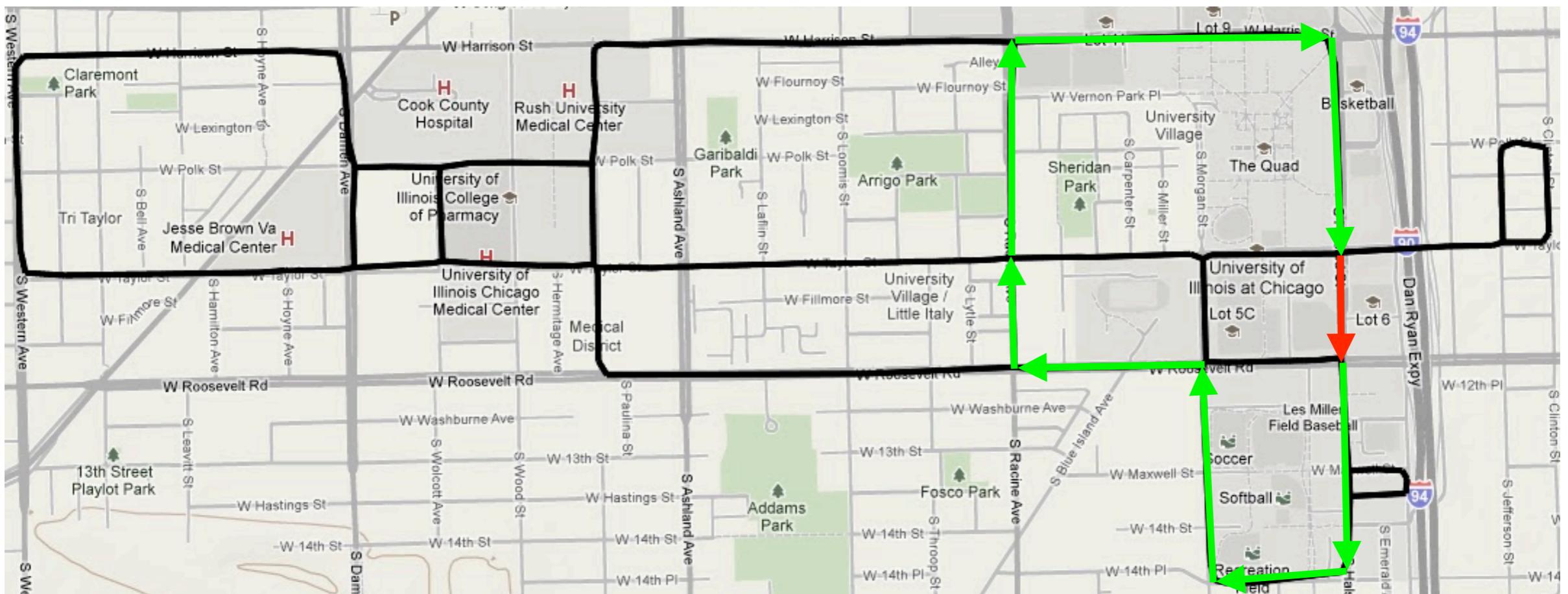
Route extraction



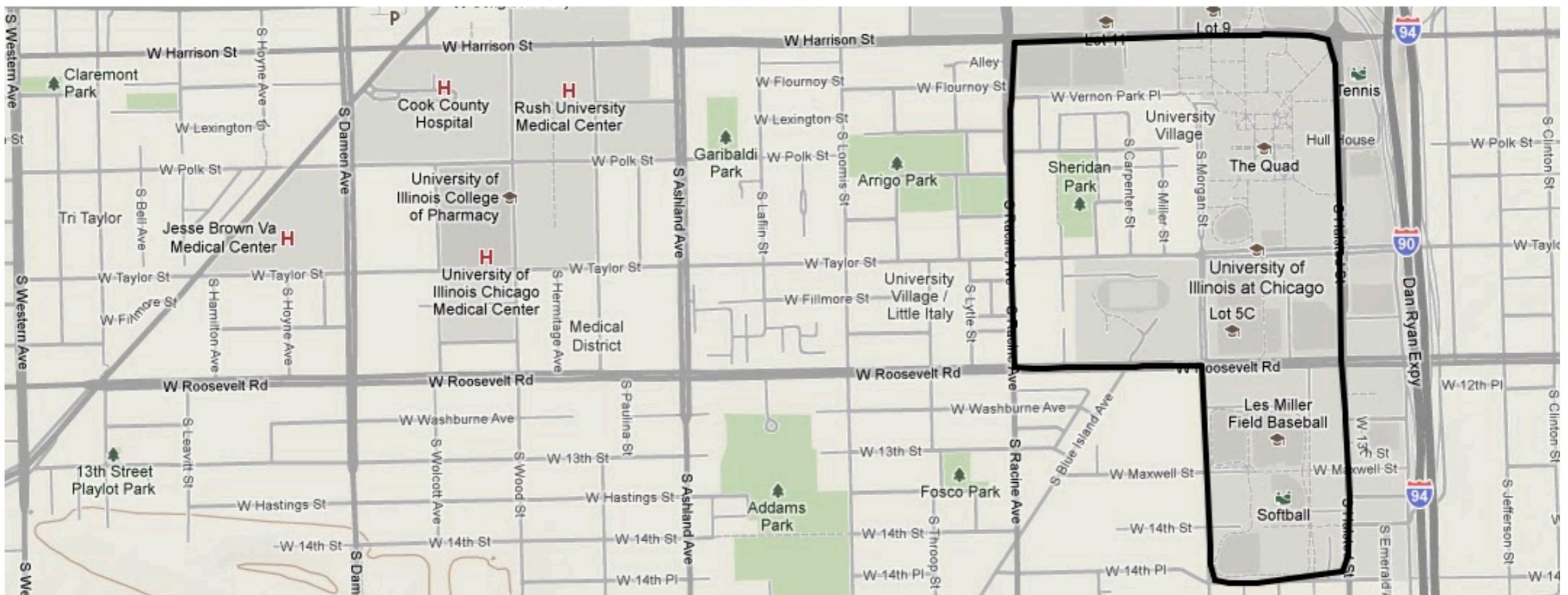
Route extraction



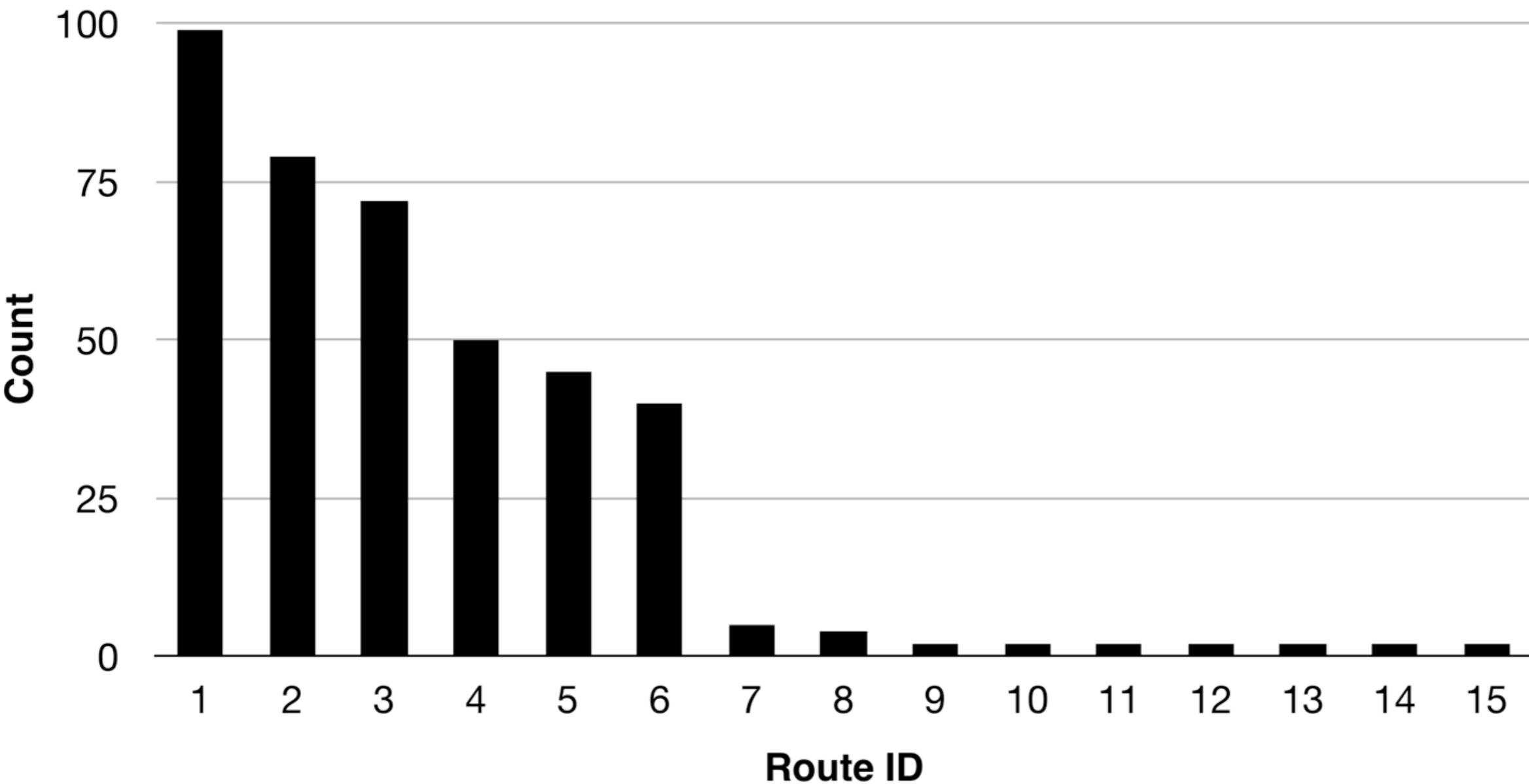
Route extraction



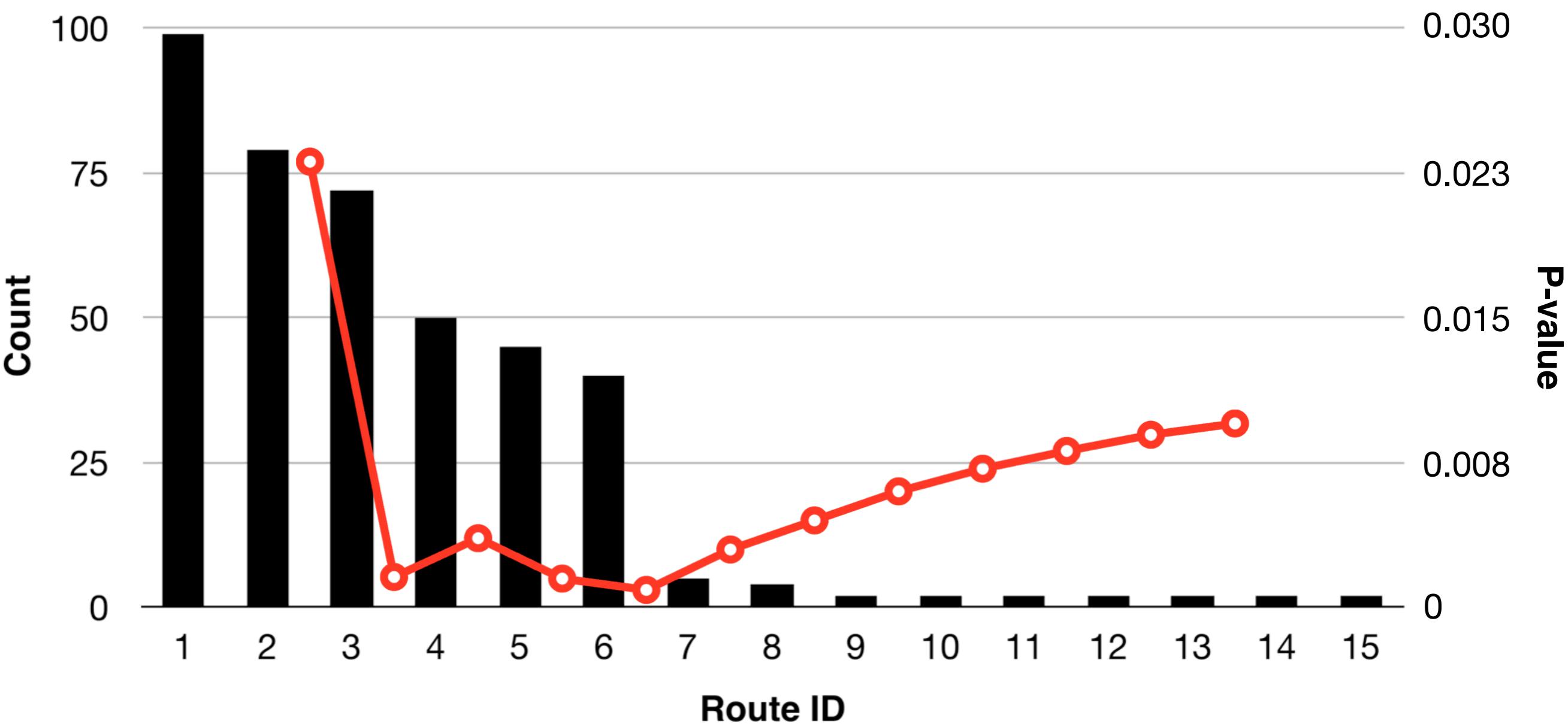
Route extraction



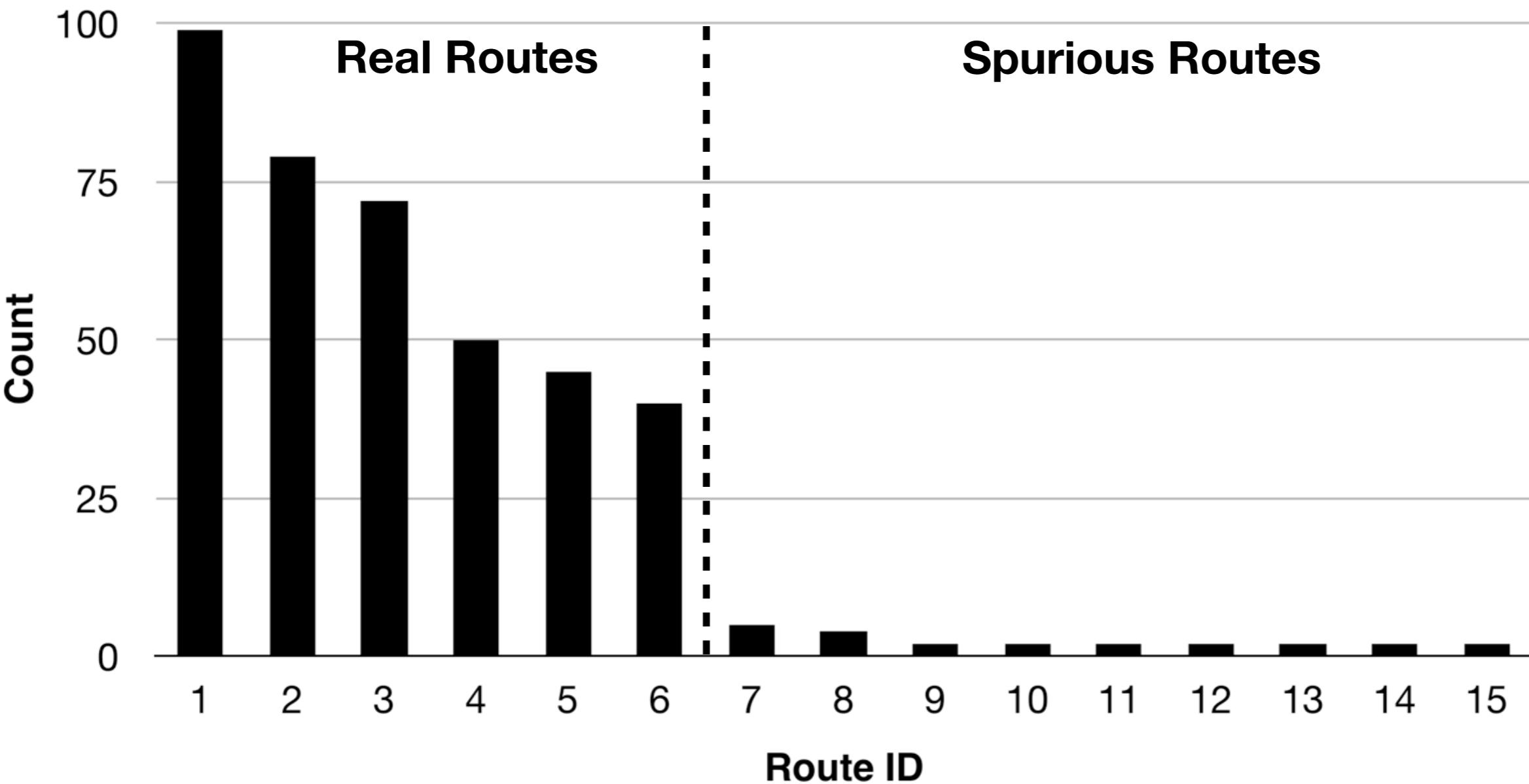
Route extraction results



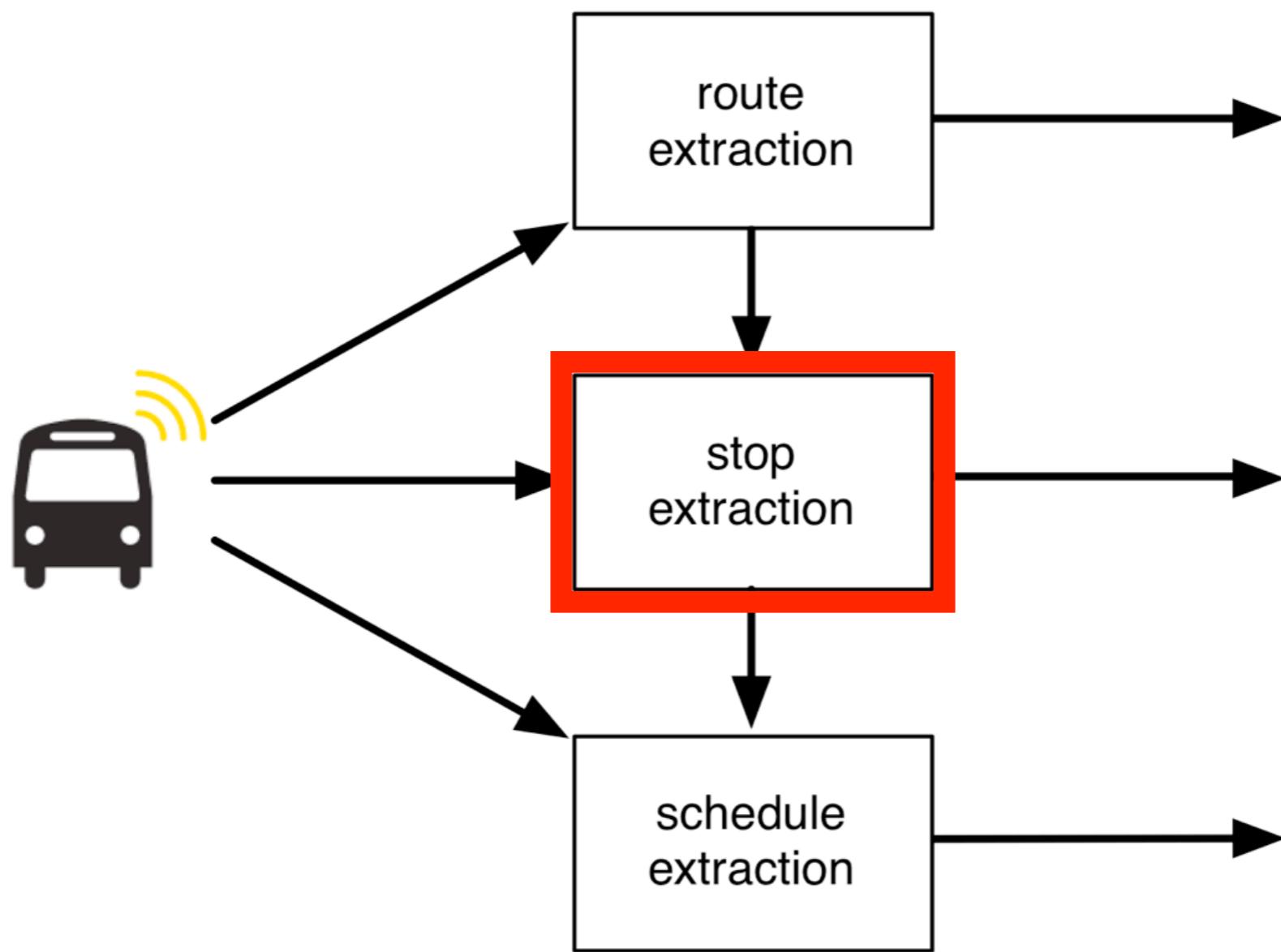
Welch's t -Test



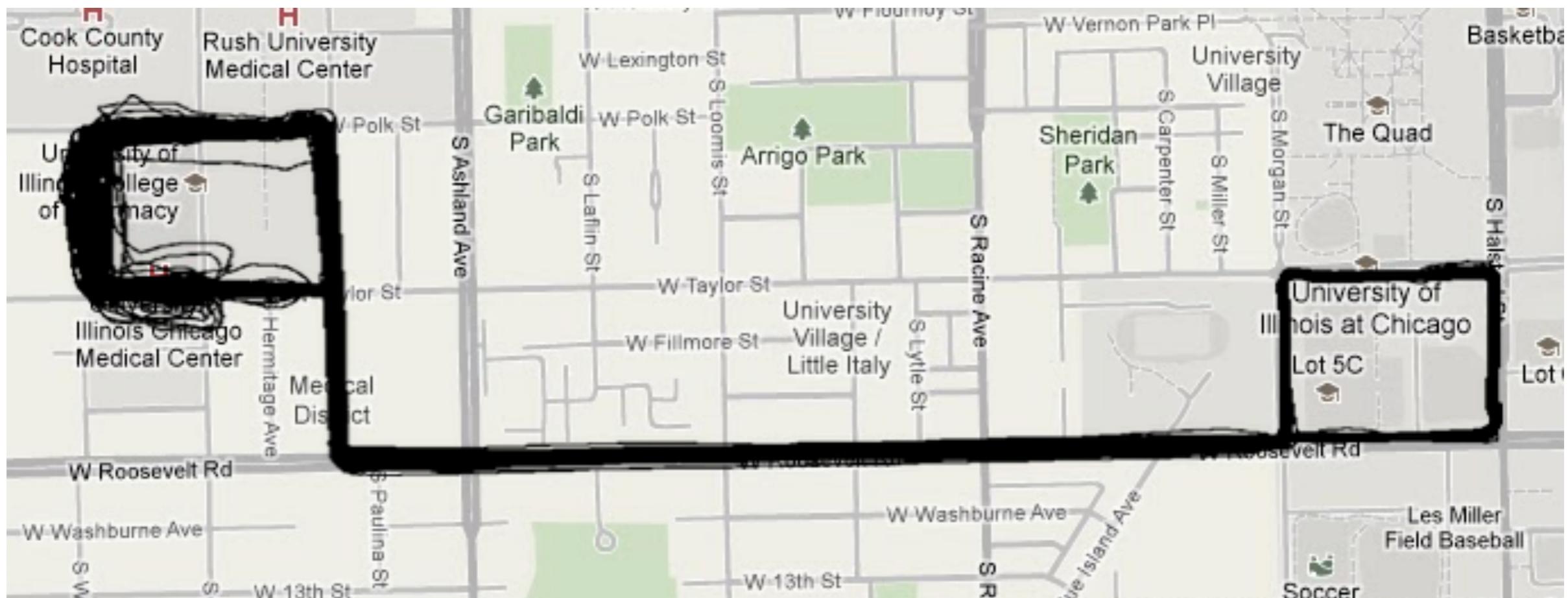
Routes separated



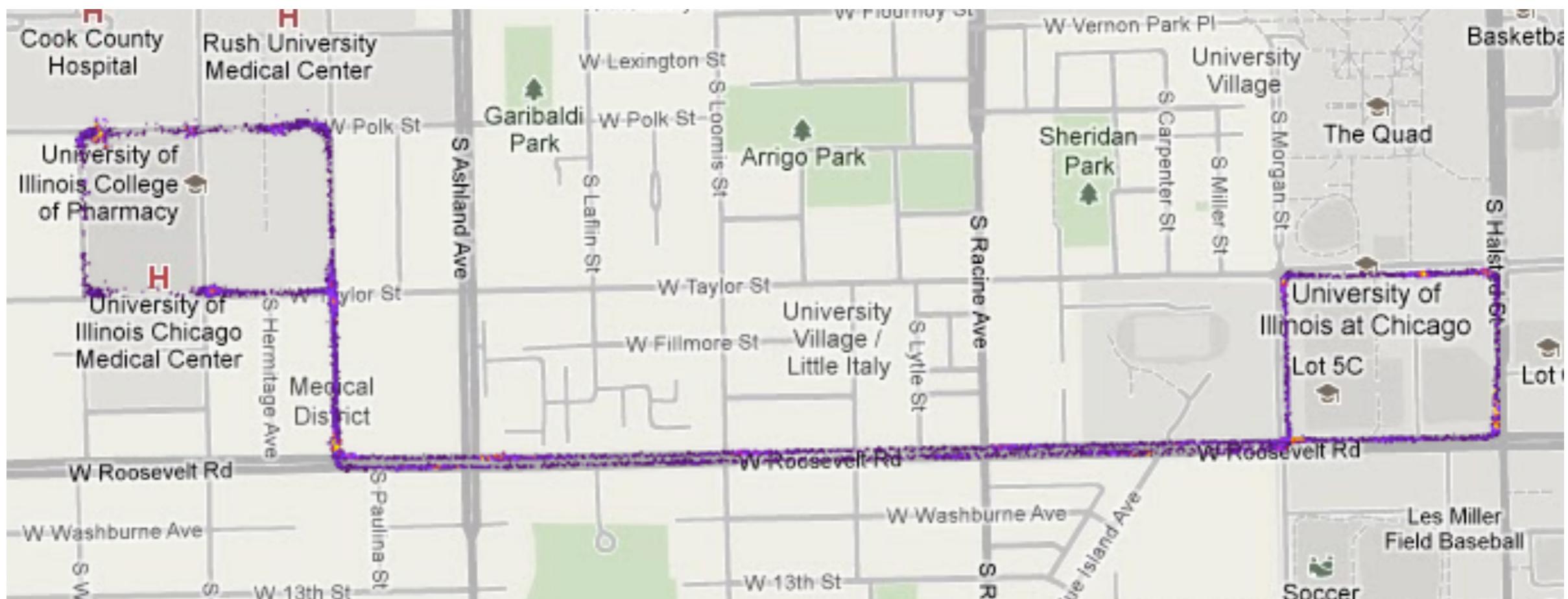
Stop extraction



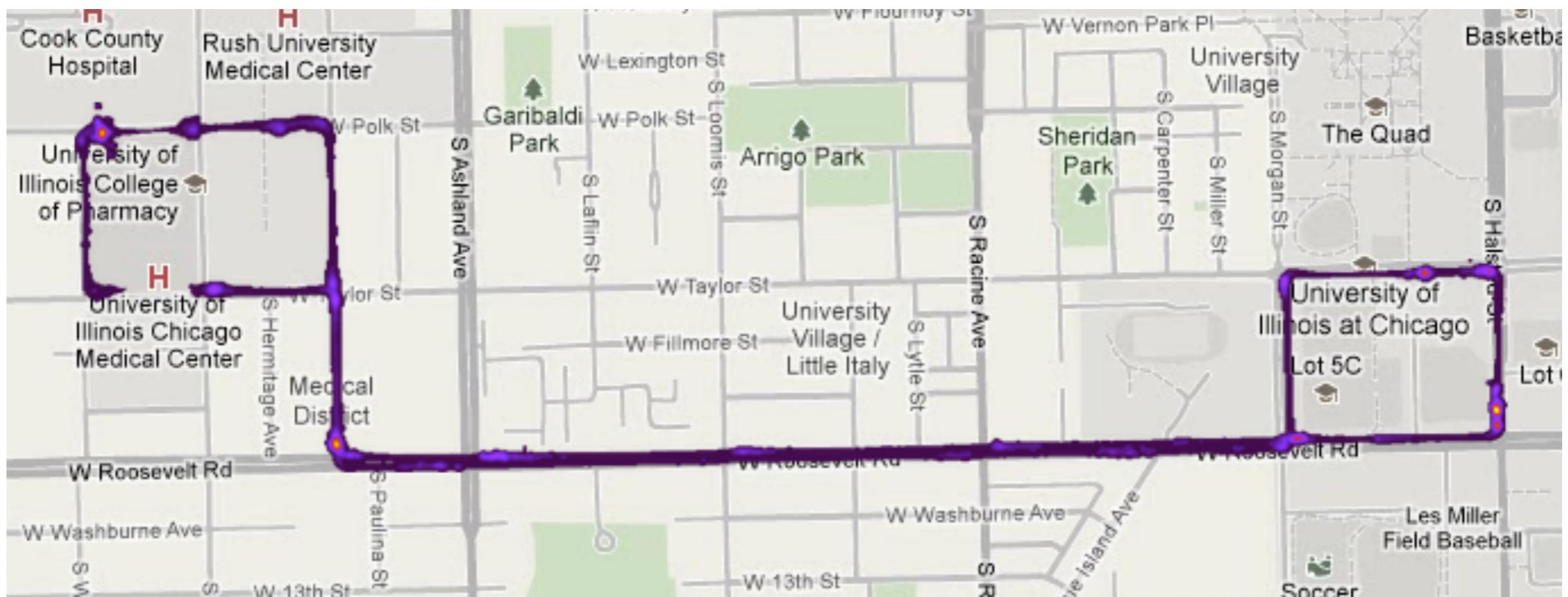
Route-labeled GPS traces



2-D histogram



Point density estimate



Thresholded binary image



Noise in binary image



Noise reduced binary image



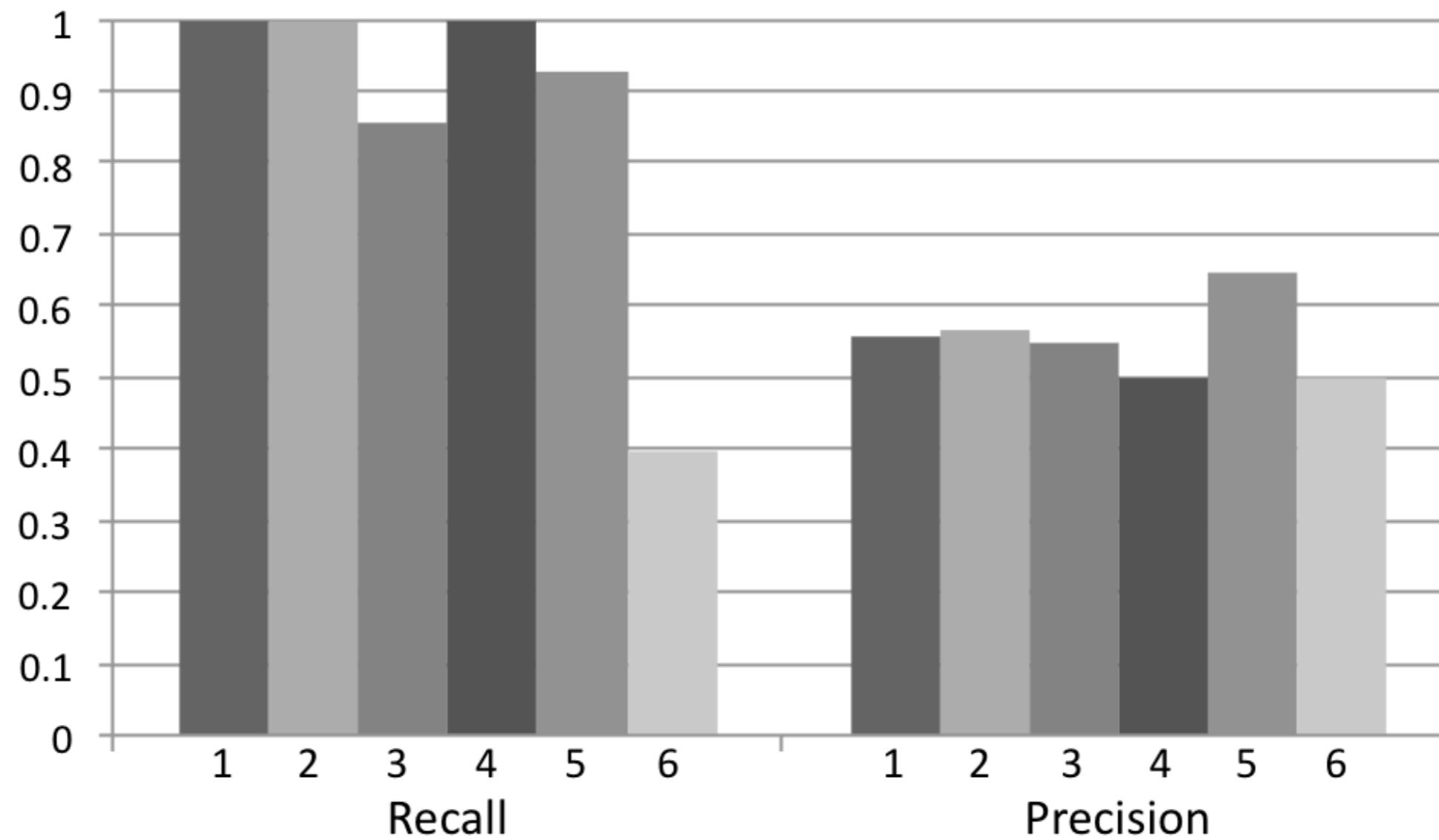
Stop extraction



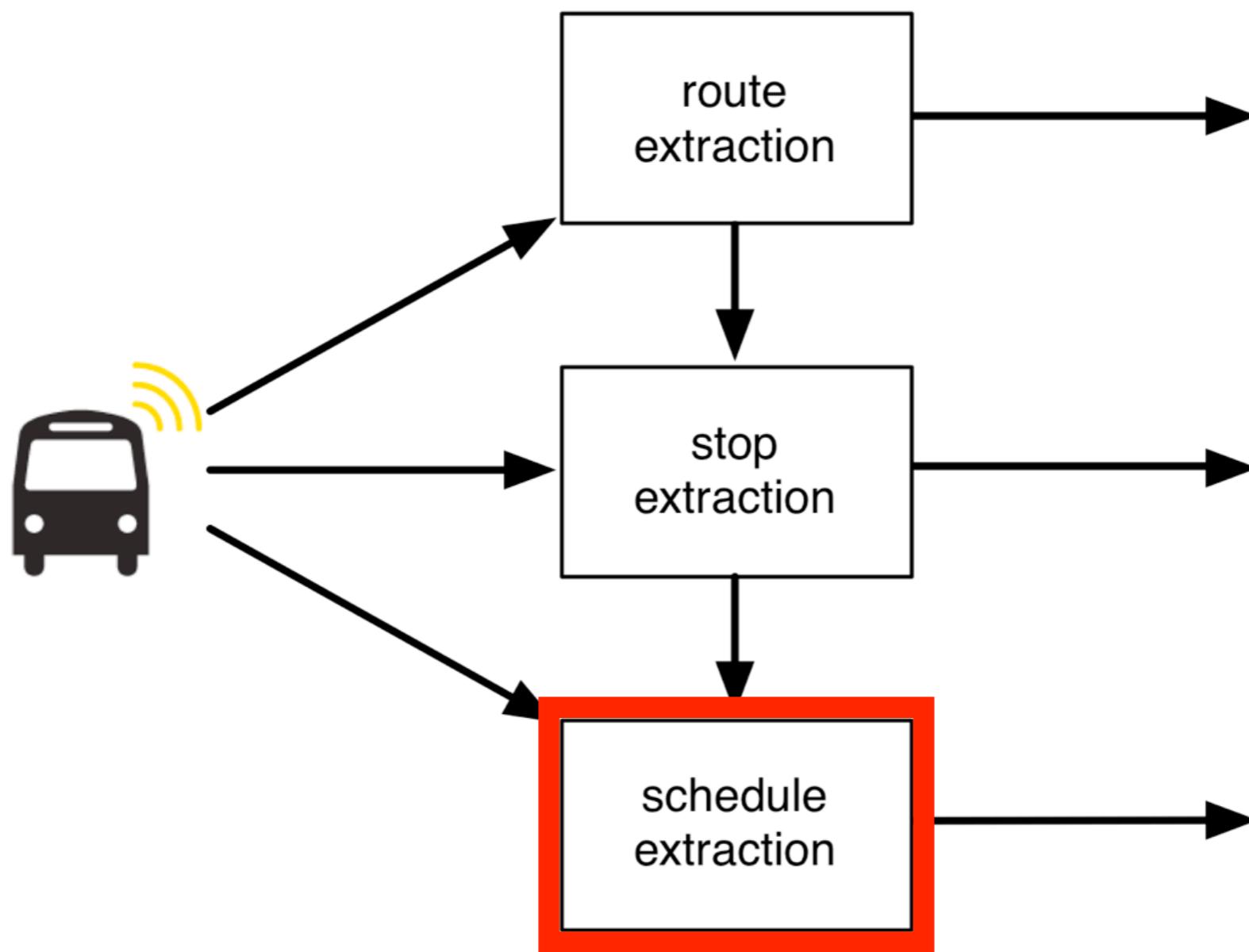
Stop extraction



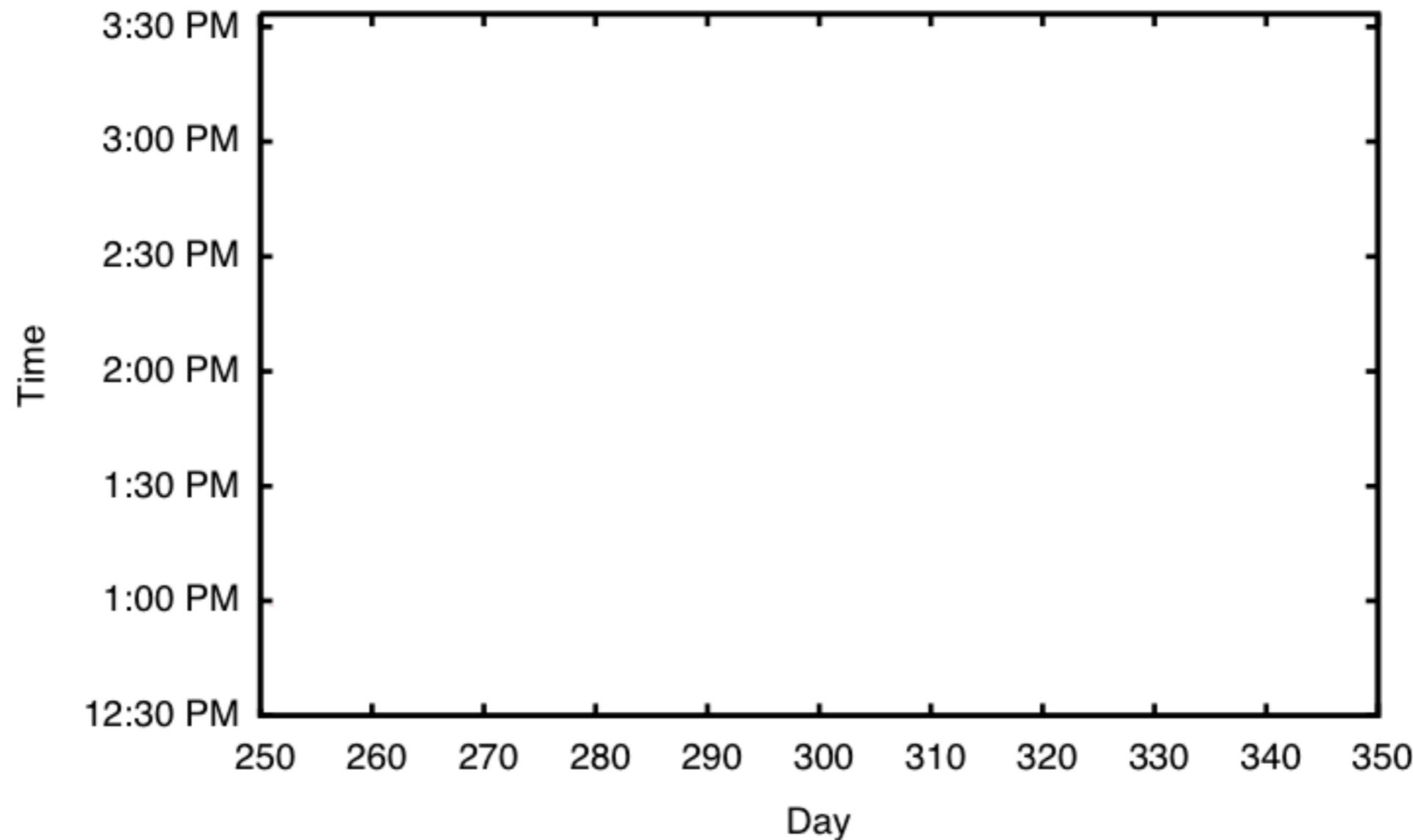
Stop extraction performance



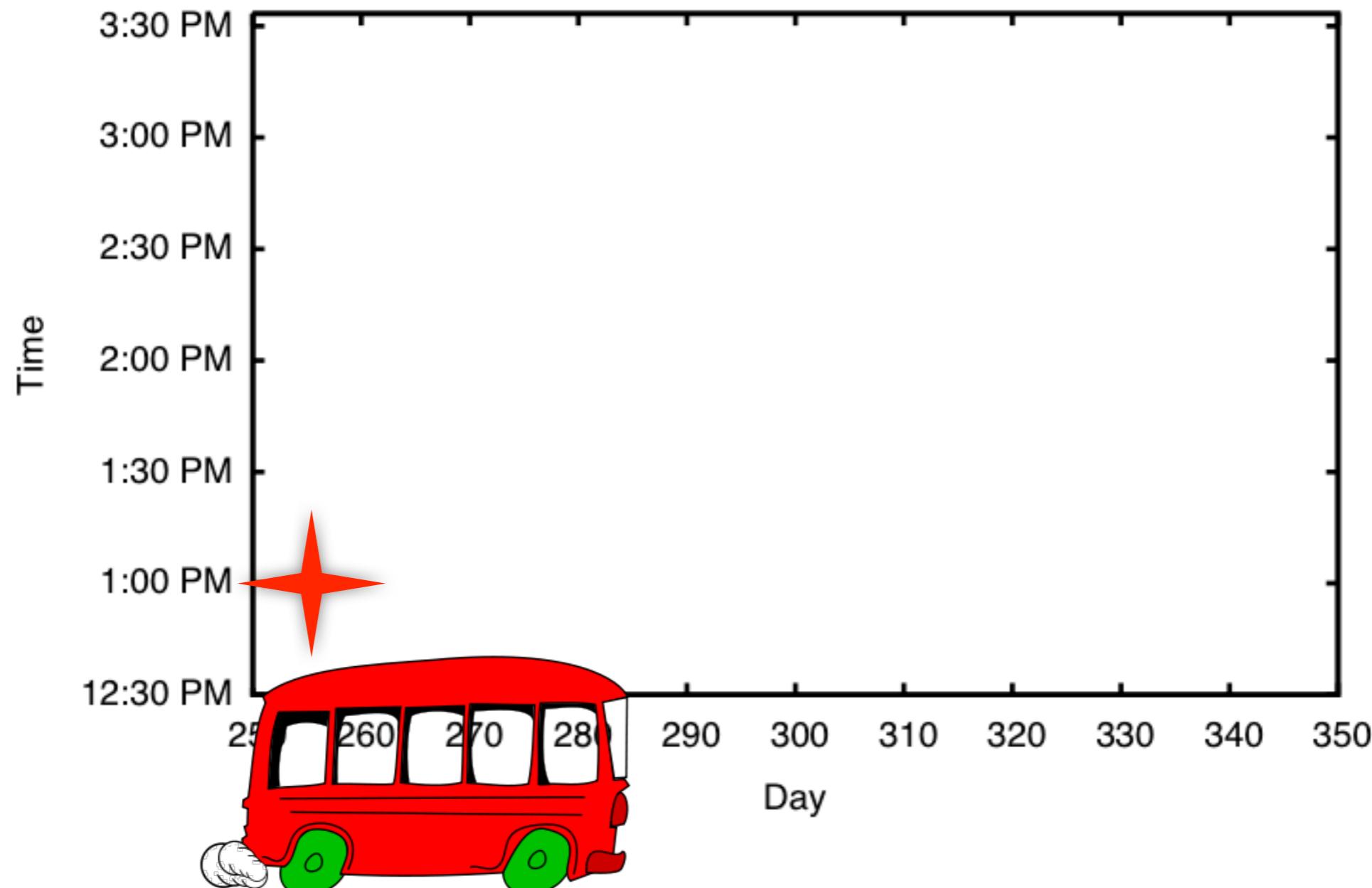
Schedule extraction



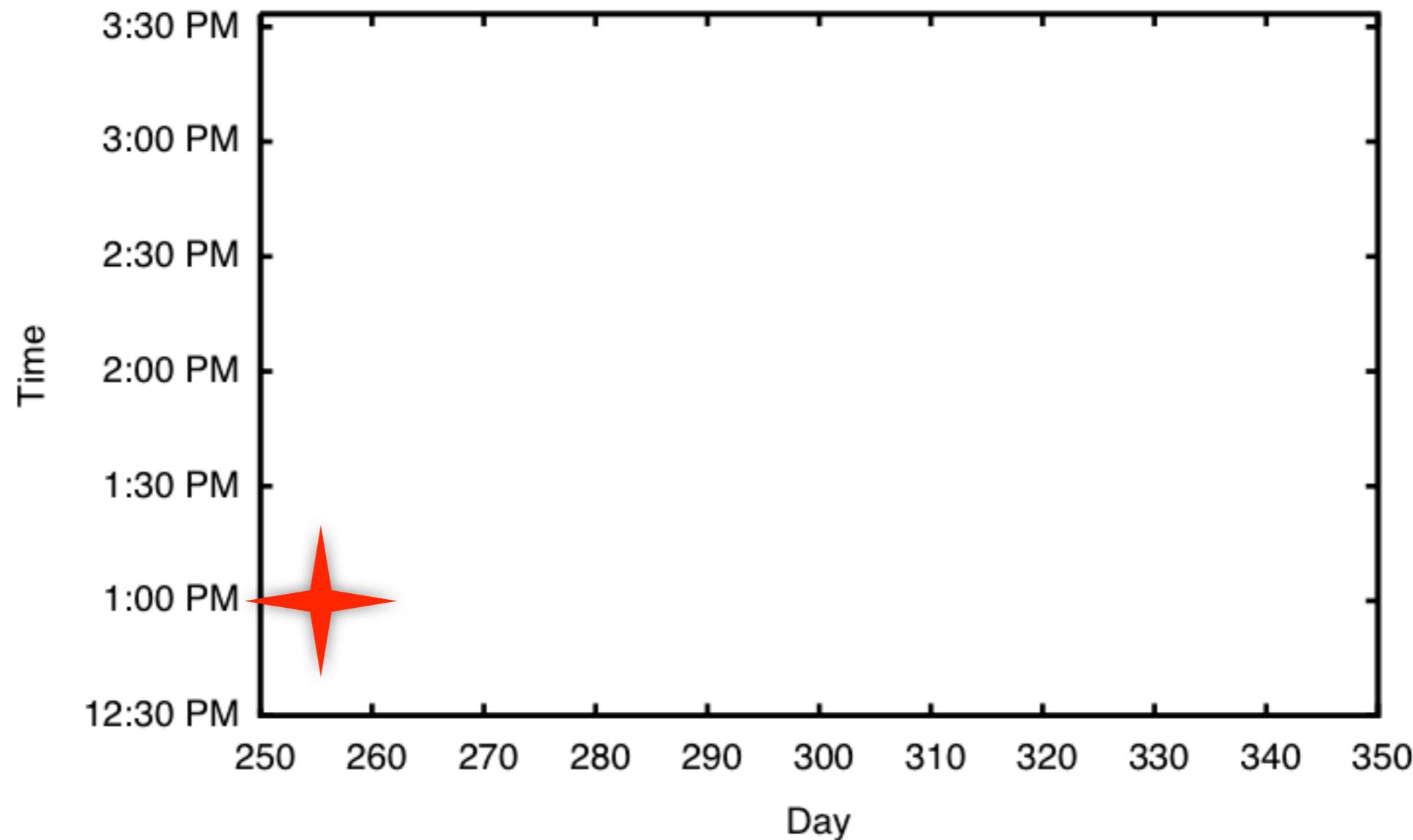
Bus stop arrival times



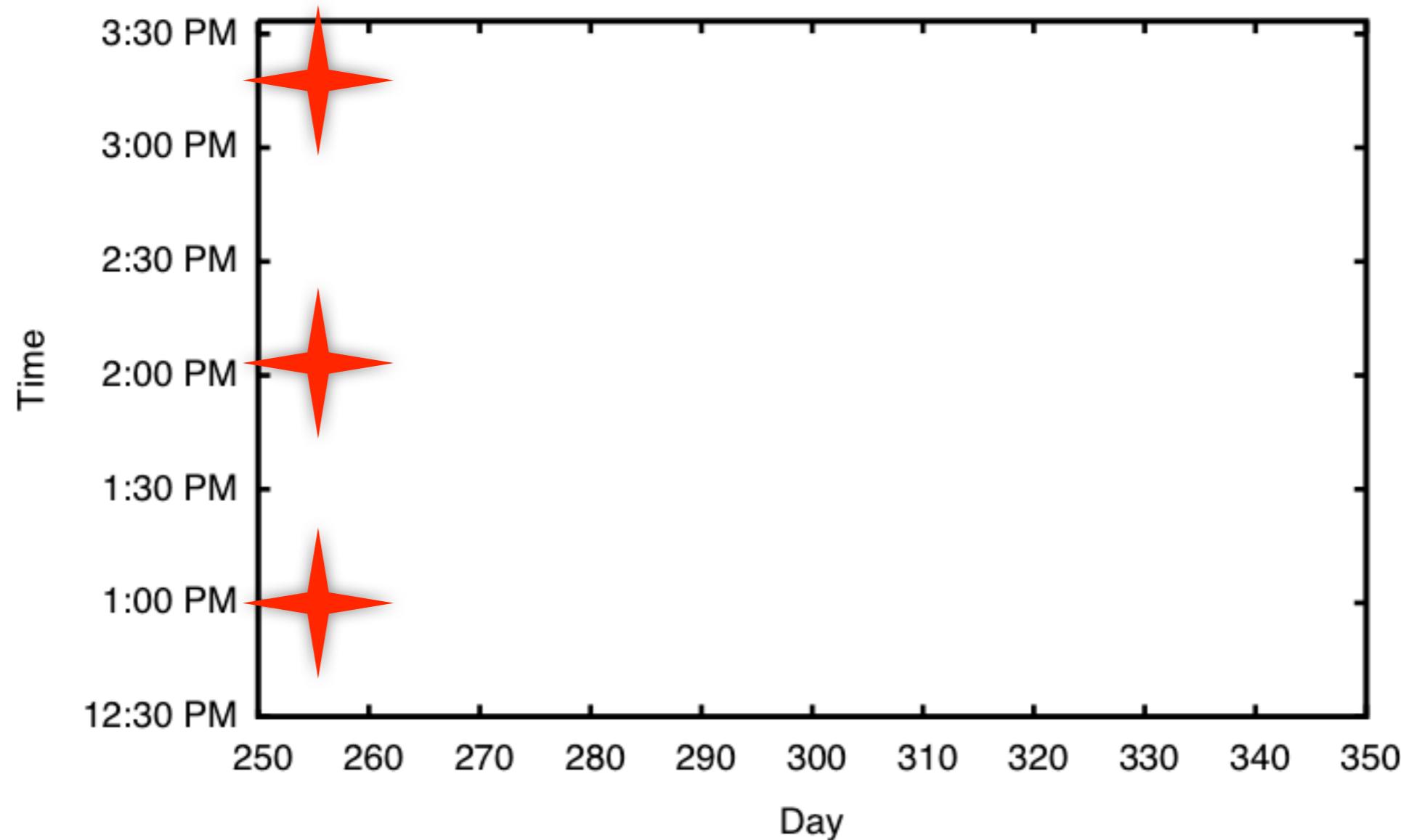
Bus stop arrival times



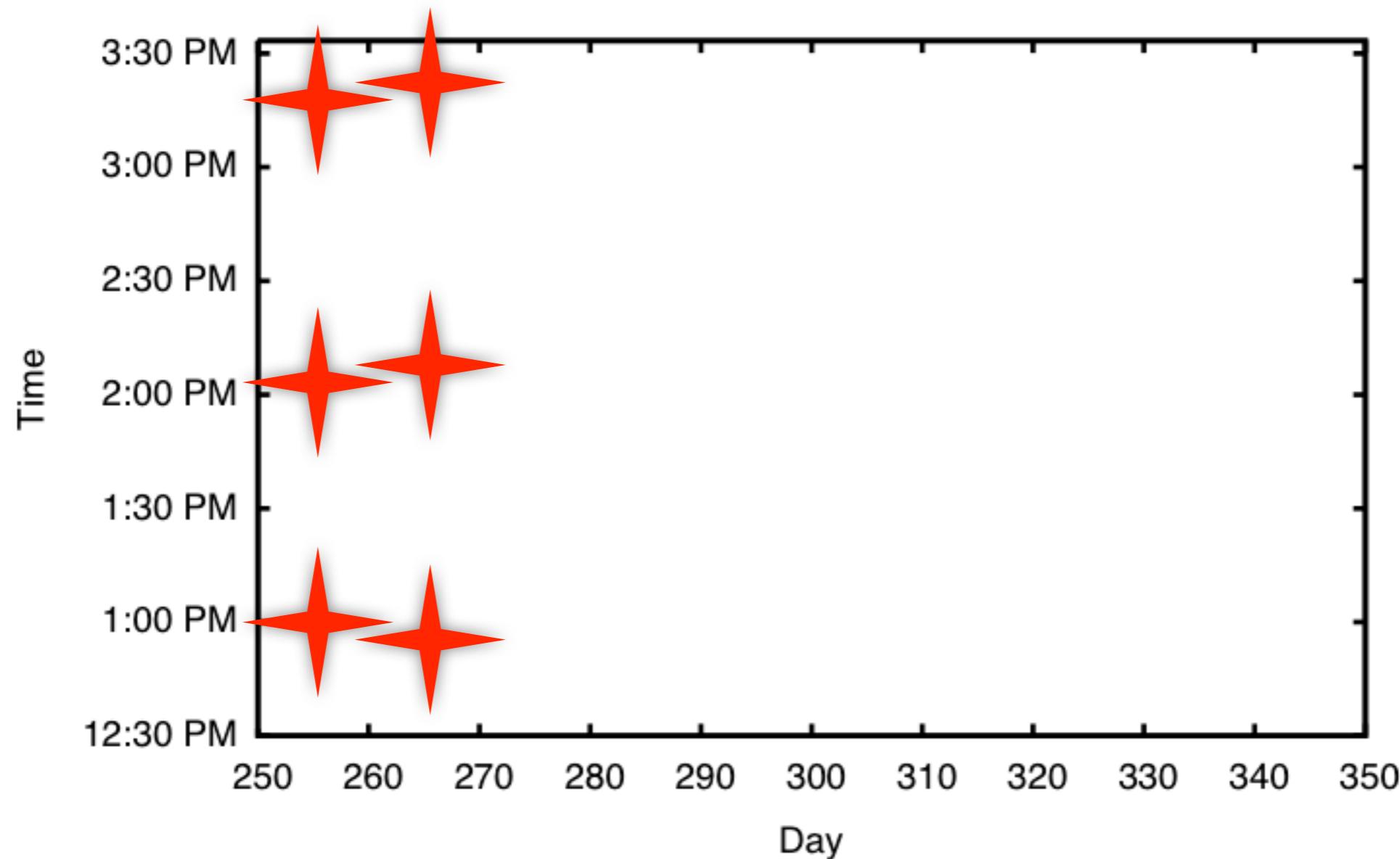
Bus stop arrival times



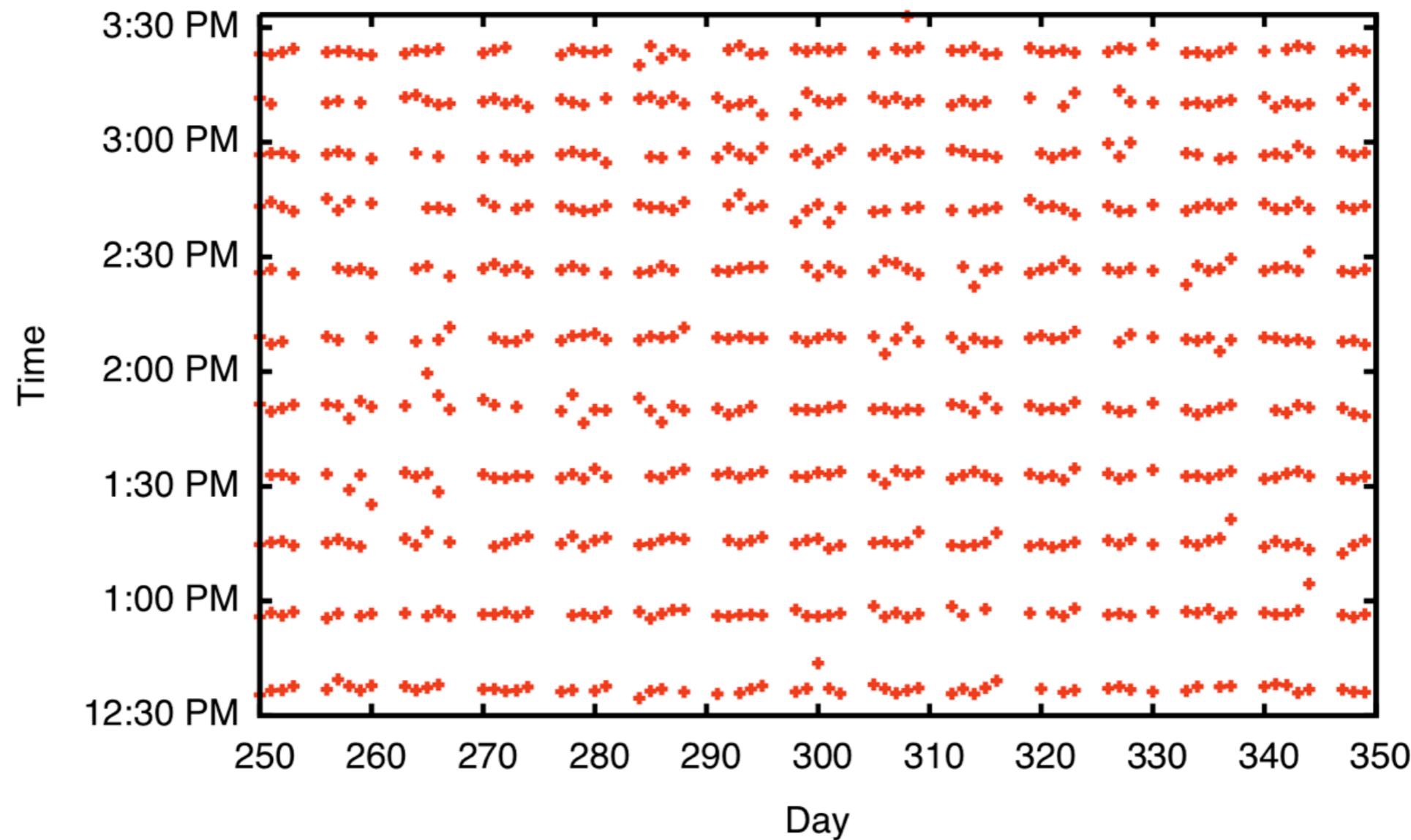
Bus stop arrival times



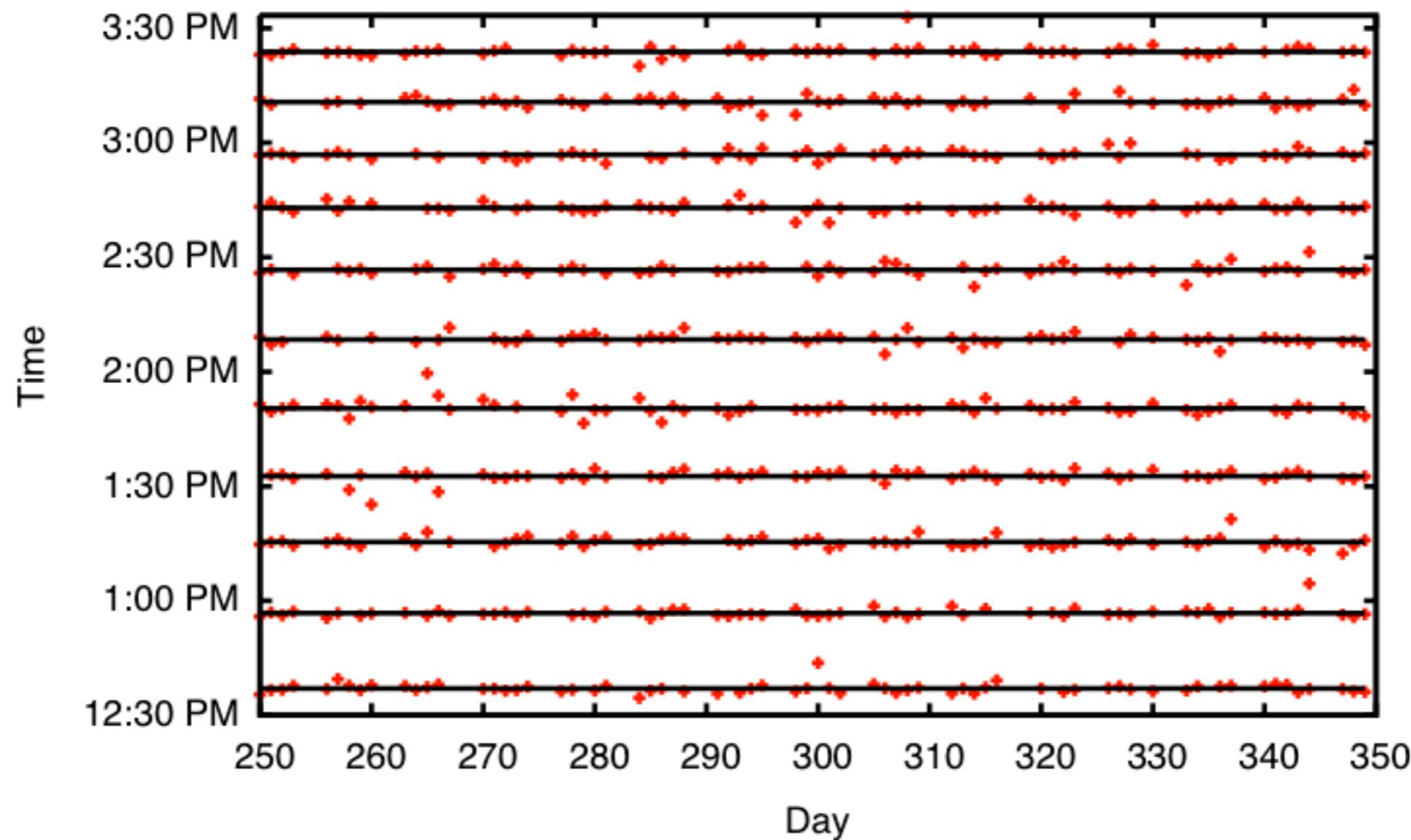
Bus stop arrival times



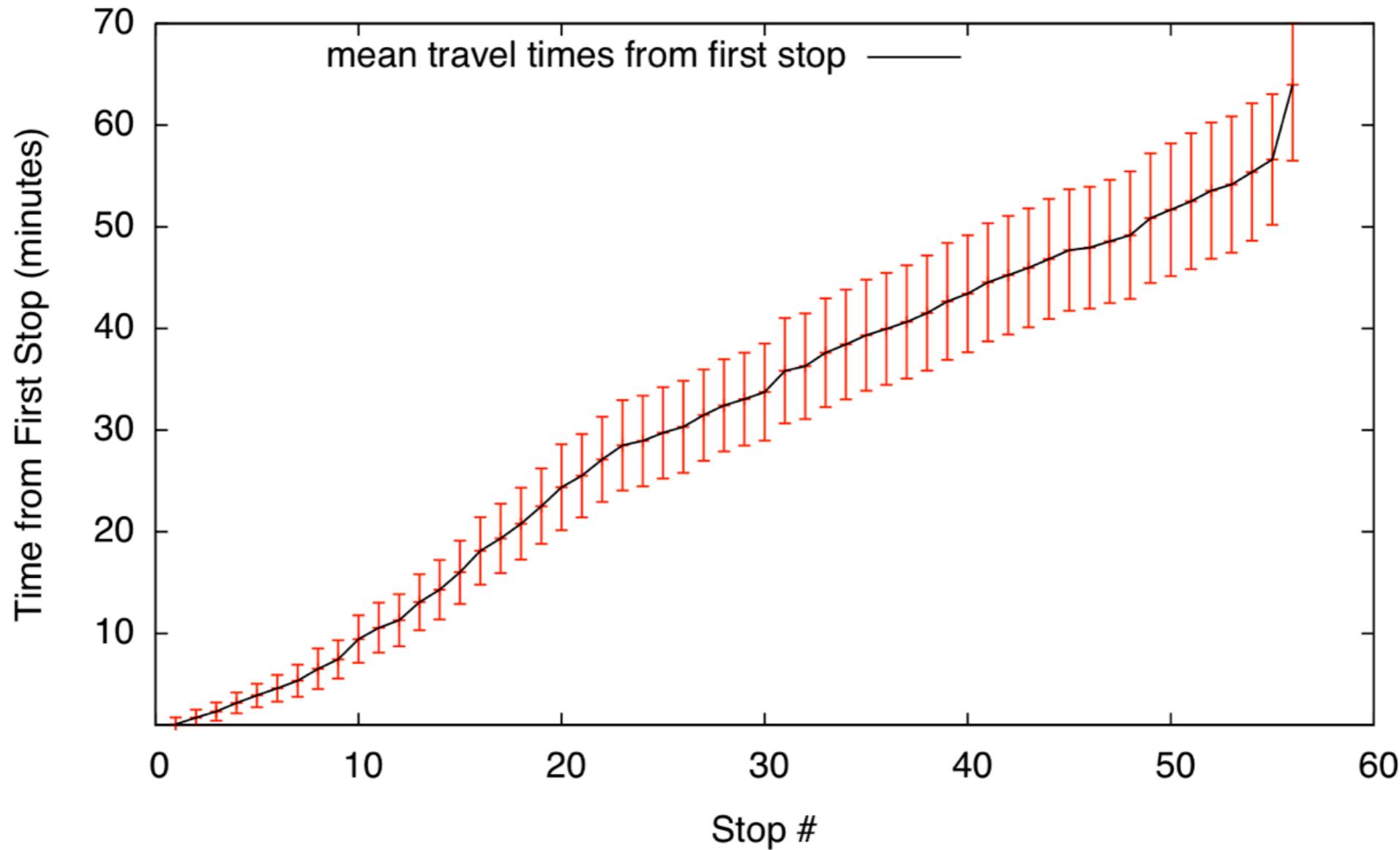
Bus stop arrival times



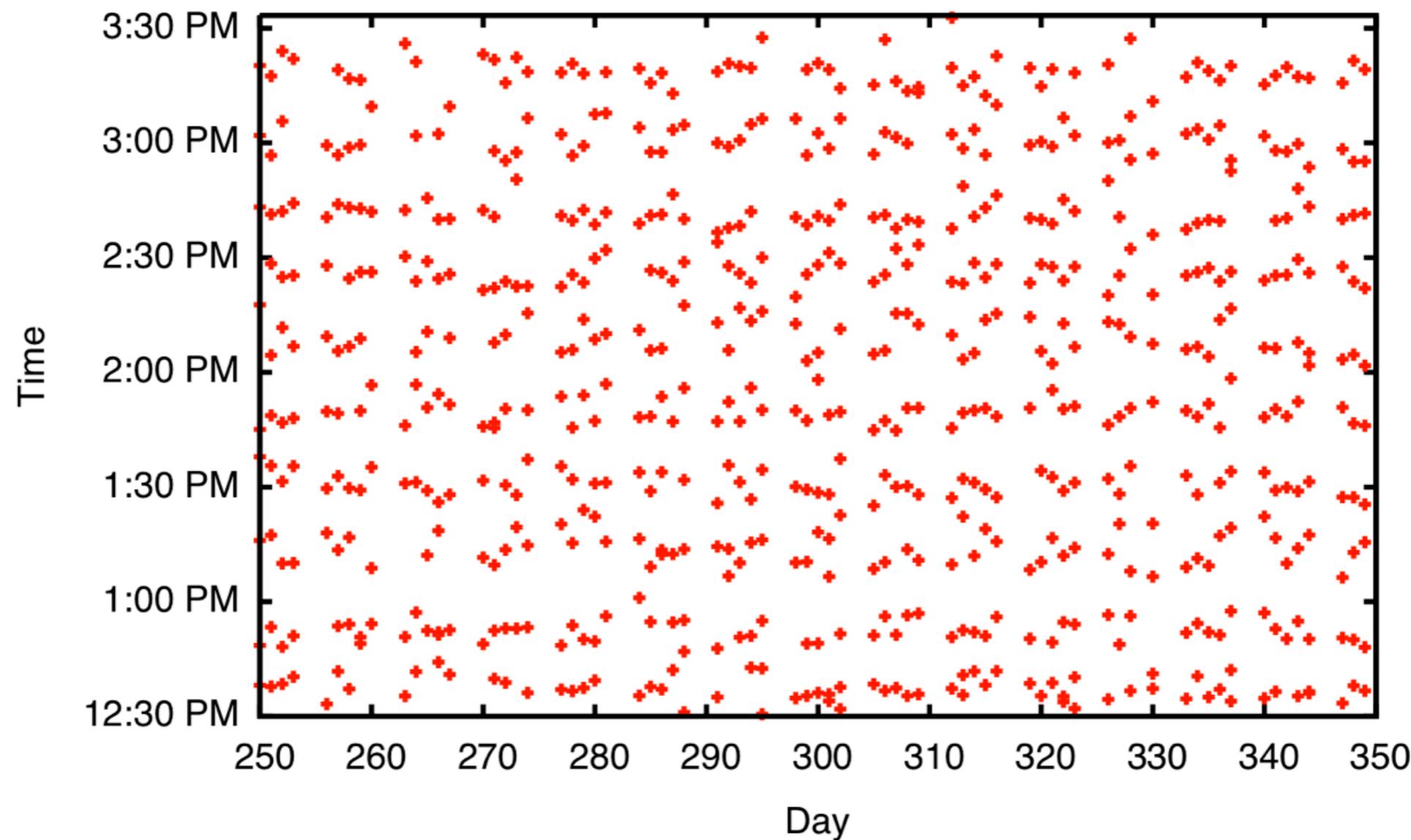
First stop schedule



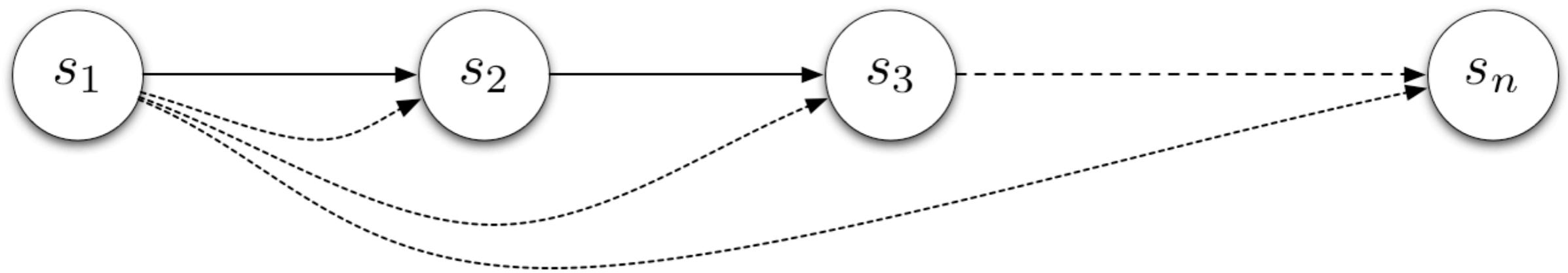
Travel time variance



Last stop arrival times

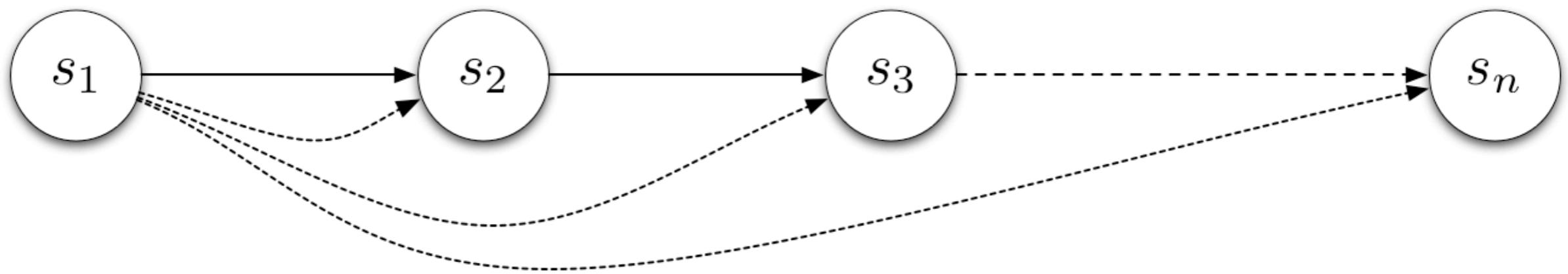


Compute mean travel times



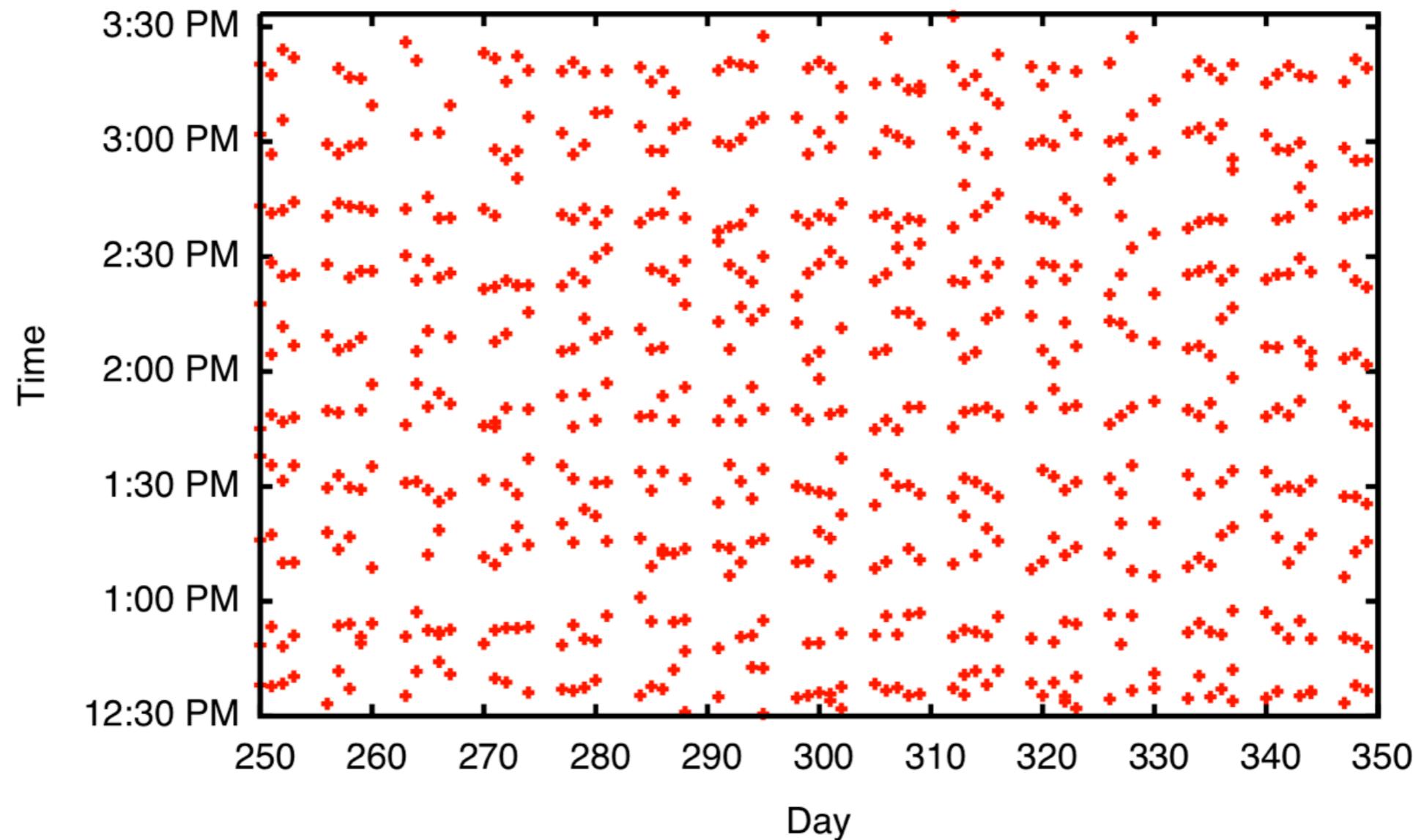
$$\text{travel_time}(1, j, t) = \frac{1}{|D|} \sum_D a_j^t - a_1^t$$

Compute downstream schedules

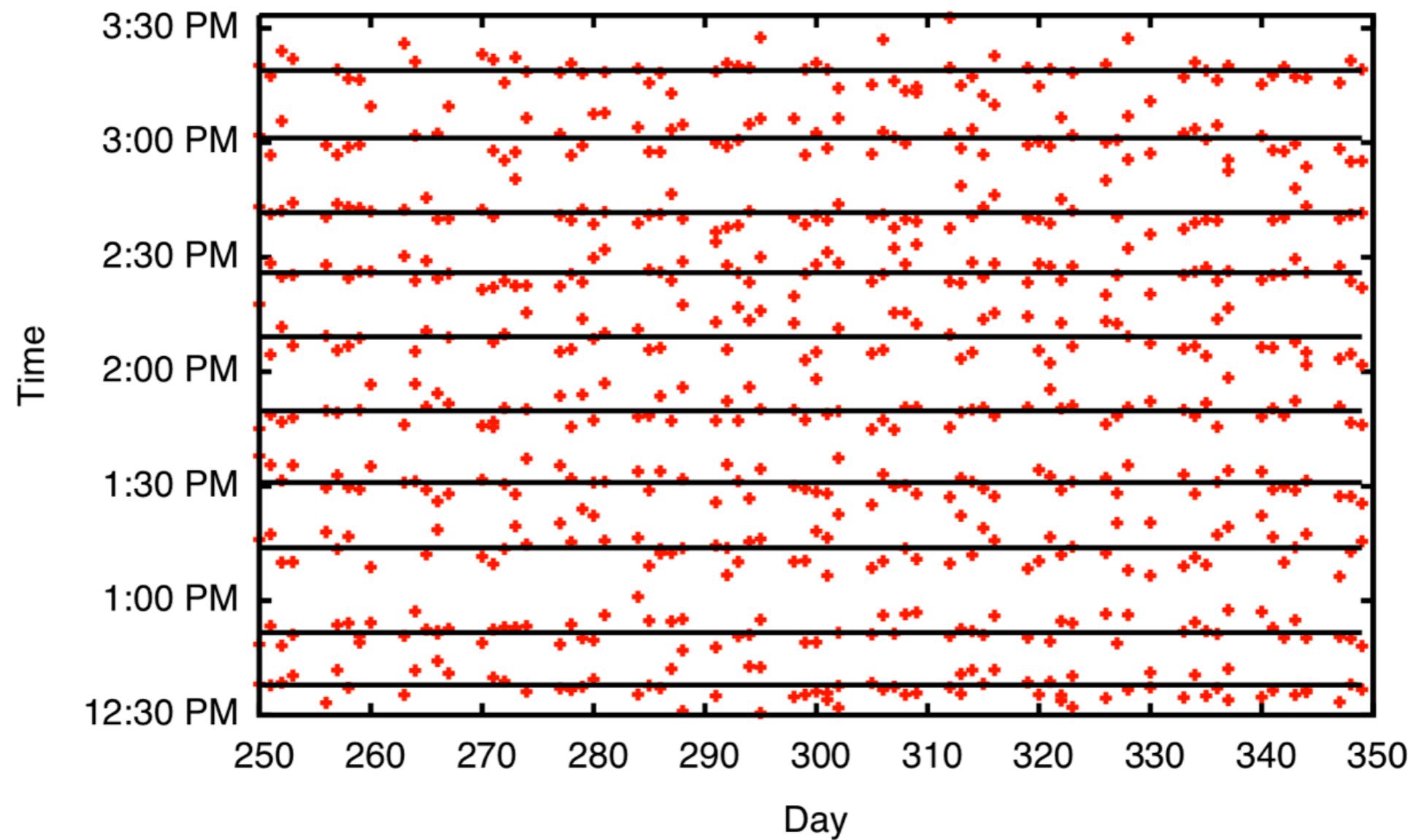


$$k_t^j = k_t^1 + \text{travel_time}(1, j, t)$$

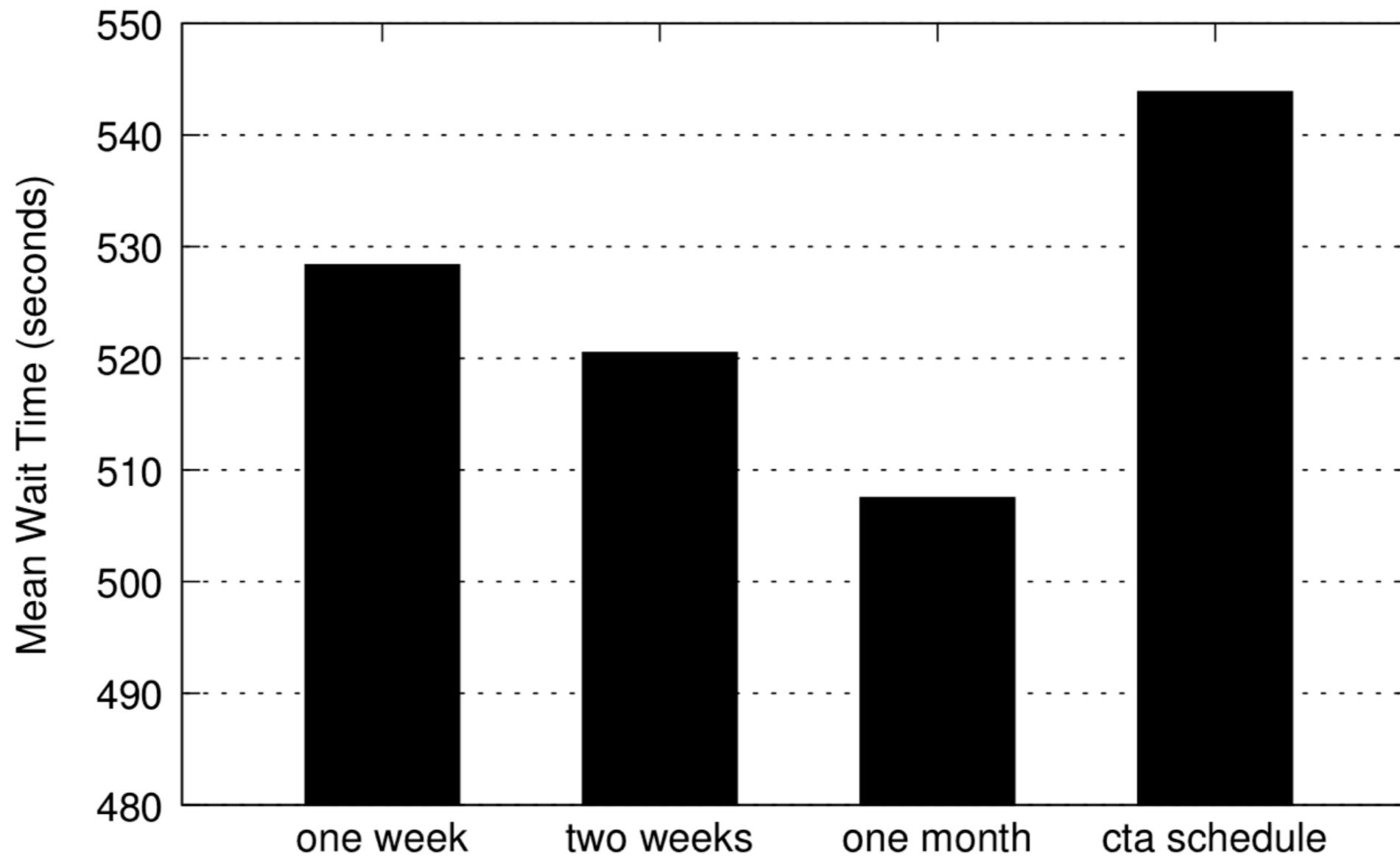
Last stop arrival times



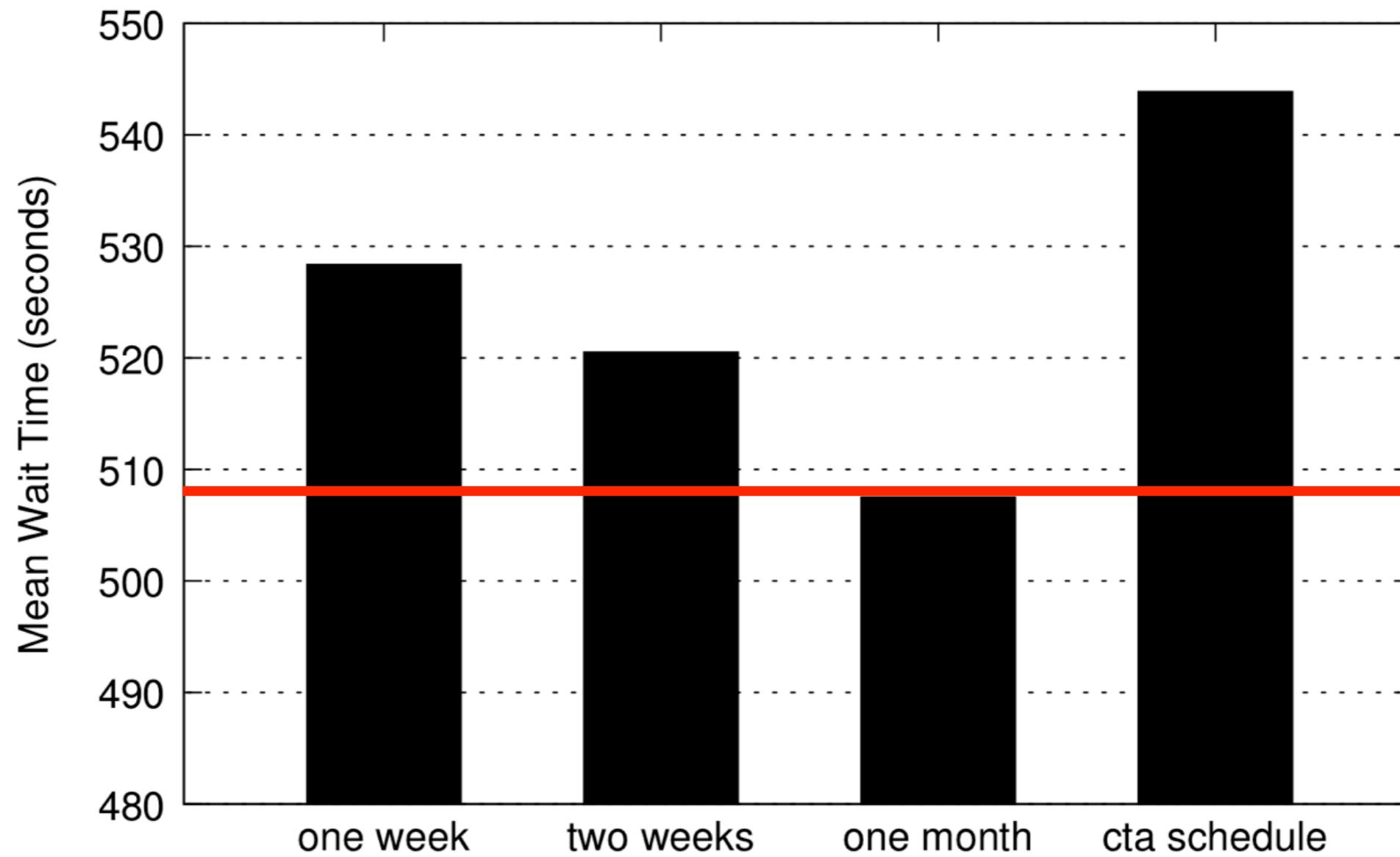
Last stop schedule



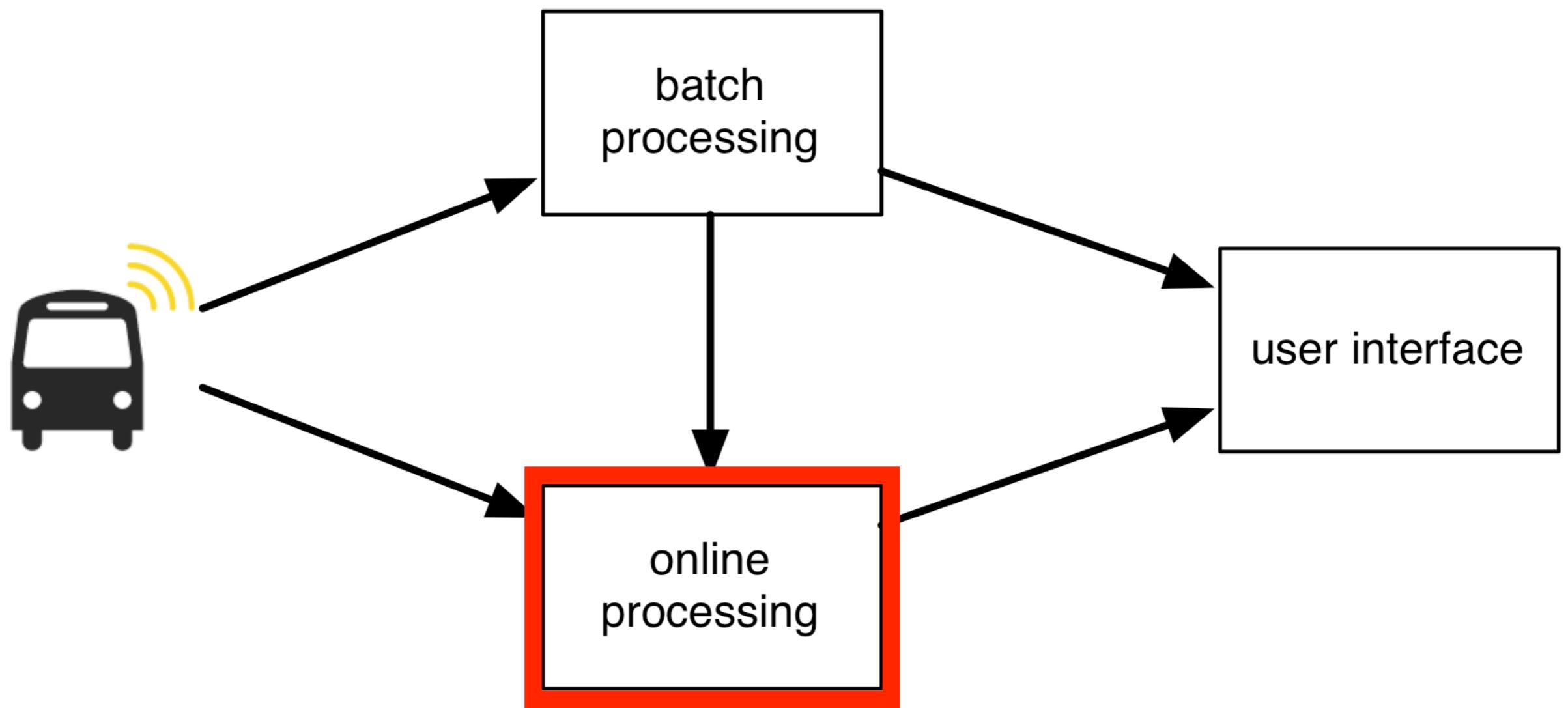
Schedule accuracy



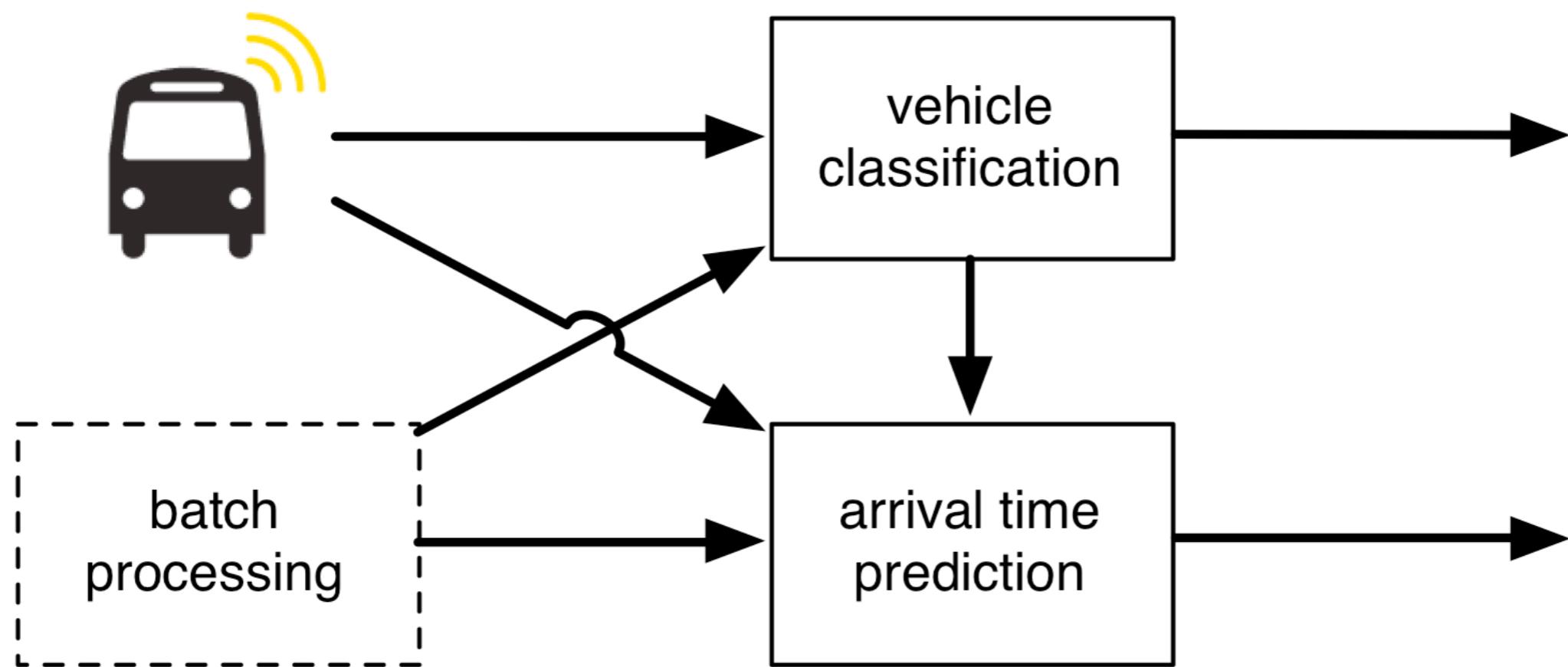
Schedule accuracy



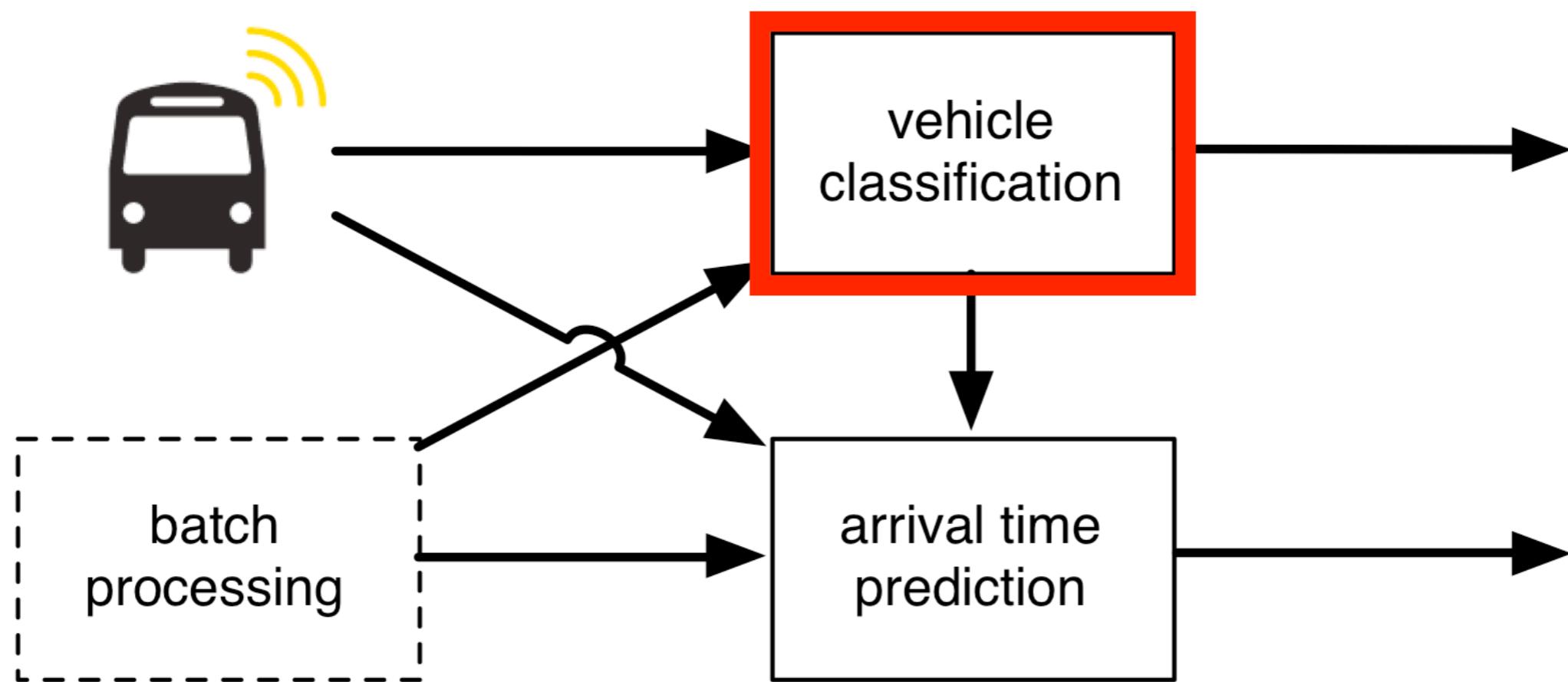
System architecture



Online processing



Online processing



Un-classified buses

The image is a screenshot of the UIC Shuttle Tracker website. At the top, there are navigation links for 'Map', 'Routes', and 'Help & About'. Below the map, there are two buttons: 'Map' (selected) and 'Satellite'. The map shows a detailed street layout of Chicago with several UIC shuttle routes highlighted in different colors (purple, yellow, red, blue). Each route is marked with a bus icon and a sequence of stops. The map includes labels for major roads like 90, 290, 94, and 95, as well as local streets and landmarks such as Rockwell Park, W. Adams St, W. Jackson Blvd, W. Van Buren St, W. Congress Pkwy, Tri Taylor, Jesse Brown Va Medical Center, Cook County Hospital, University of Illinois Chicago Medical Center, University of Illinois at Chicago, and various parks and university lots. A legend in the bottom right corner provides a scale (200 m/1000 ft) and a north arrow. A copyright notice at the bottom right states 'Map data ©2011 Google'.

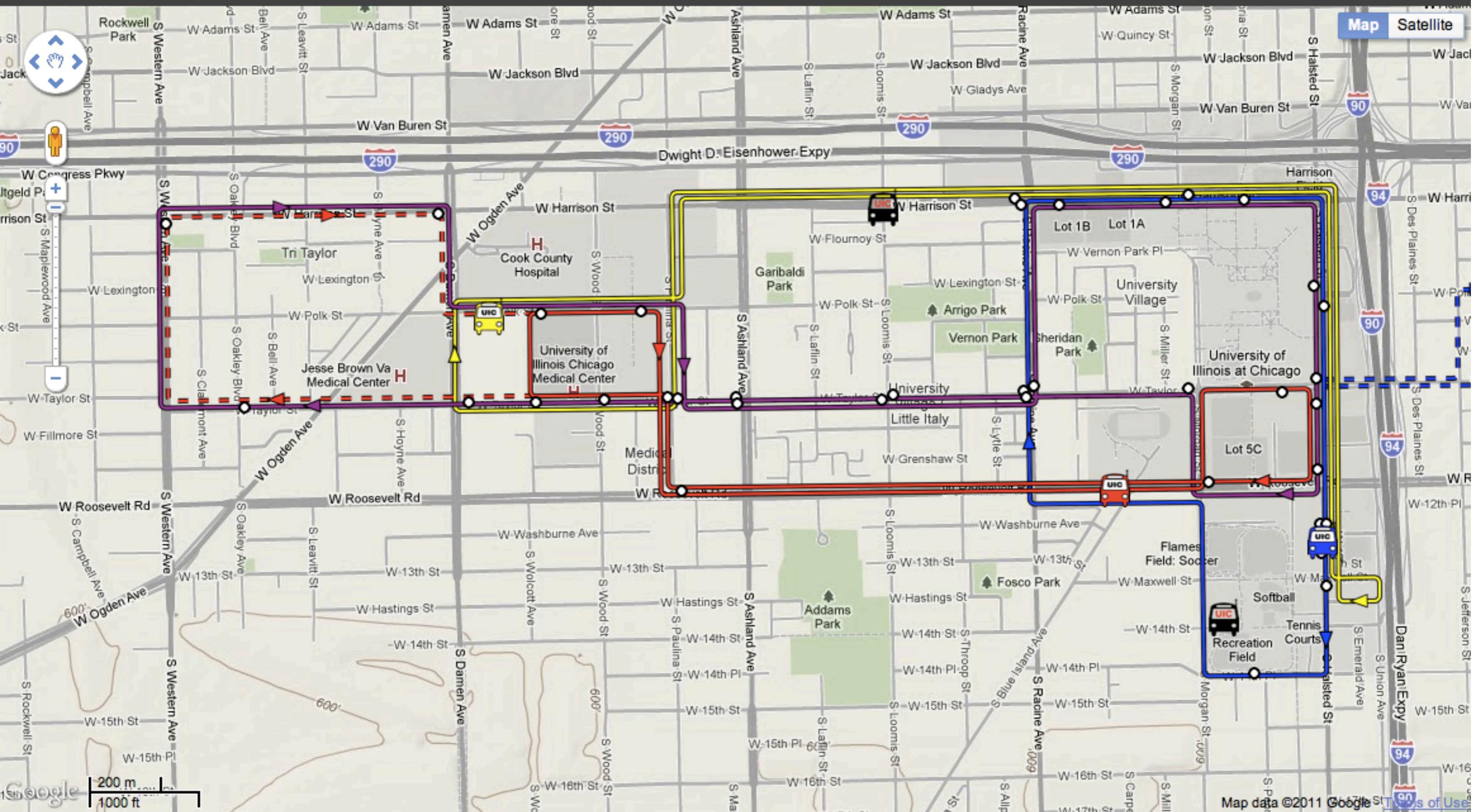
Classified buses

UIC Shuttle Tracker

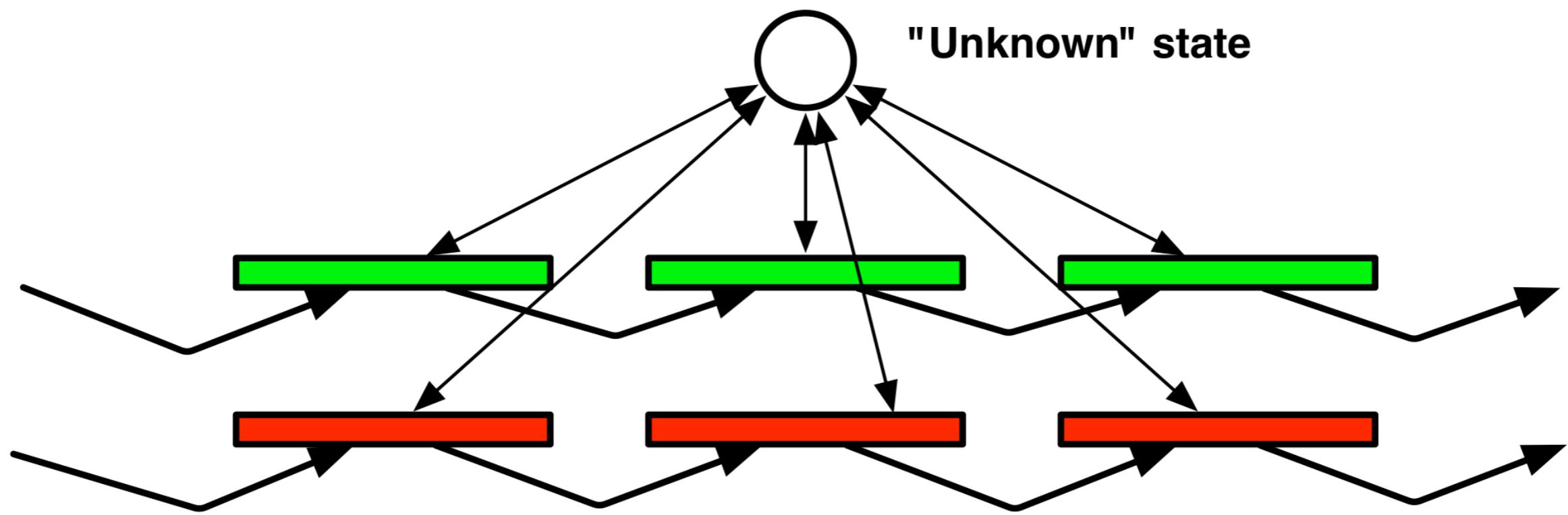
Click on a bus or stop to see arrival predictions.

[Map](#) [Routes](#) [Help & About](#)

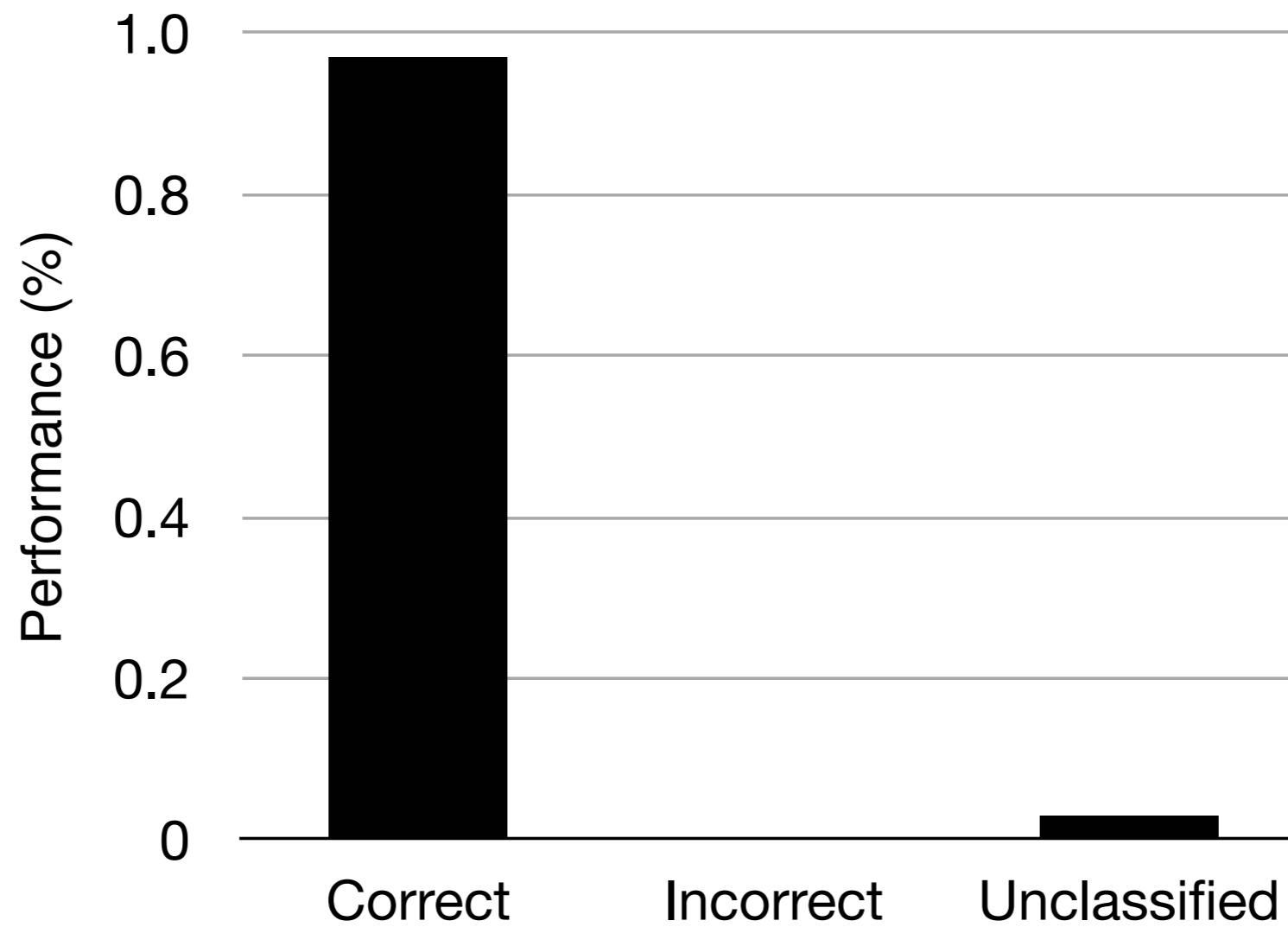
Map [Satellite](#)



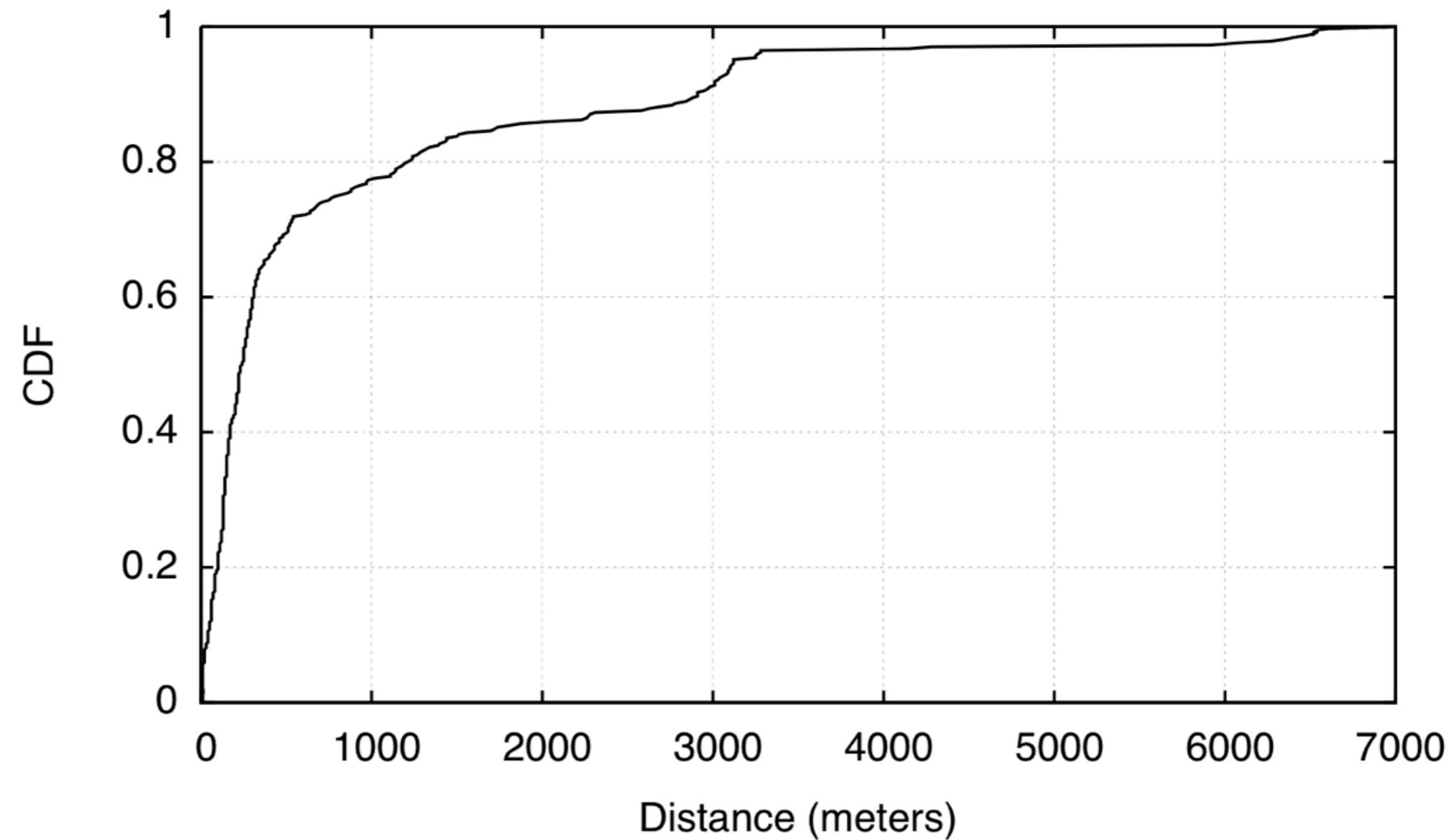
Hidden Markov model



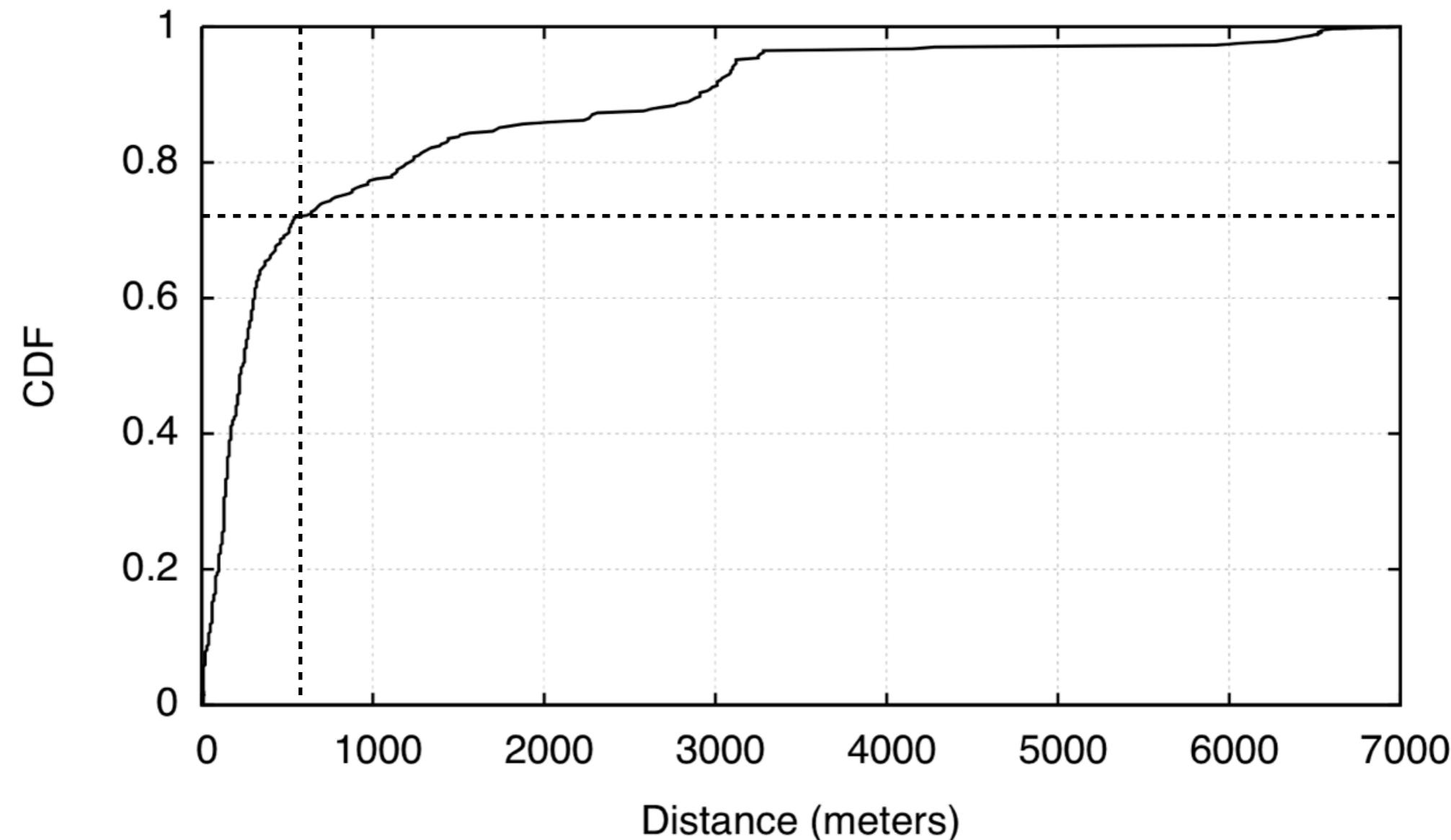
Classification accuracy



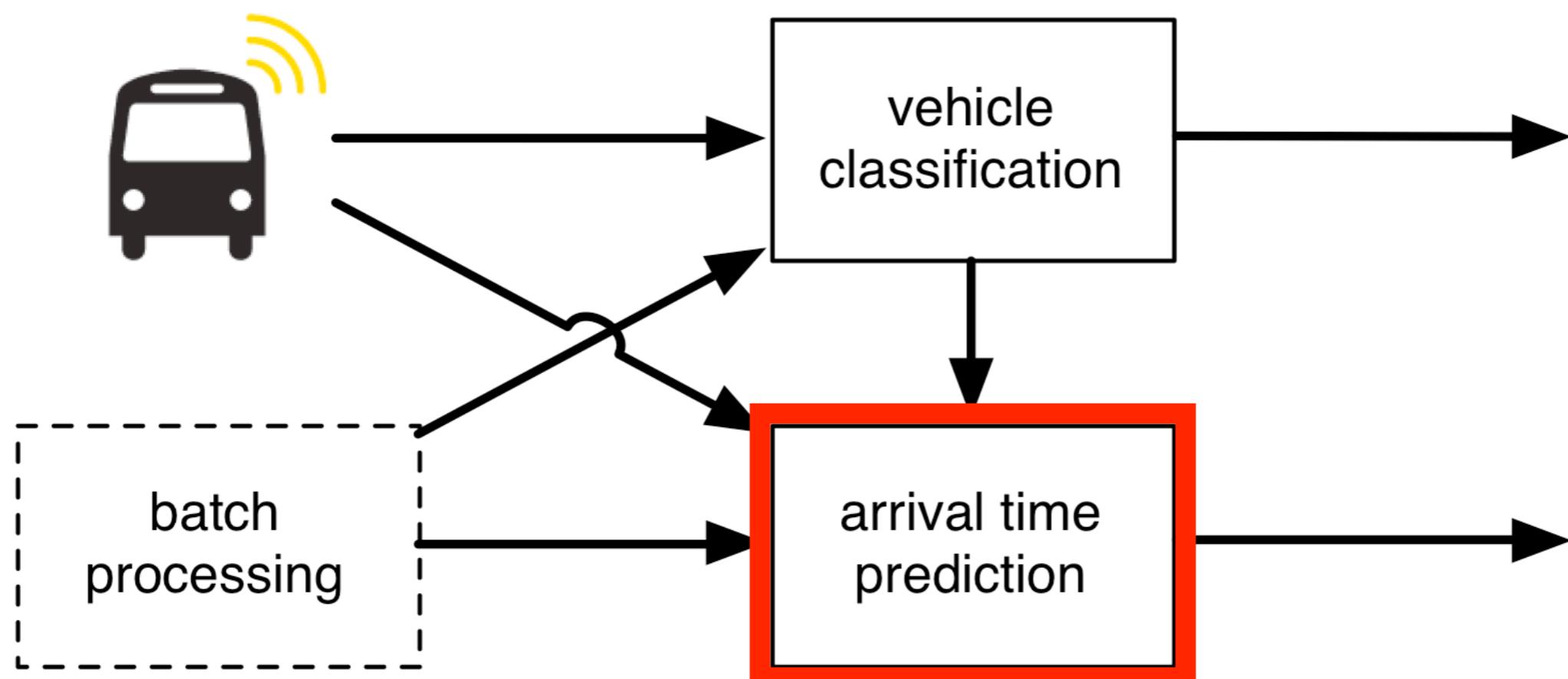
Classification delay



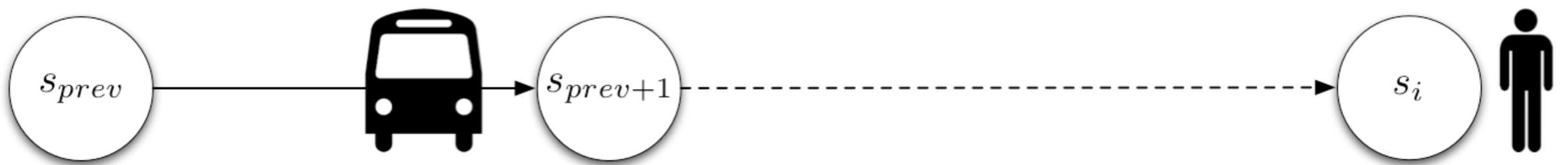
Classification delay



Arrival time prediction

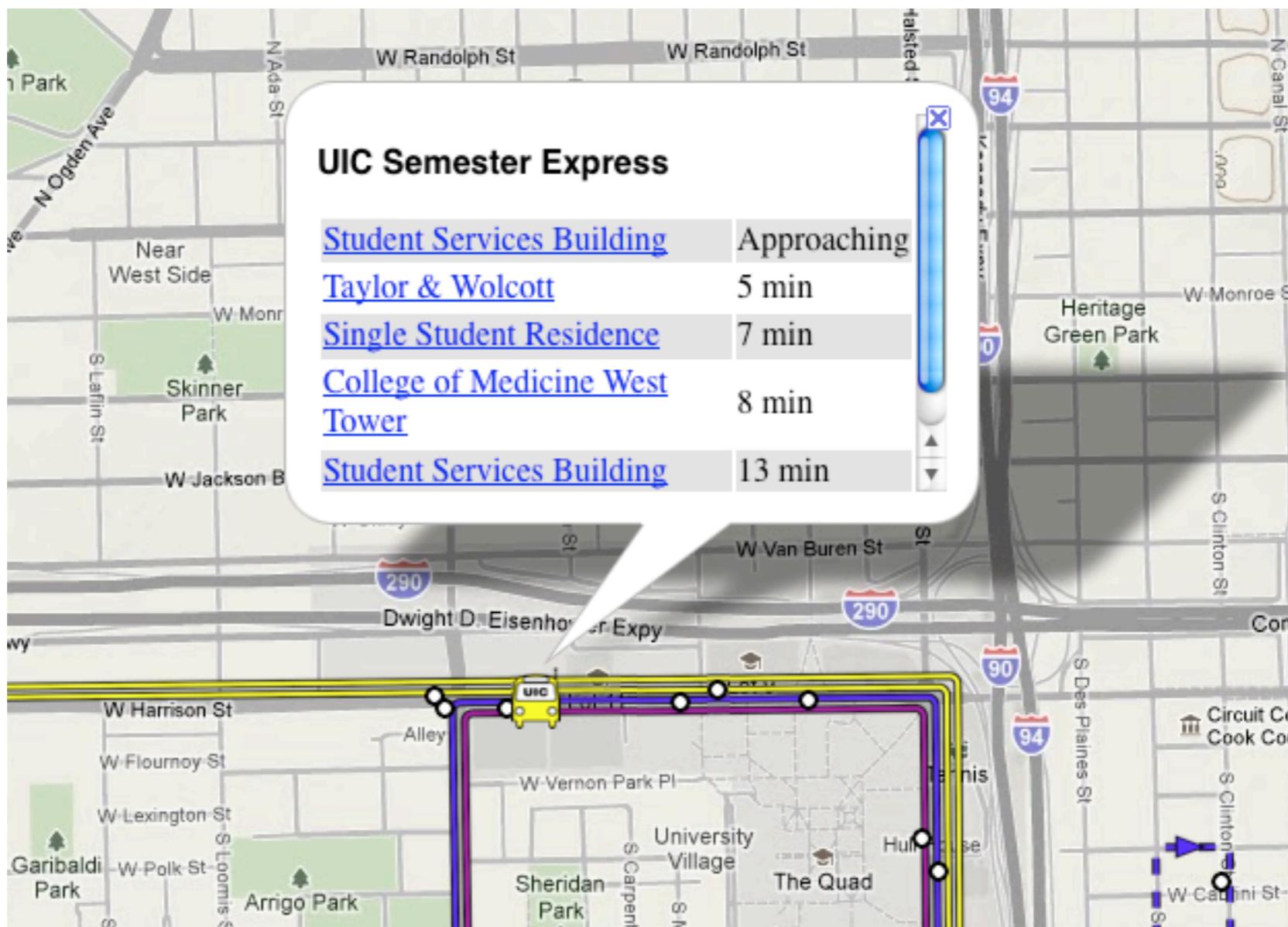


Predicting arrival times

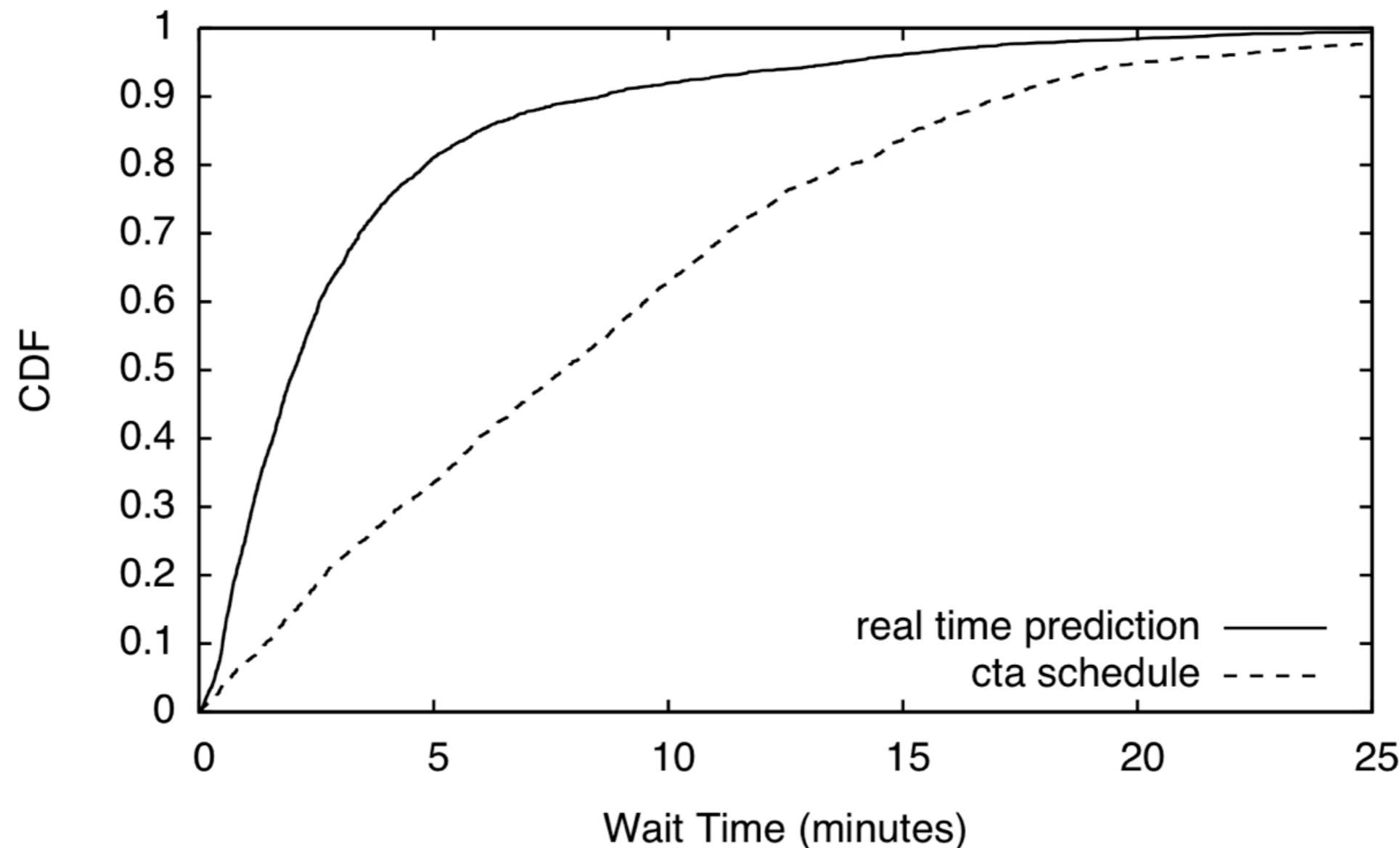


$$\begin{aligned} \text{time_until_arrival}(s_i) = & \gamma \text{travel_time}(s_{prev+1}, s_i) + \\ & (1 - \gamma) \text{travel_time}(s_{prev}, s_i) \end{aligned}$$

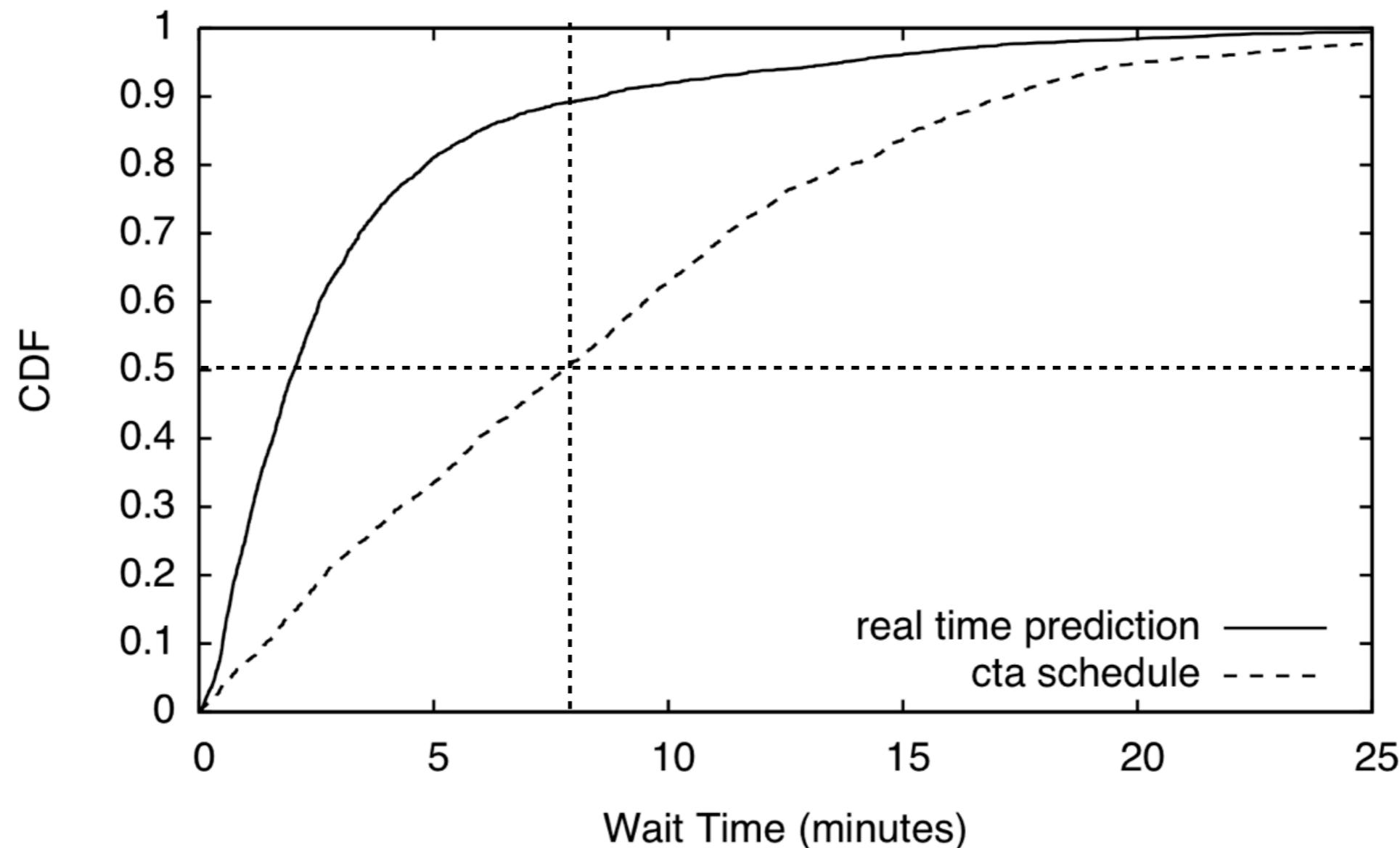
Arrival time predictions



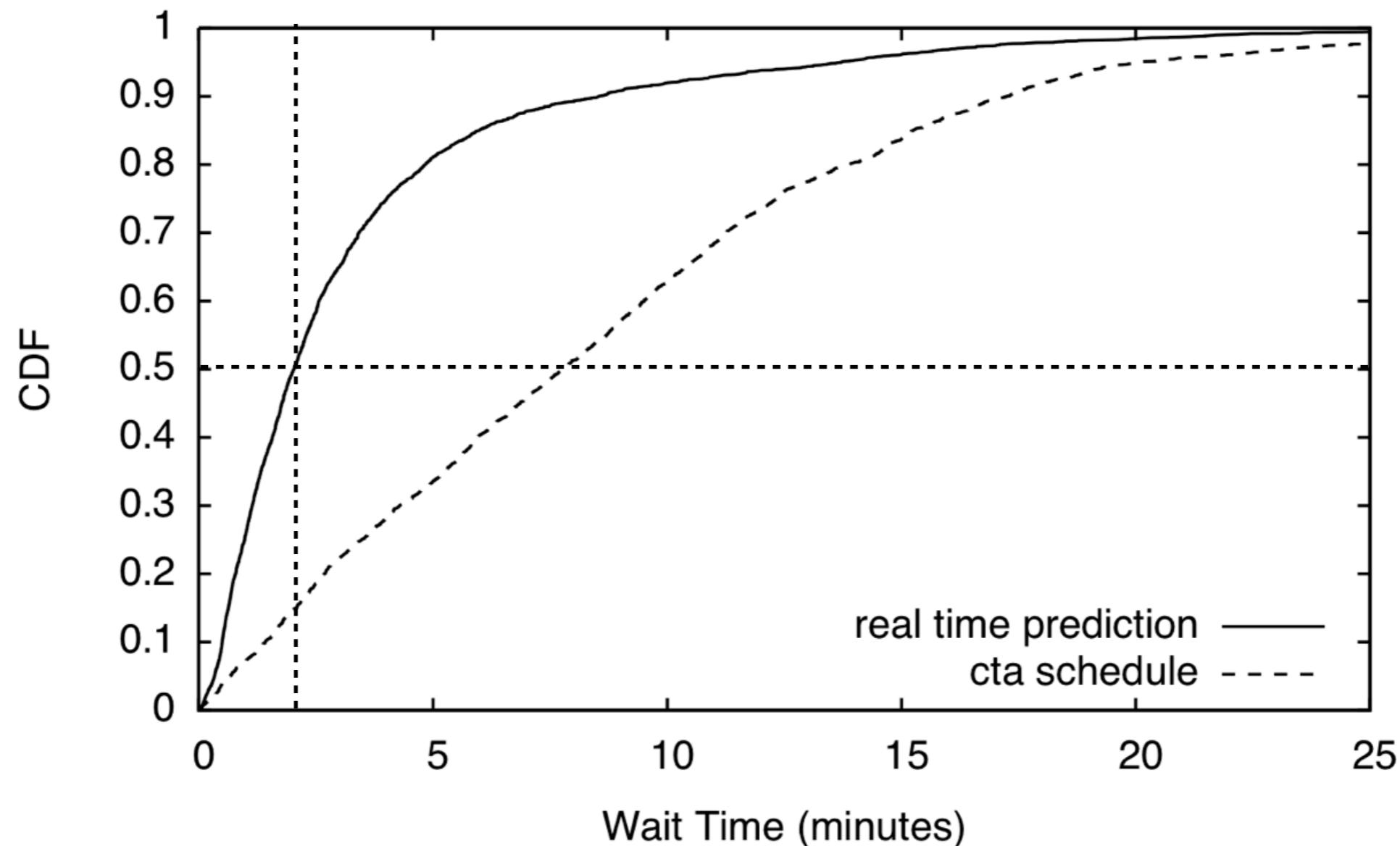
Schedule vs. real-time



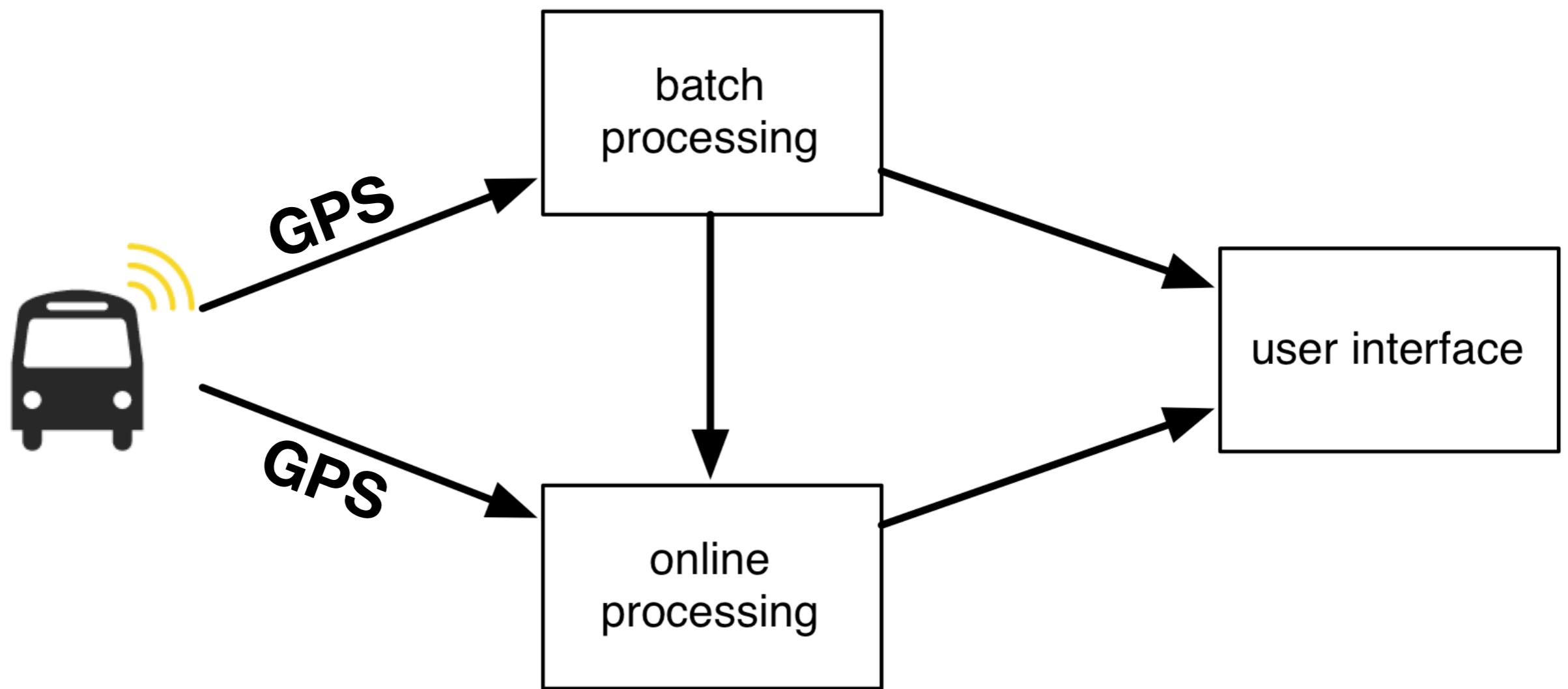
Schedule vs. real-time



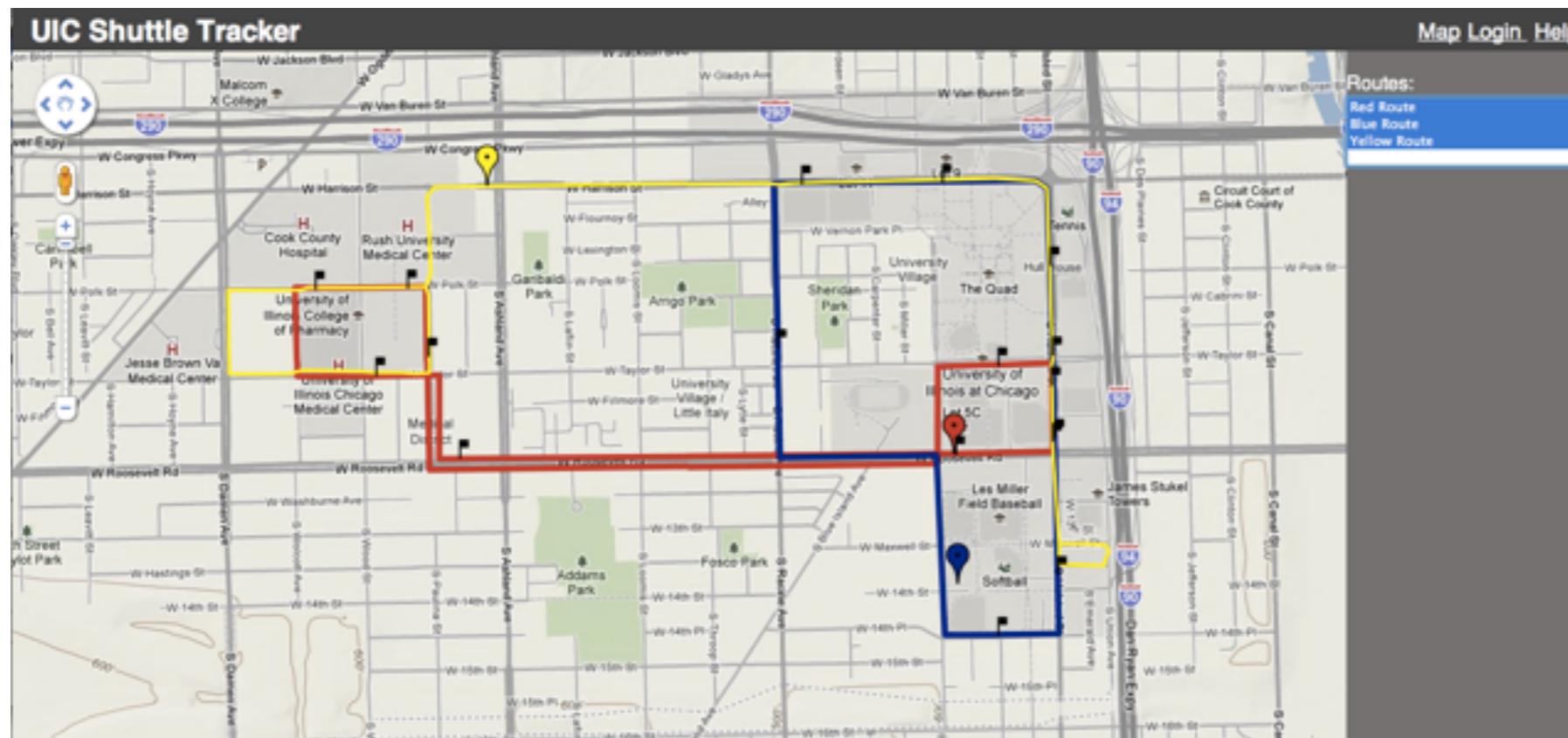
Schedule vs. real-time



System overview



Come and see our demo!



- ▶ Thursday, 3:30p-7:30p

Thanks!

Questions?

UIC Bits Networked
UNIVERSITY OF ILLINOIS
AT CHICAGO
Systems Laboratory
COLLEGE OF ENGINEERING