

EasyTracker

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

James Biagioni, Tomas Gerlich,
Timothy Merrifield and Jakob Eriksson

We love bus trackers!



Winter in Chicago



Our shuttle web (before)



Sections:

Welcome

Bus Service

Car Rental

Chauffer
Service

Paratransit
Service

Red Car
Service

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)



Sections:

Welcome

Bus Service

Car Rental

Chauffer Service

Paratransit Service

Red Car Service

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](#)

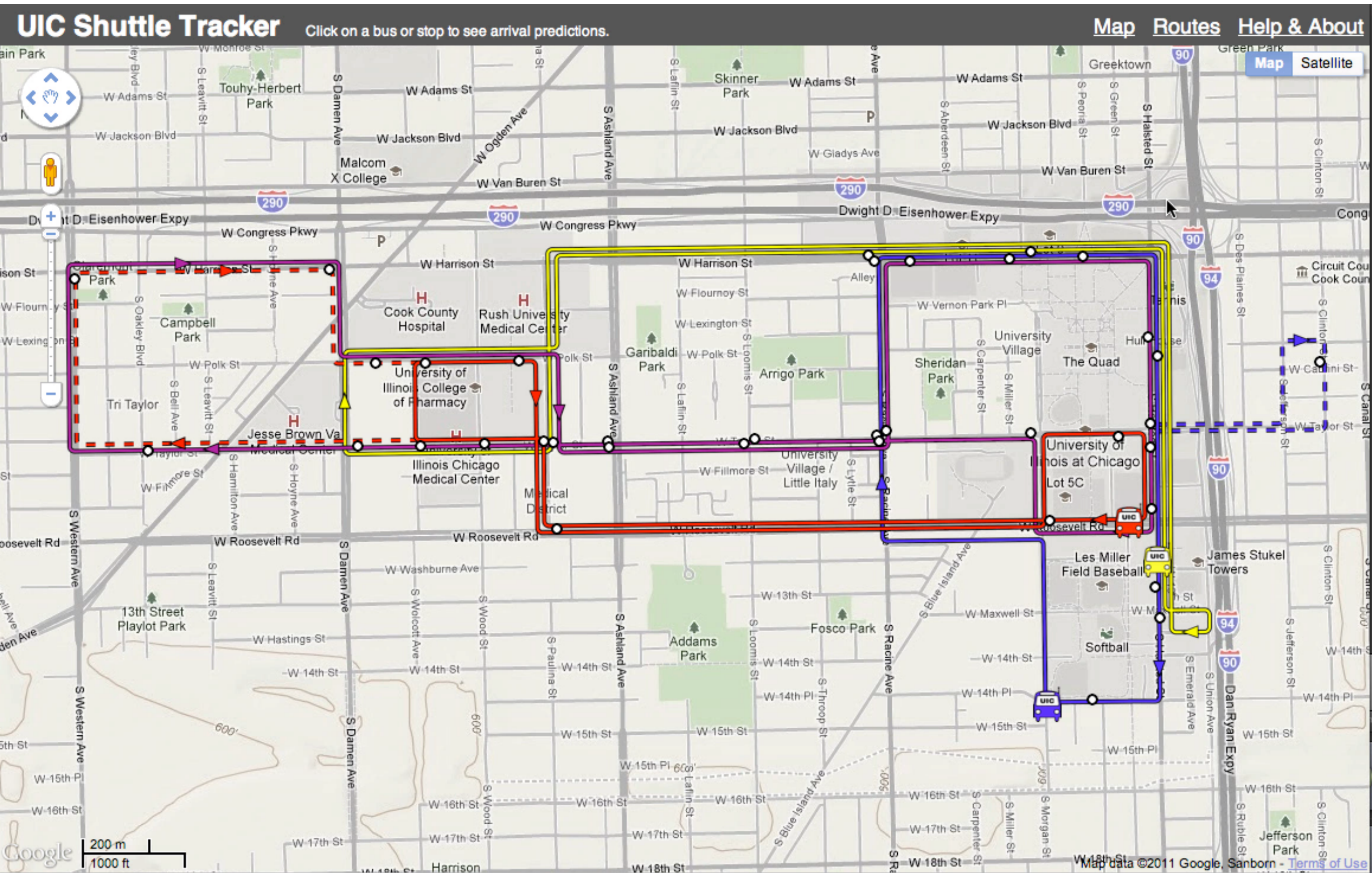
UIC East Side Route

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.

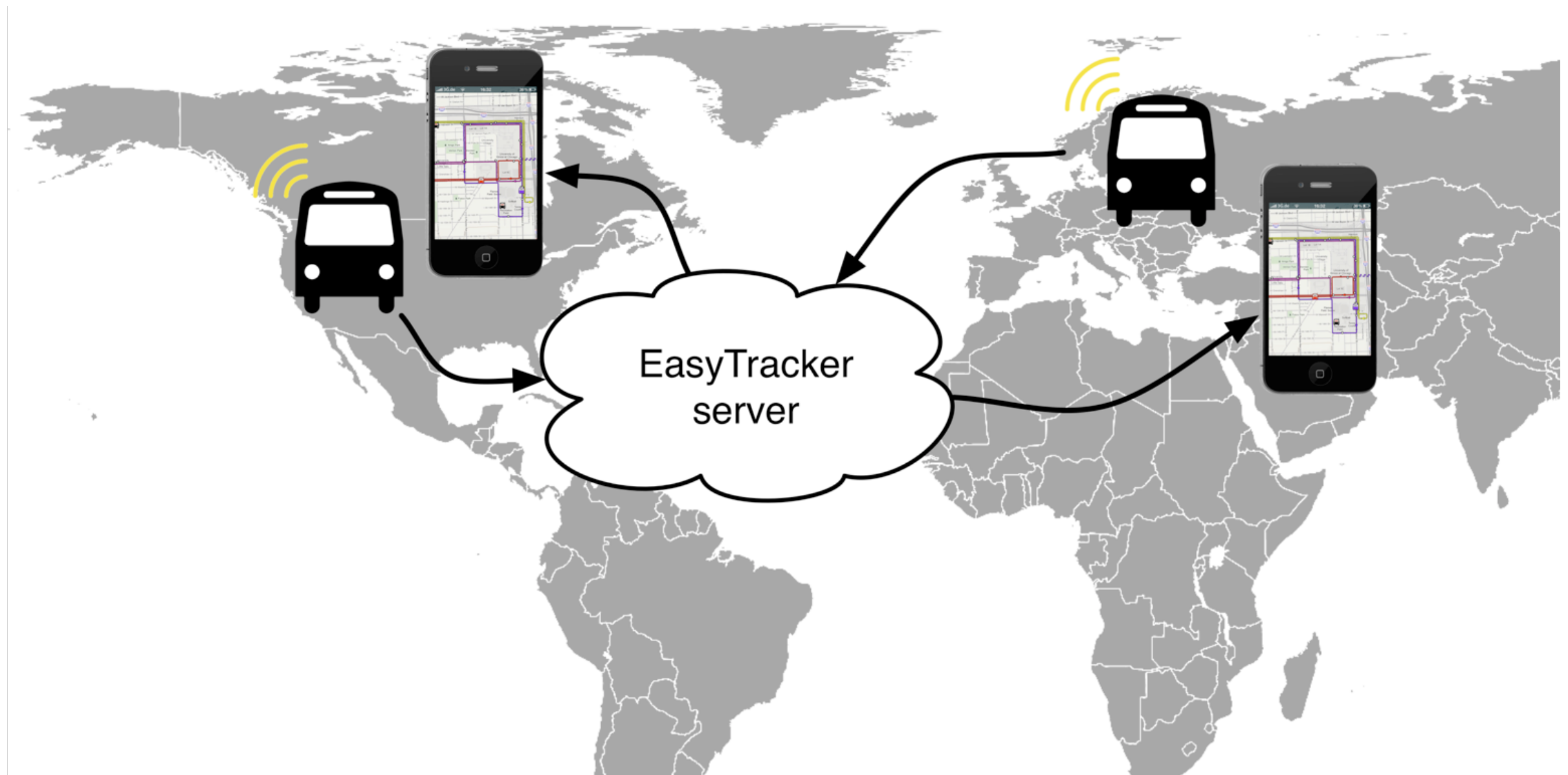
Hours of Operation

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

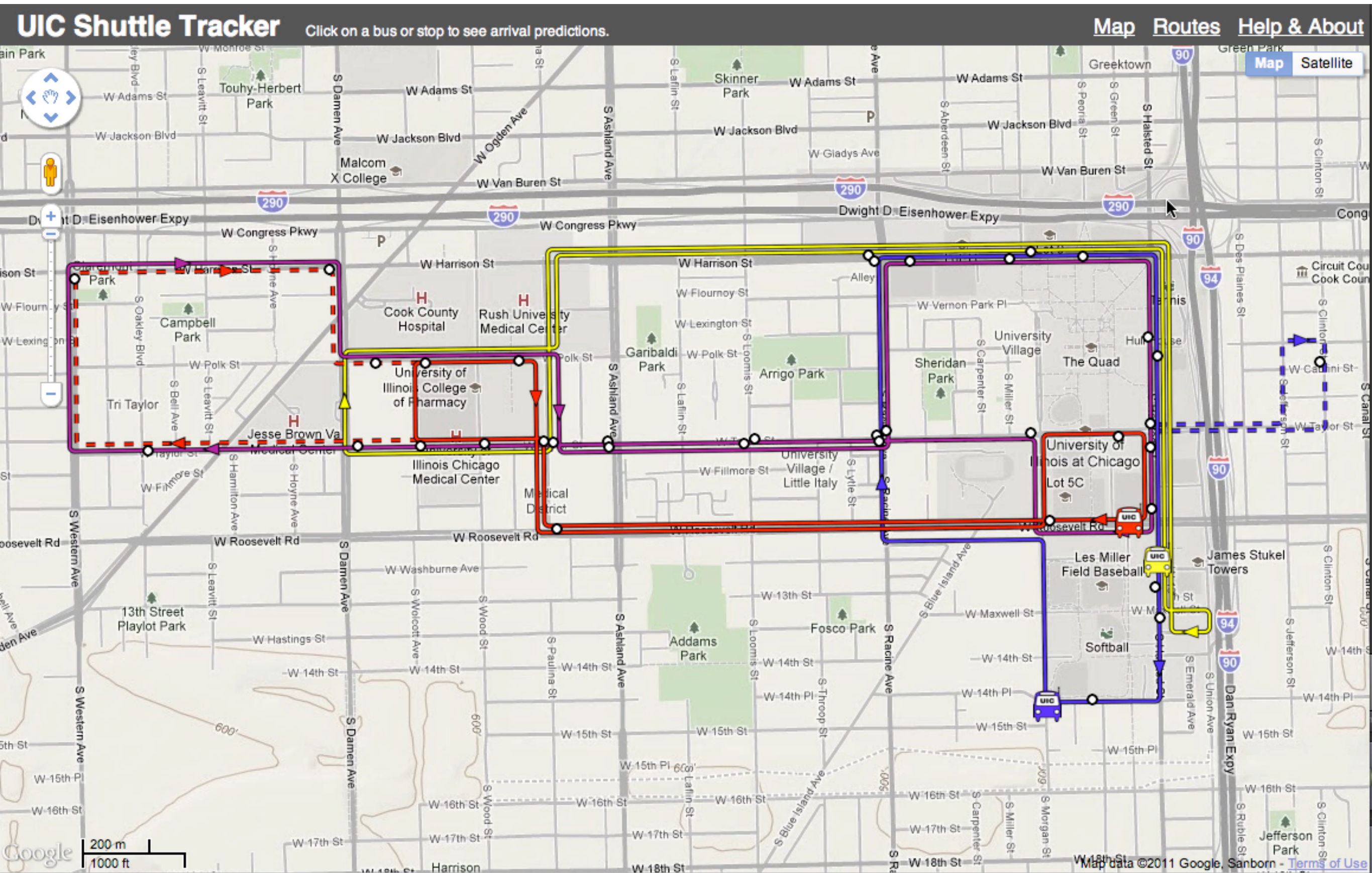
Our shuttle web (after)



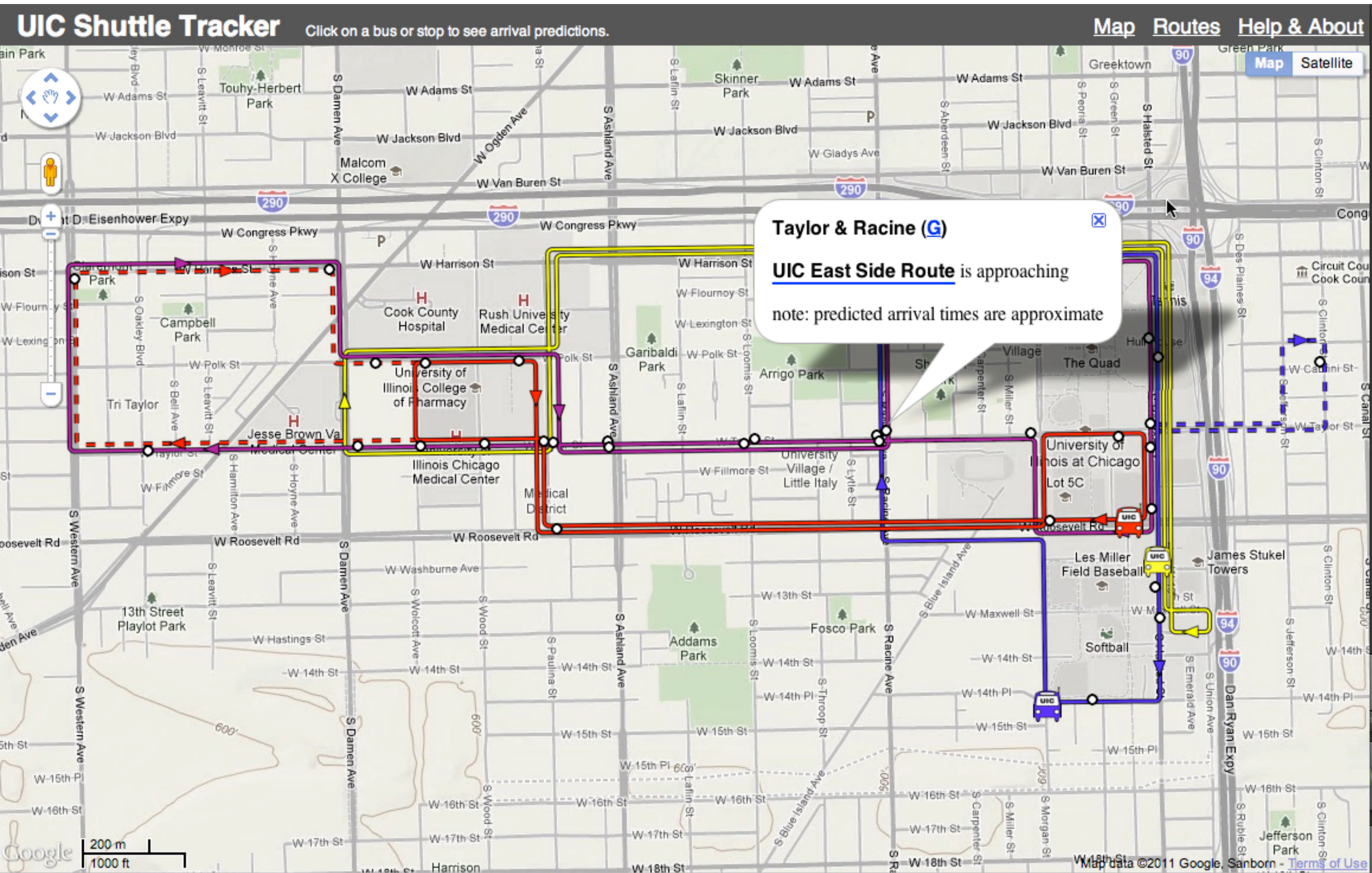
One service for everyone



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



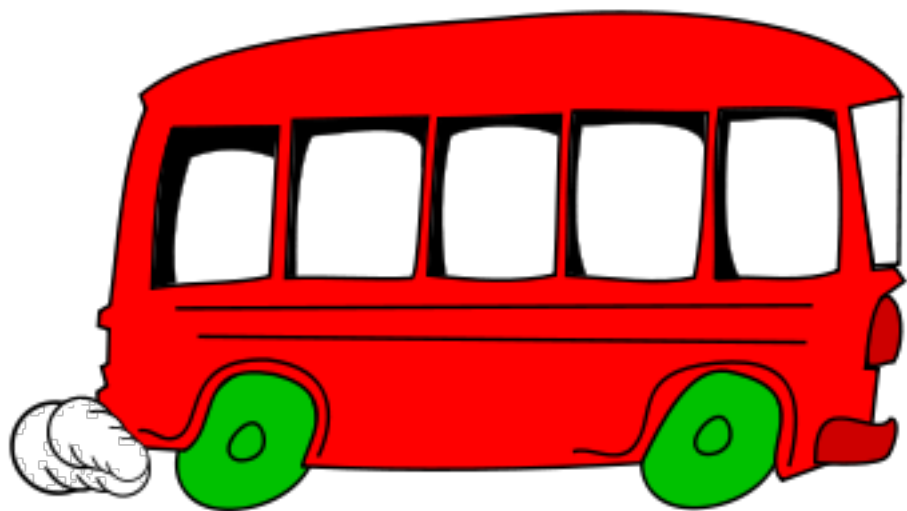
EasyTracker installation

1. Obtain smartphone
2. Install EasyTracker app



EasyTracker installation

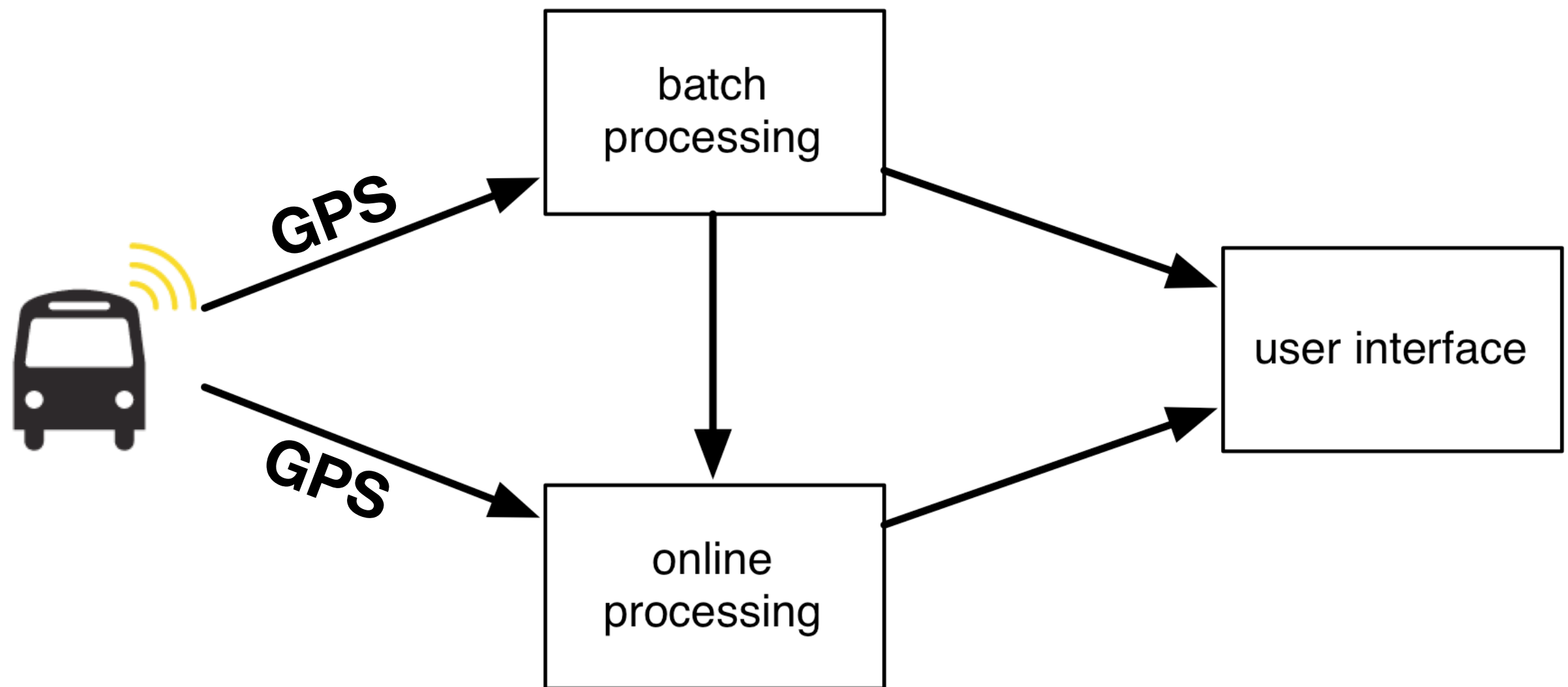
1. Obtain smartphone
2. Install EasyTracker app
3. Stick phone in bus



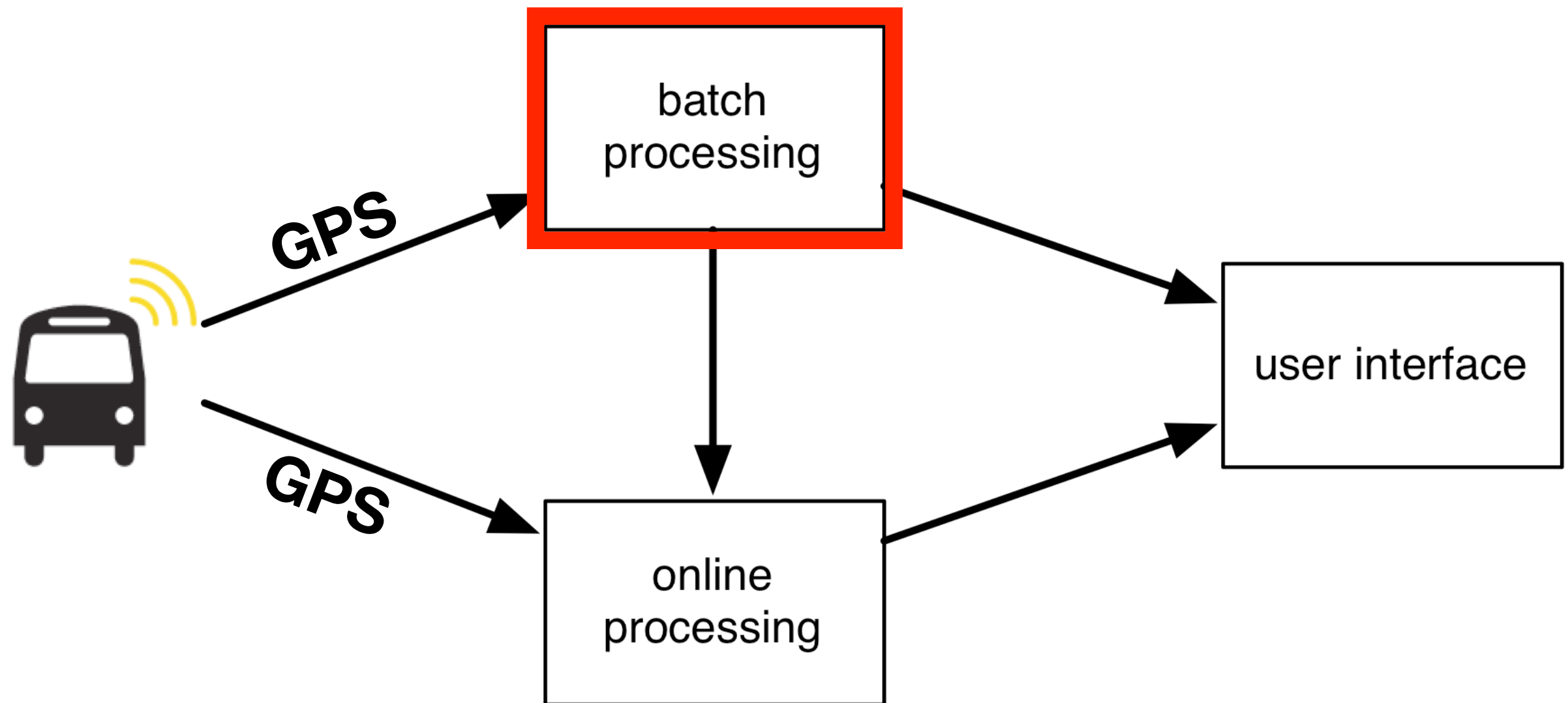
4. Relax



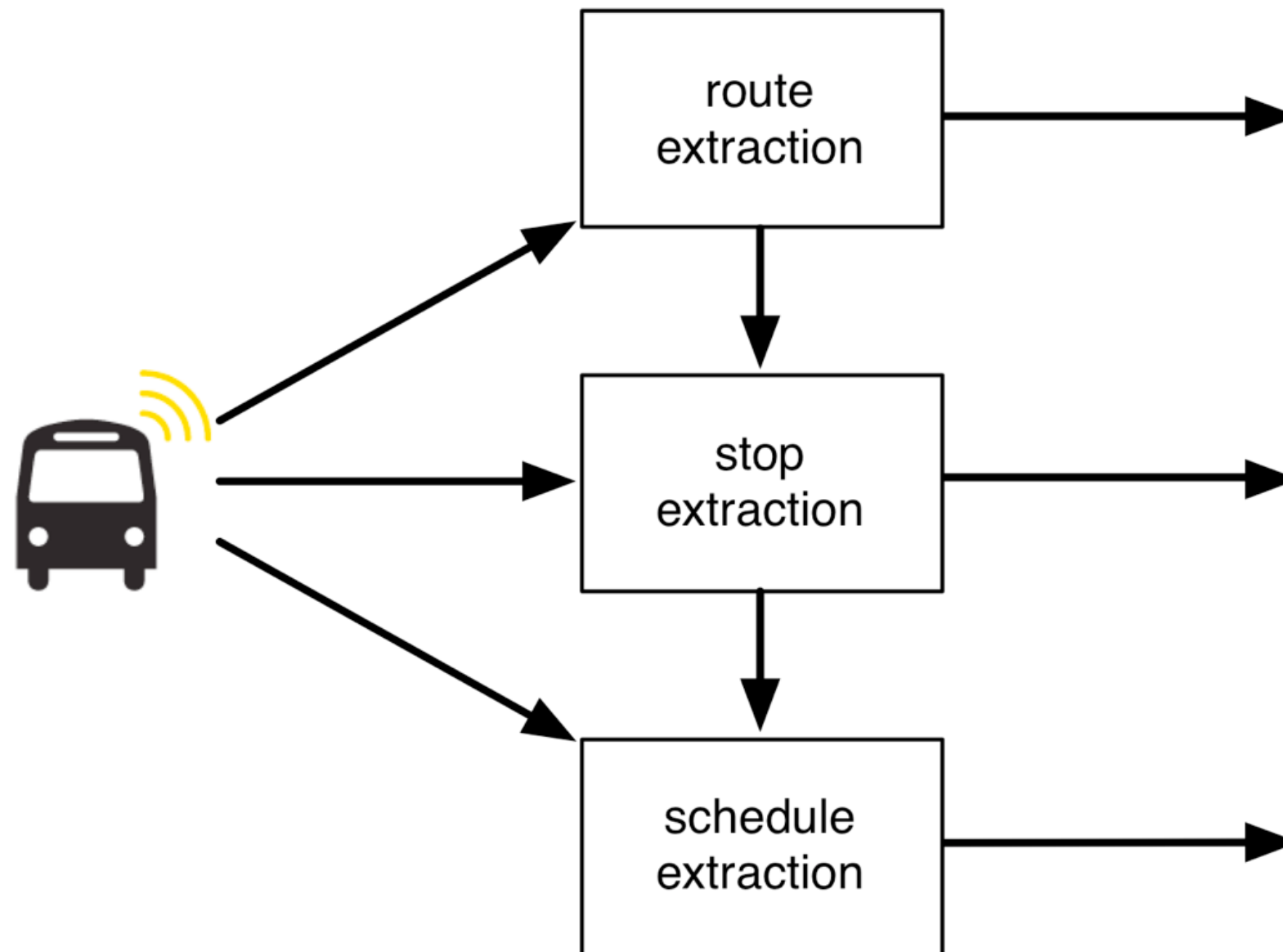
System overview



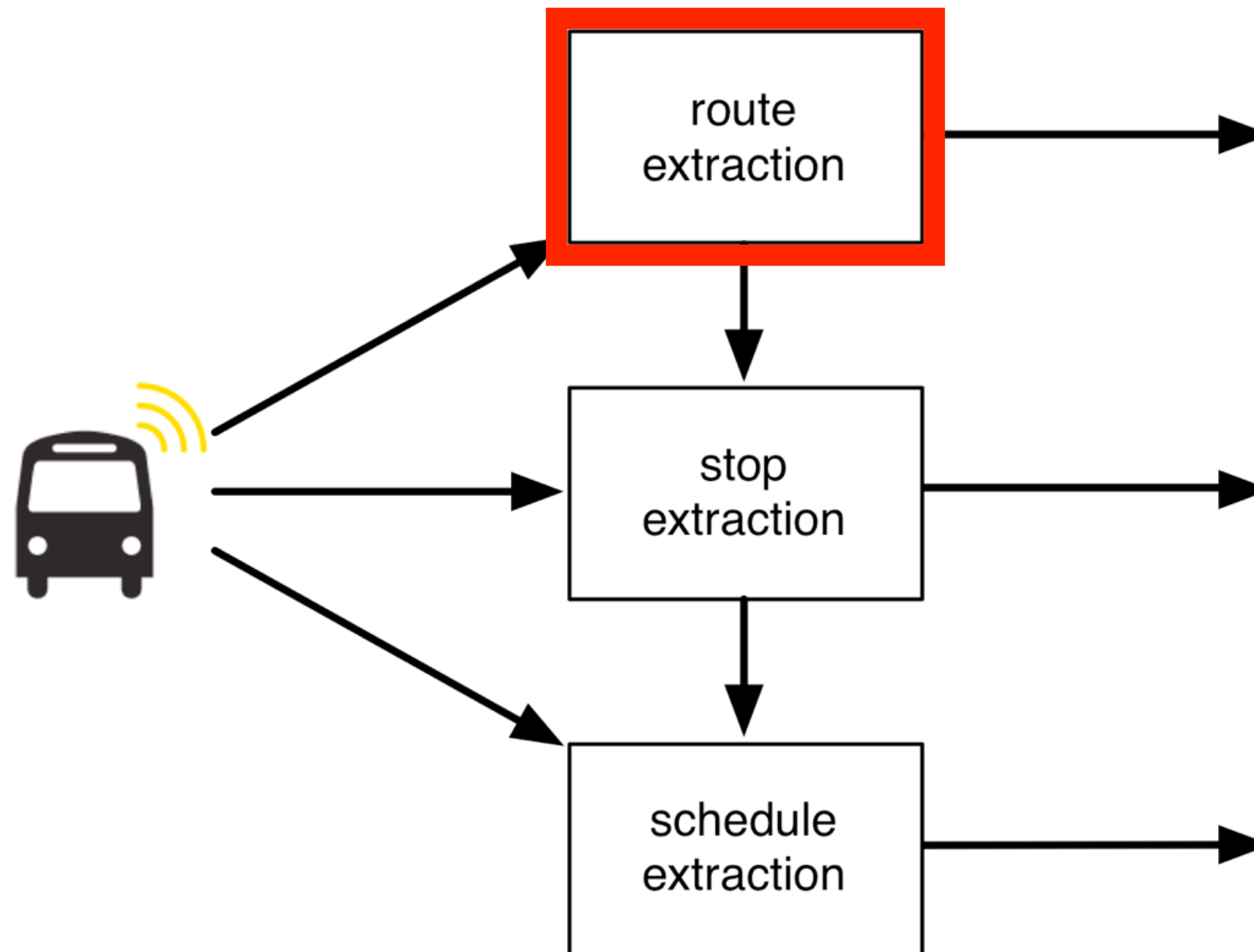
System overview



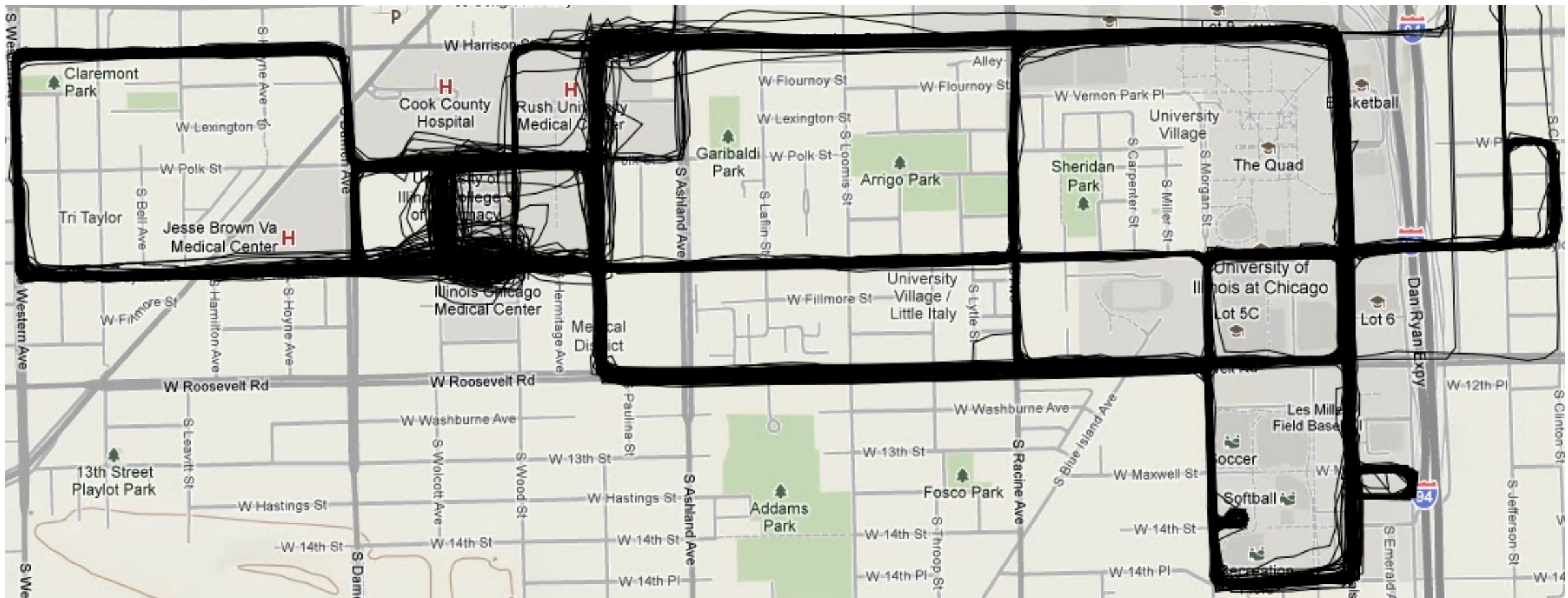
Batch processing



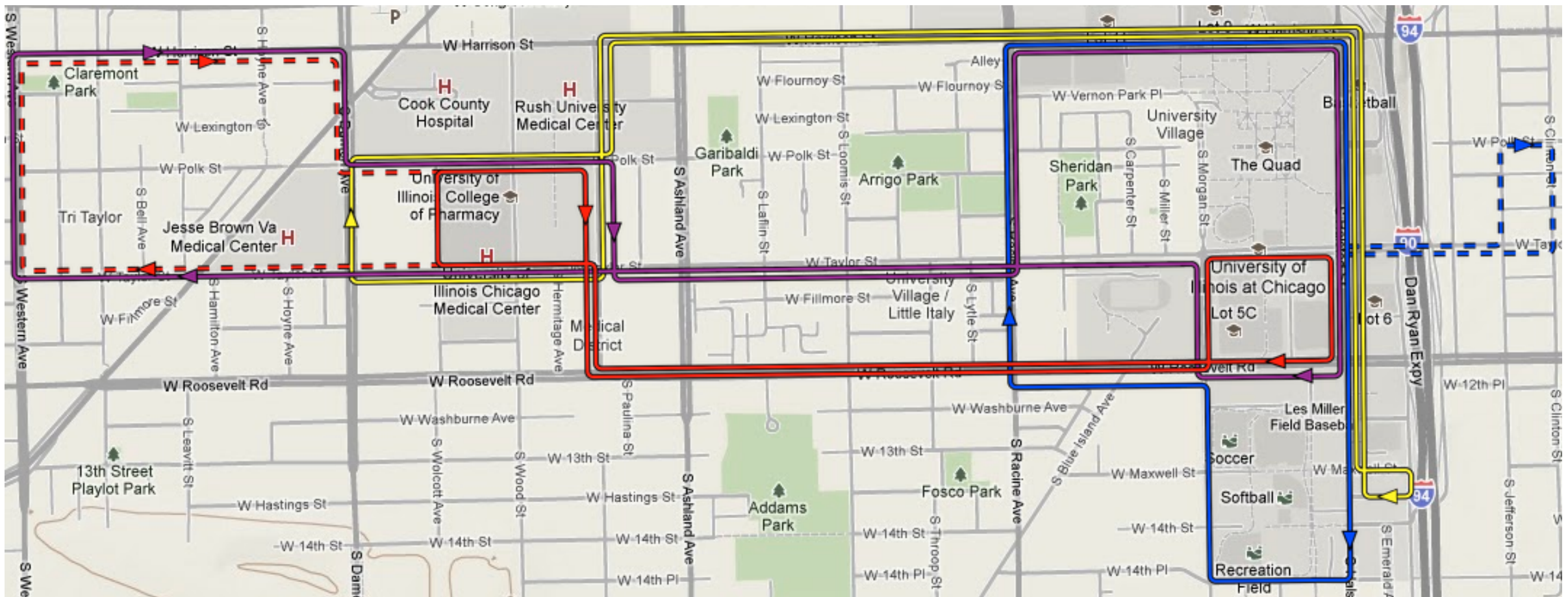
Batch processing



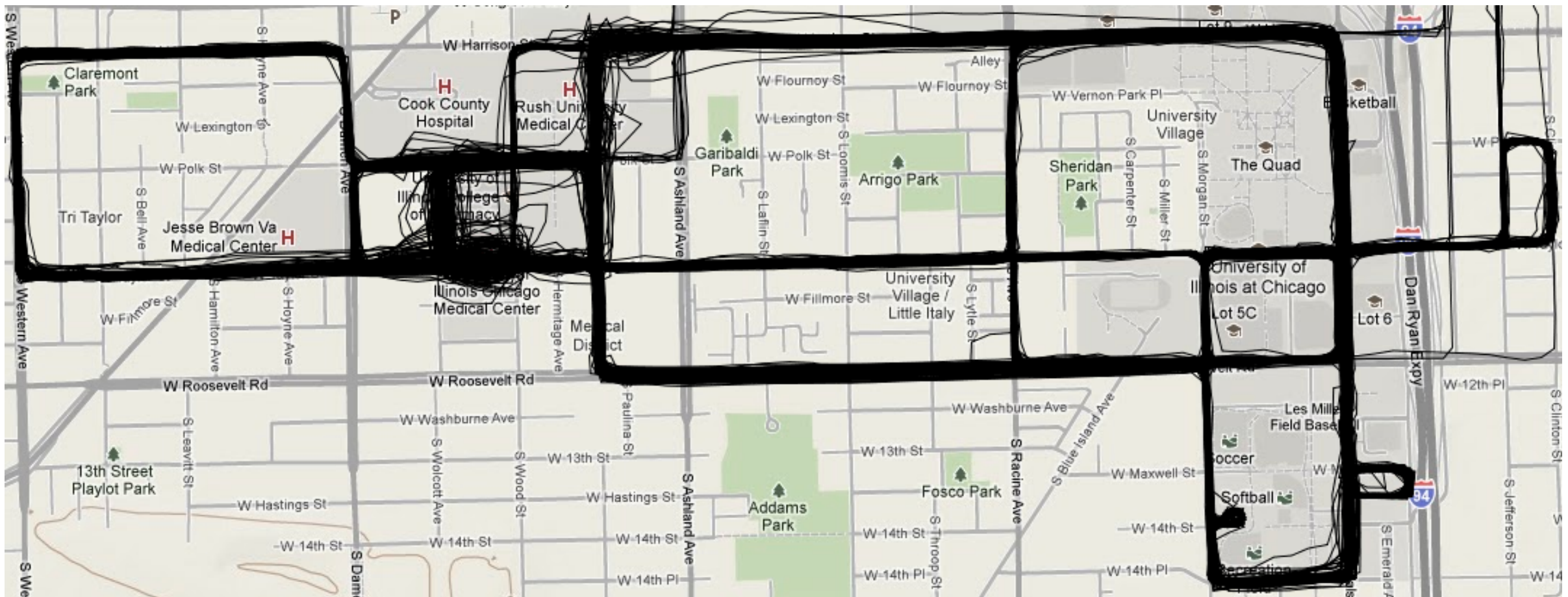
Raw GPS traces



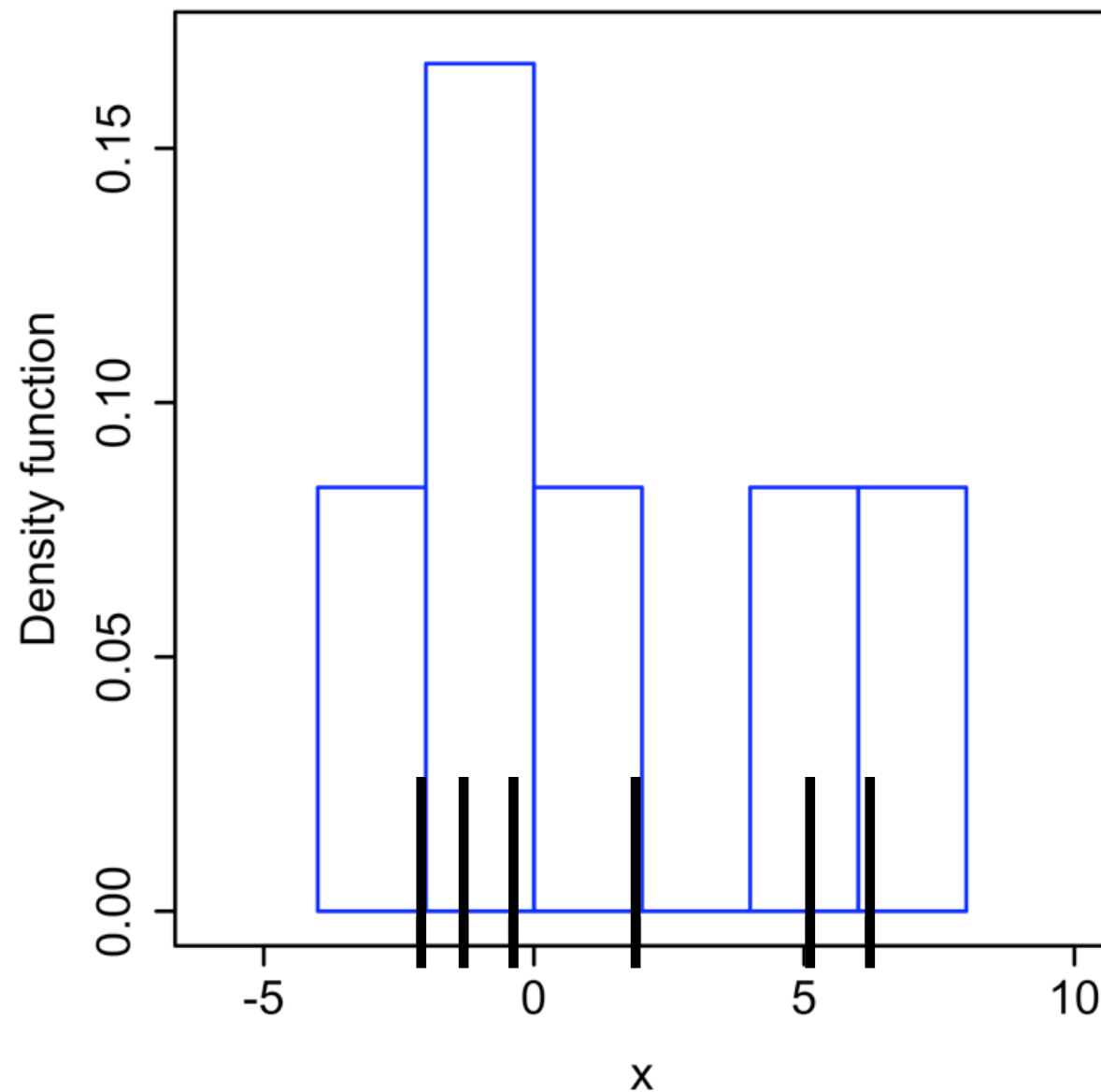
Route map



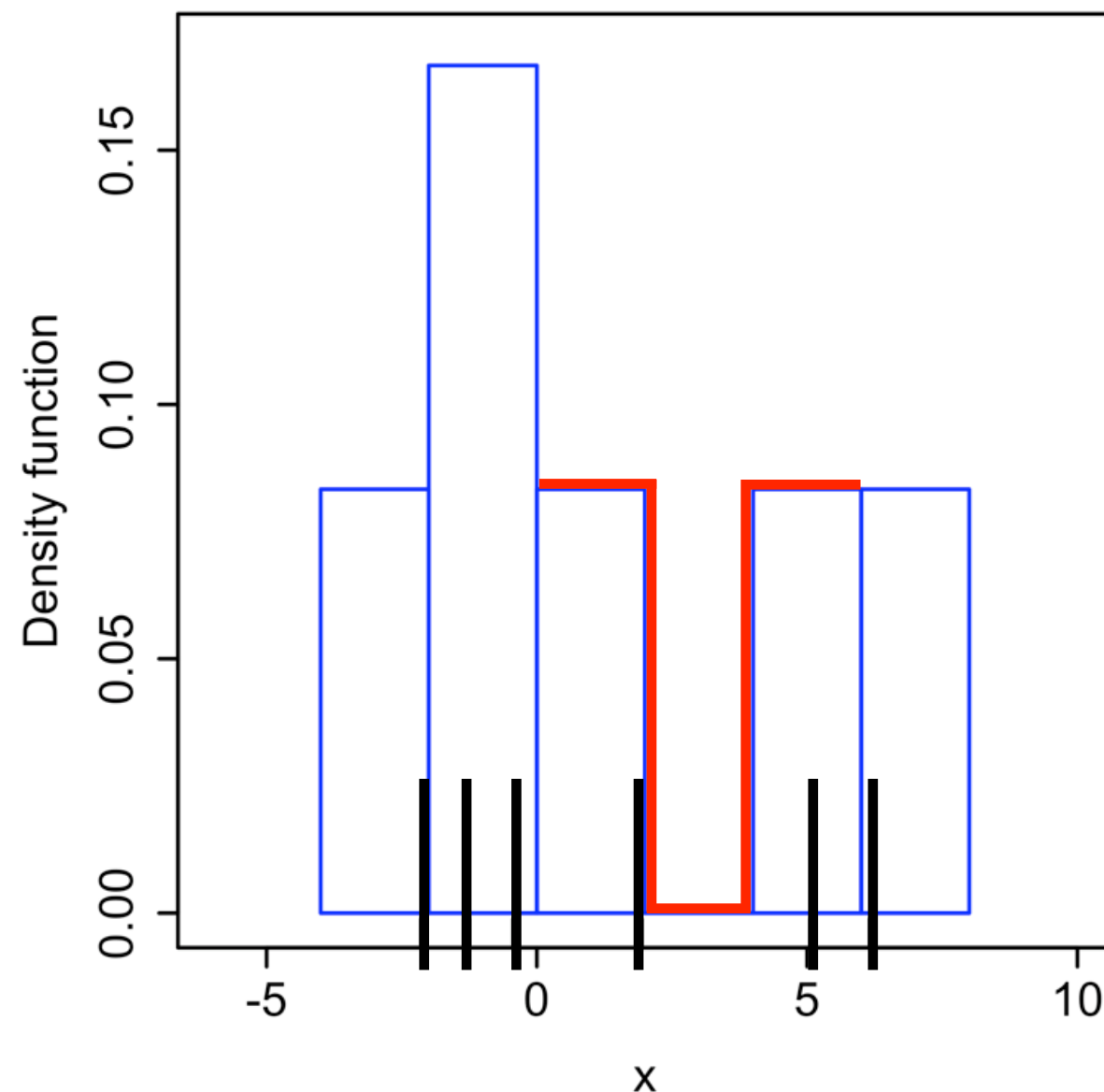
Raw GPS traces



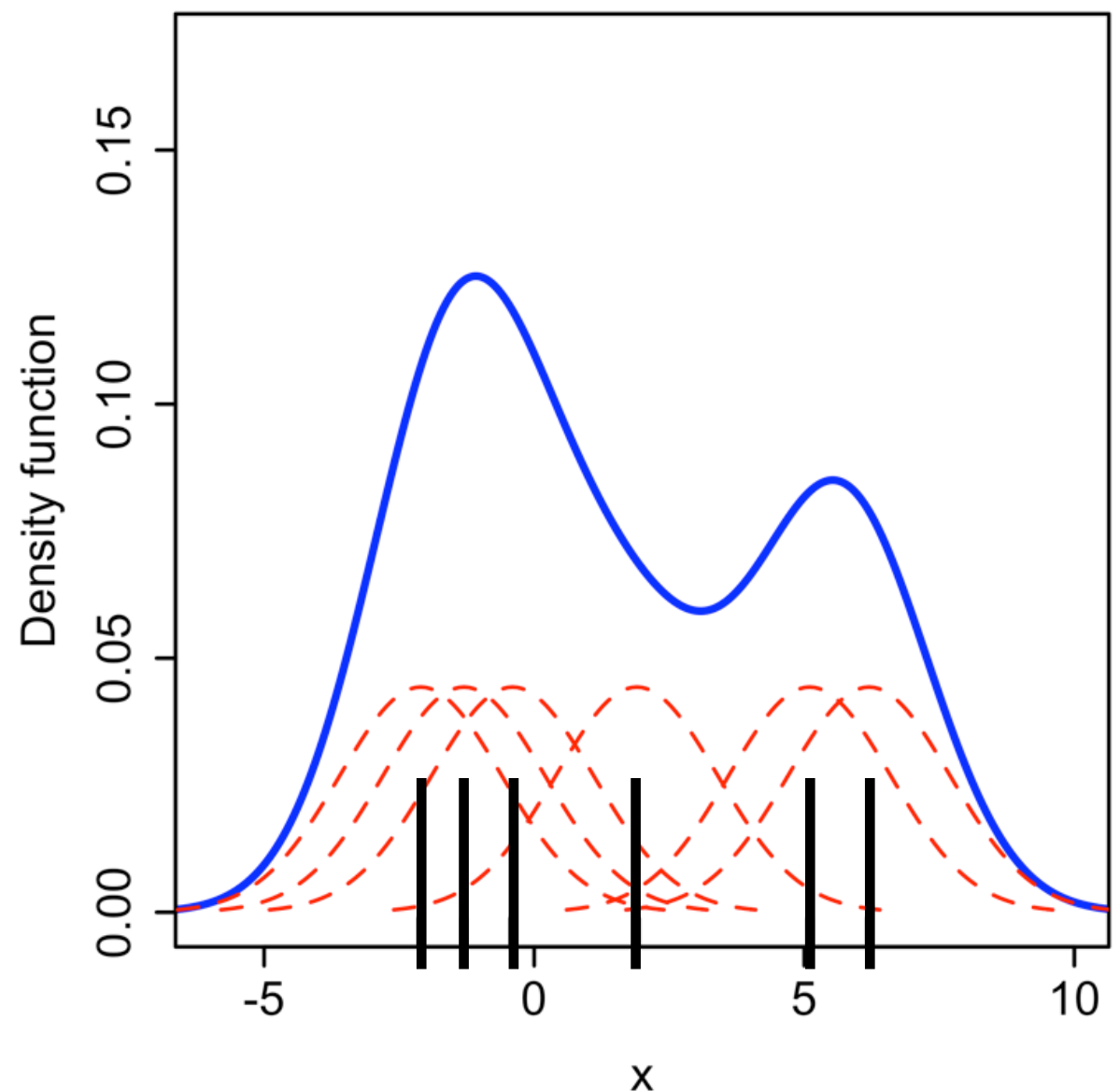
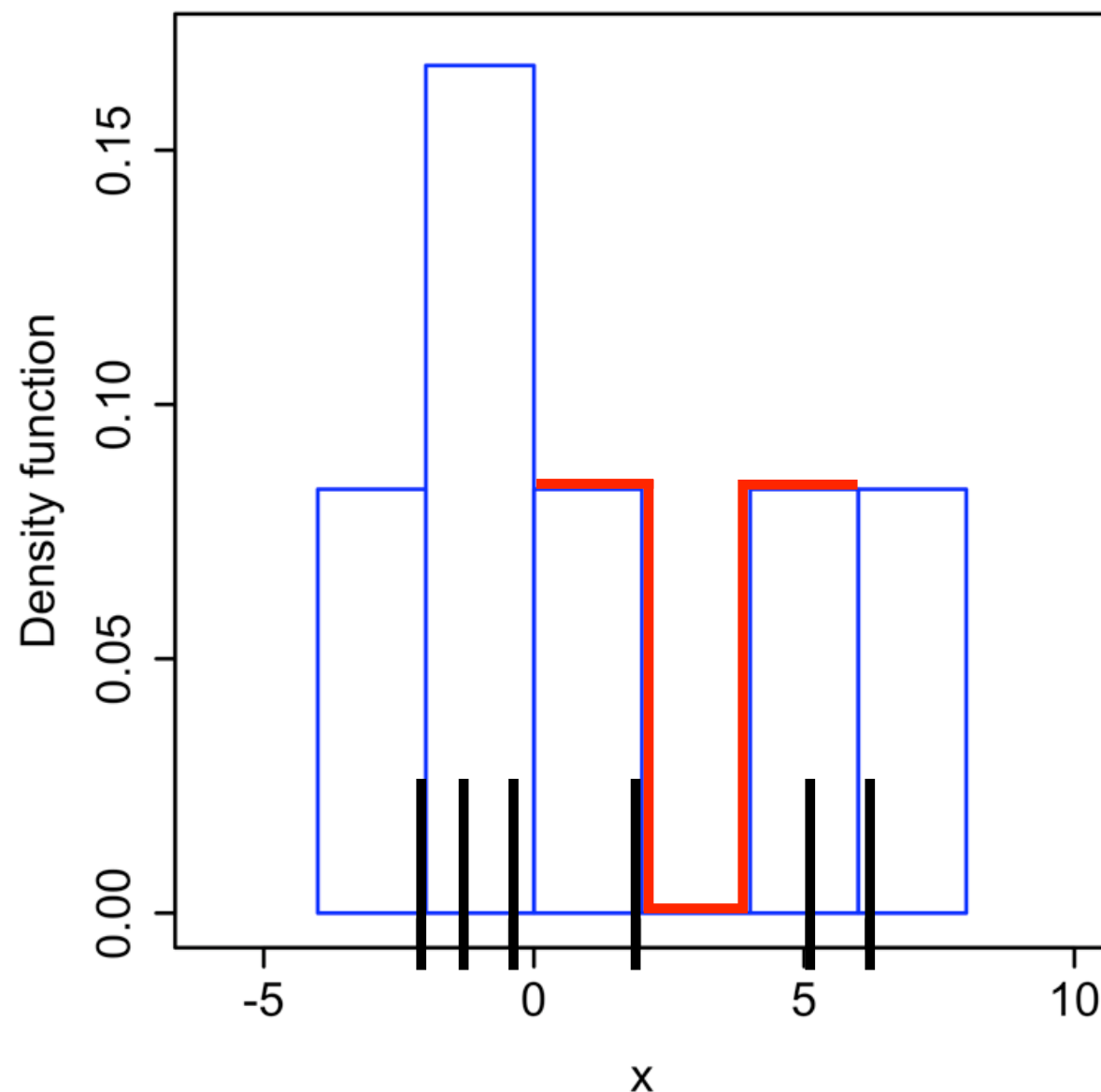
Kernel Density Estimation



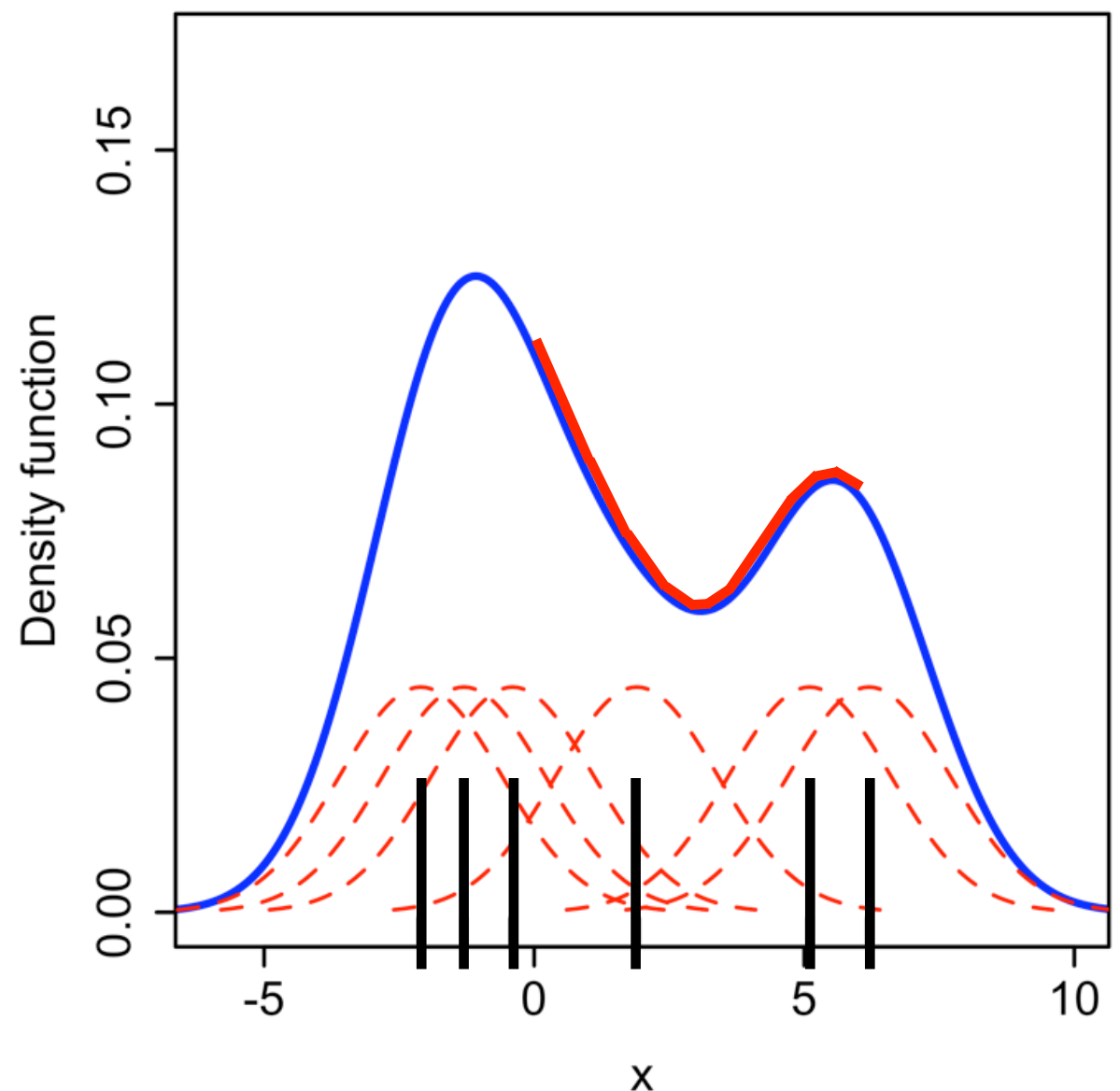
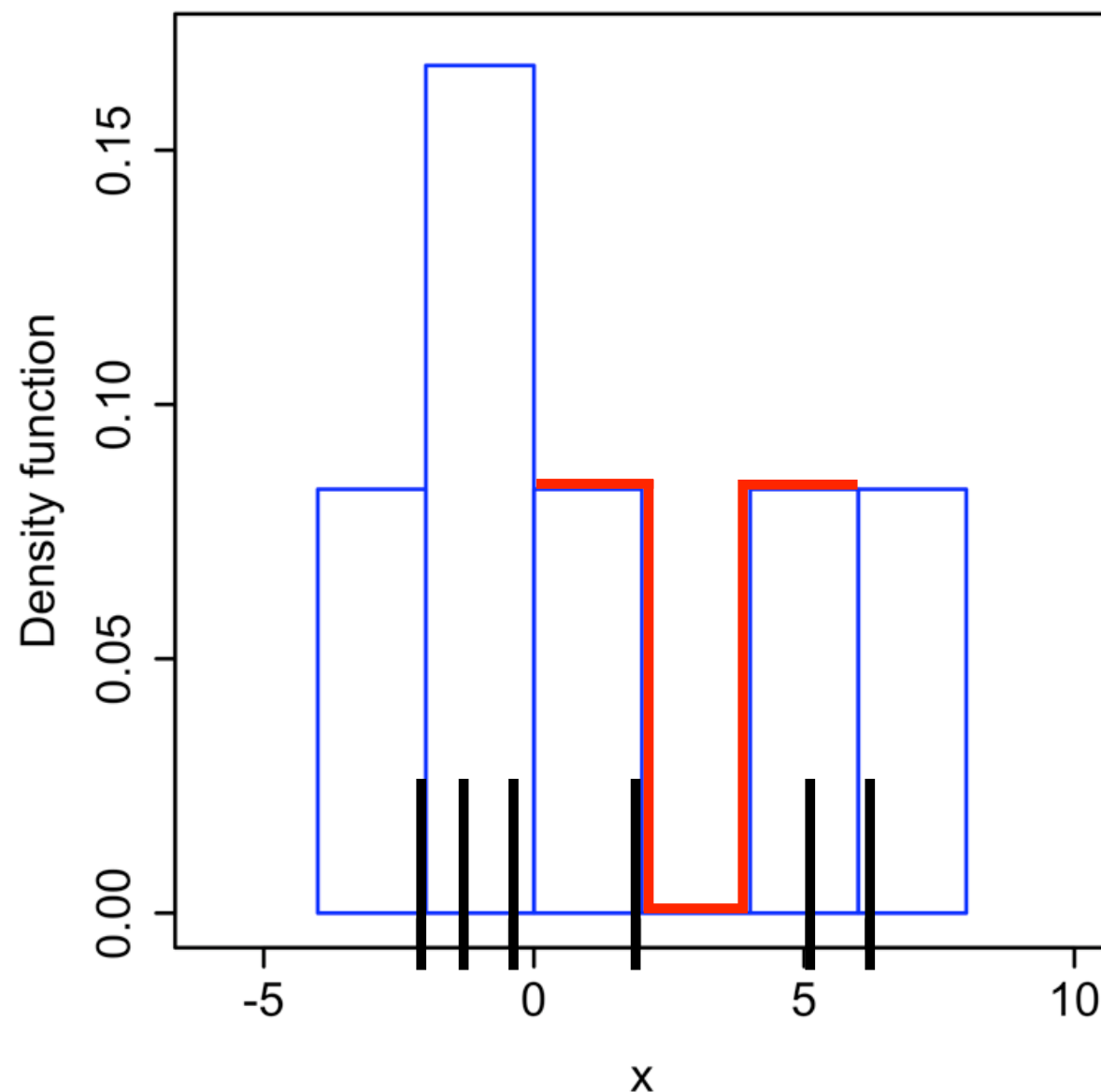
Kernel Density Estimation



Kernel Density Estimation



Kernel Density Estimation

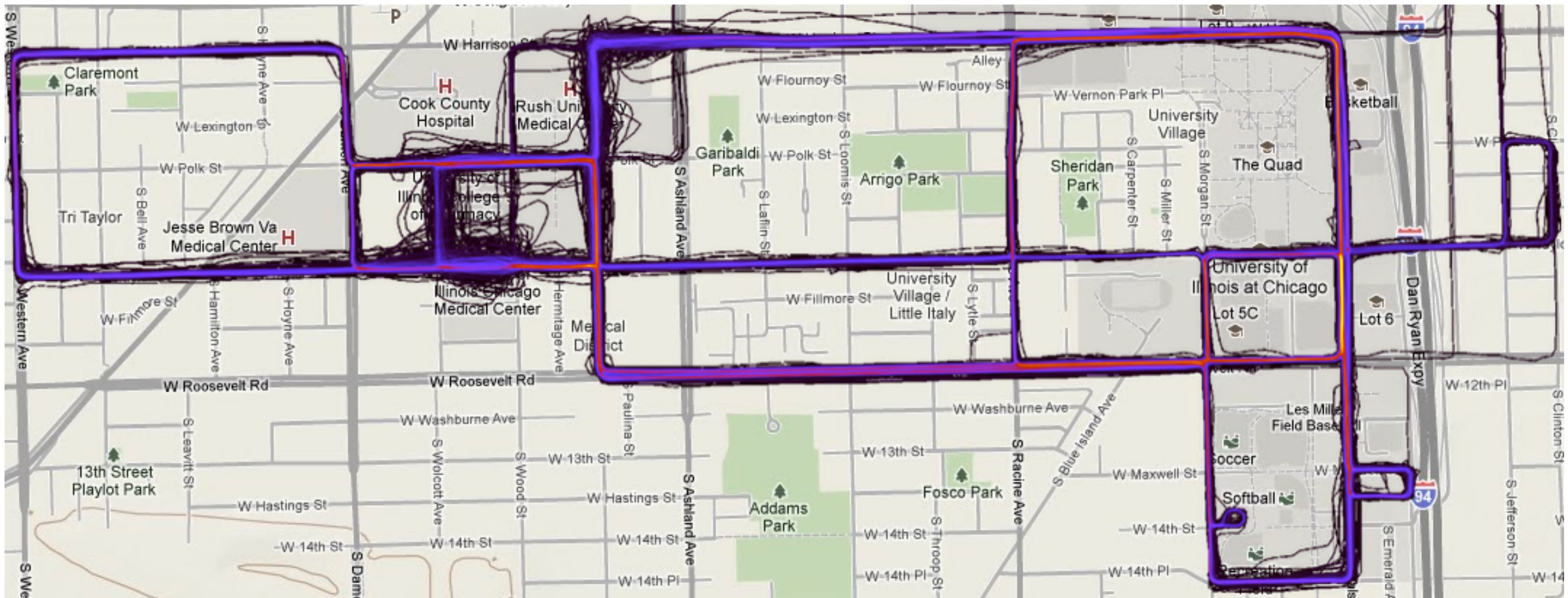


Kernel density estimation

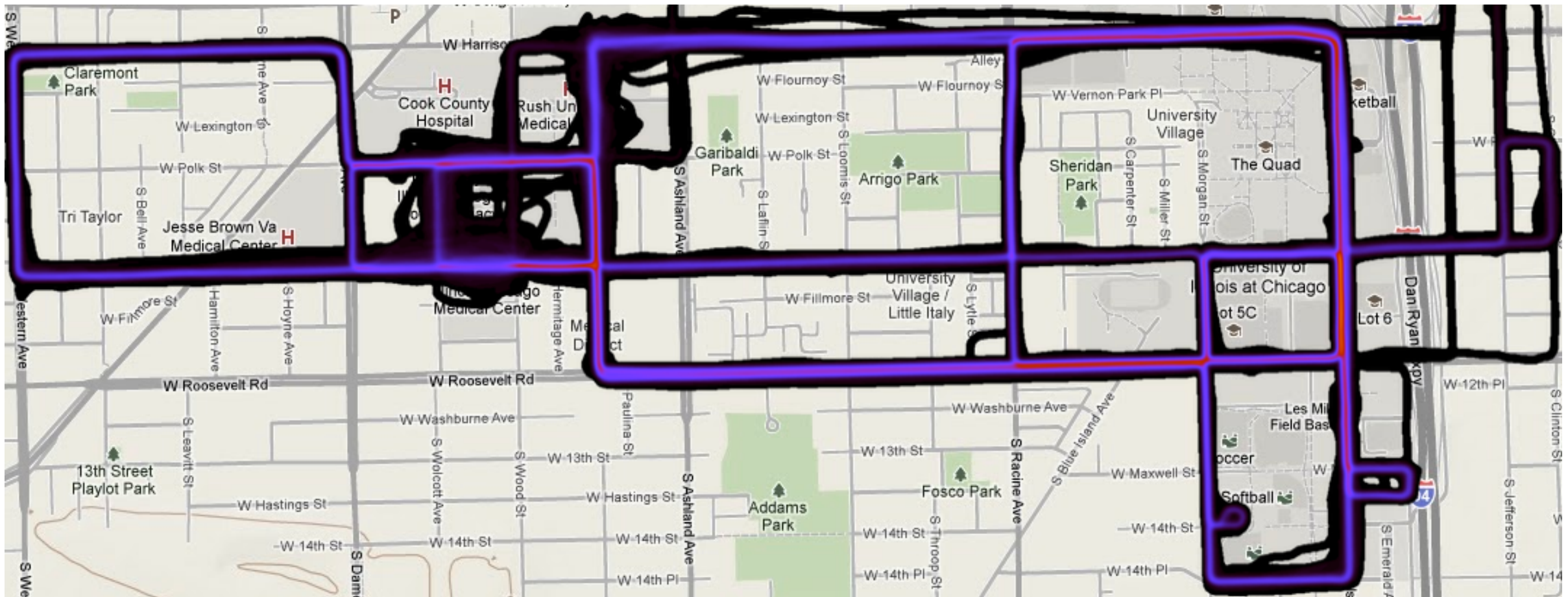
$$\hat{f}(x) = \frac{1}{n} \sum_{i=1}^n K(x - x_i)$$

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

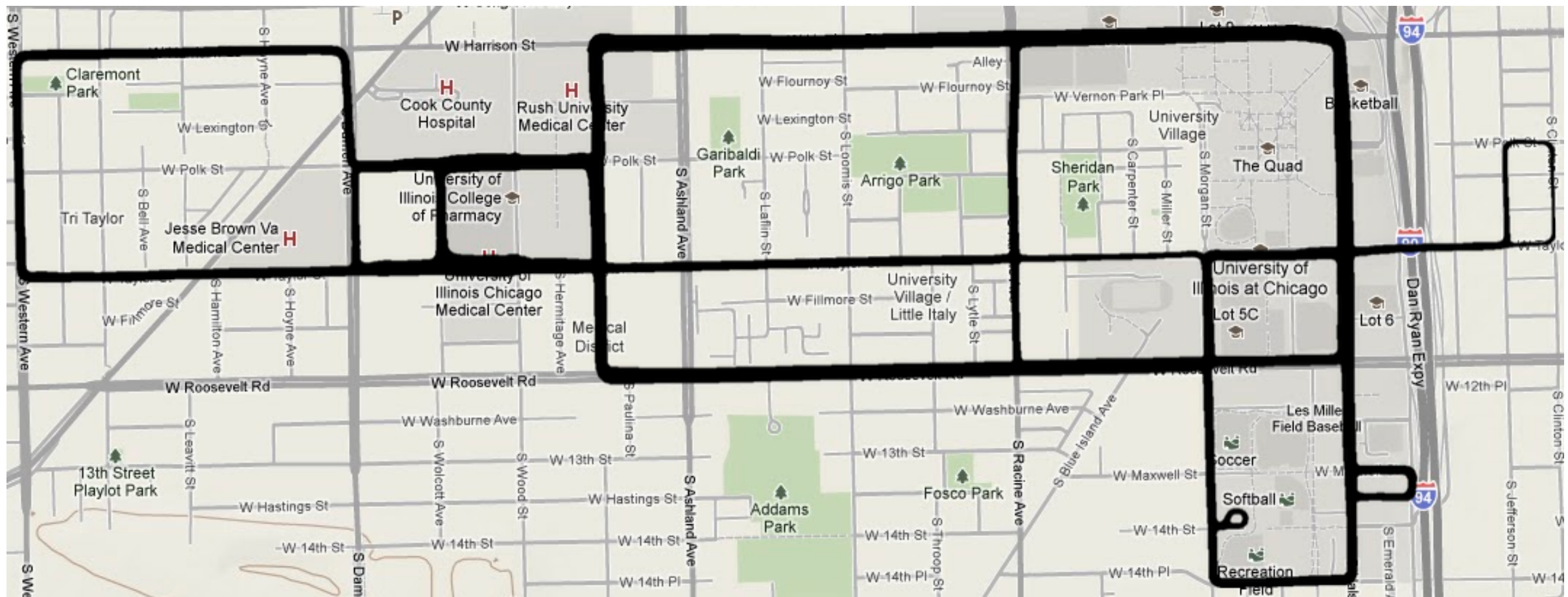
2-D histogram



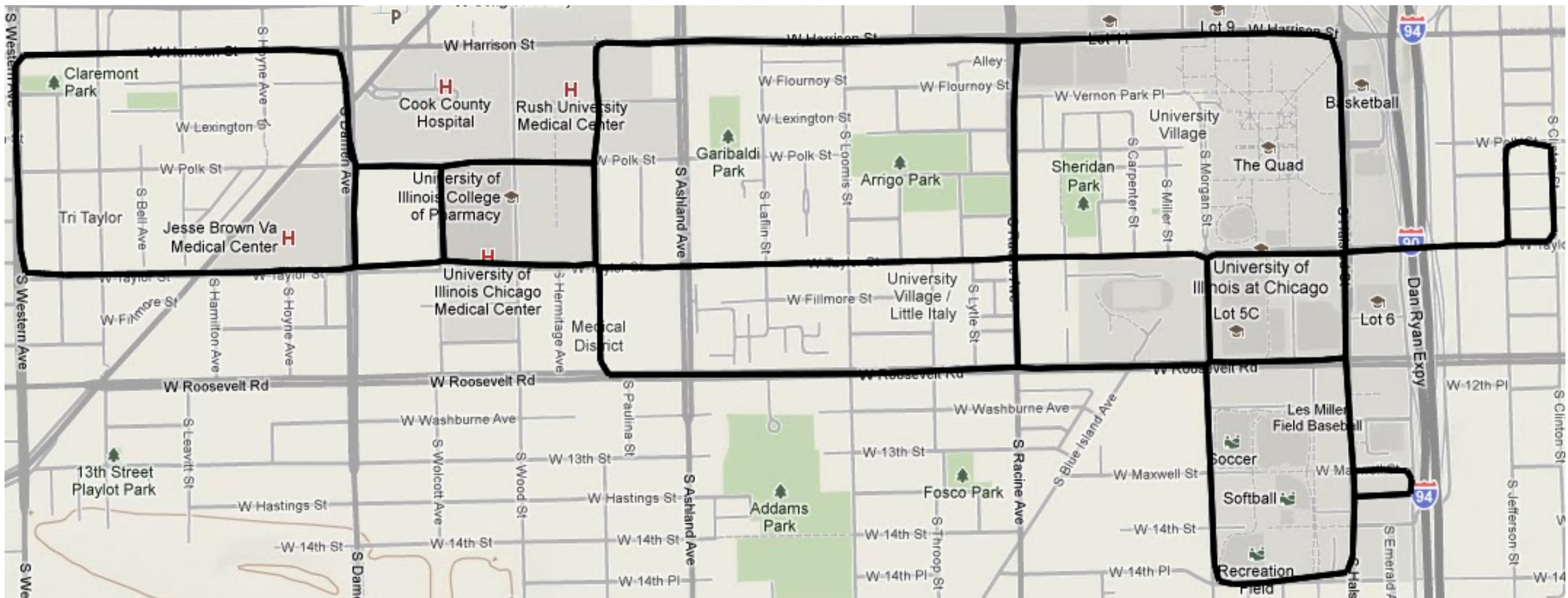
Trajectory density estimate



Thresholded image



Map extraction

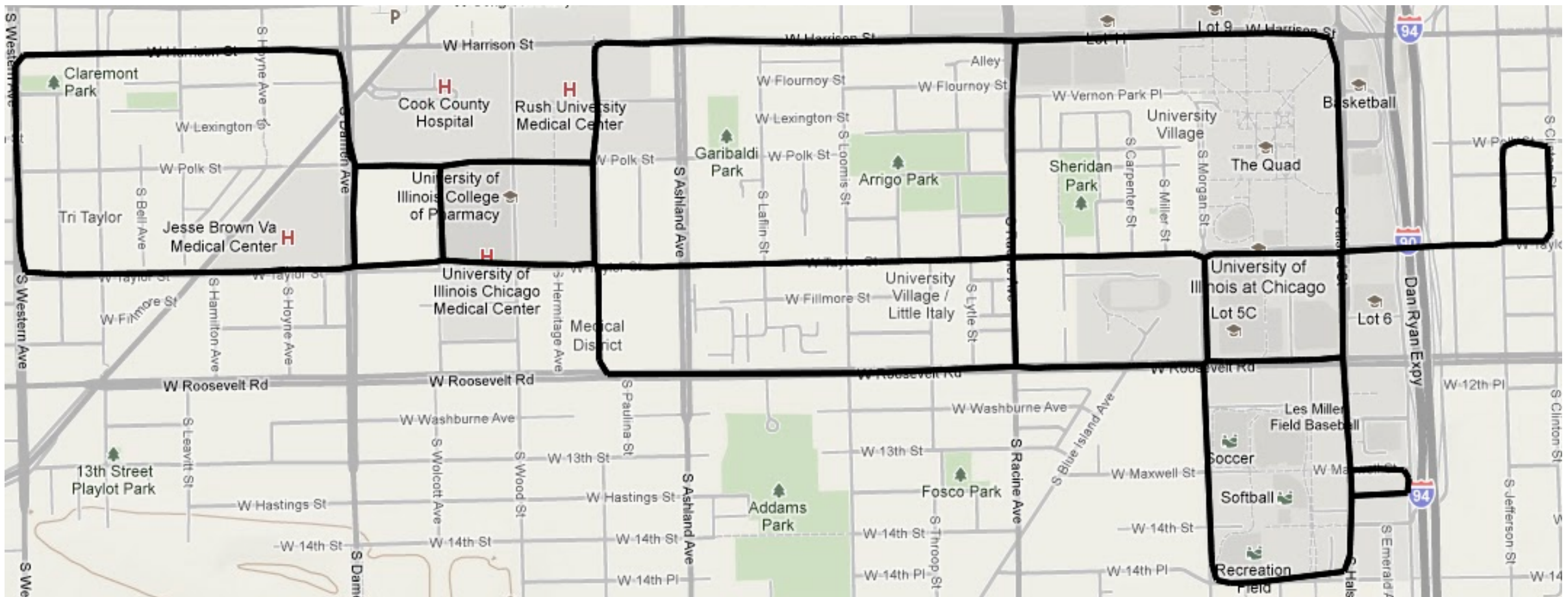


► Davies et al., 2006

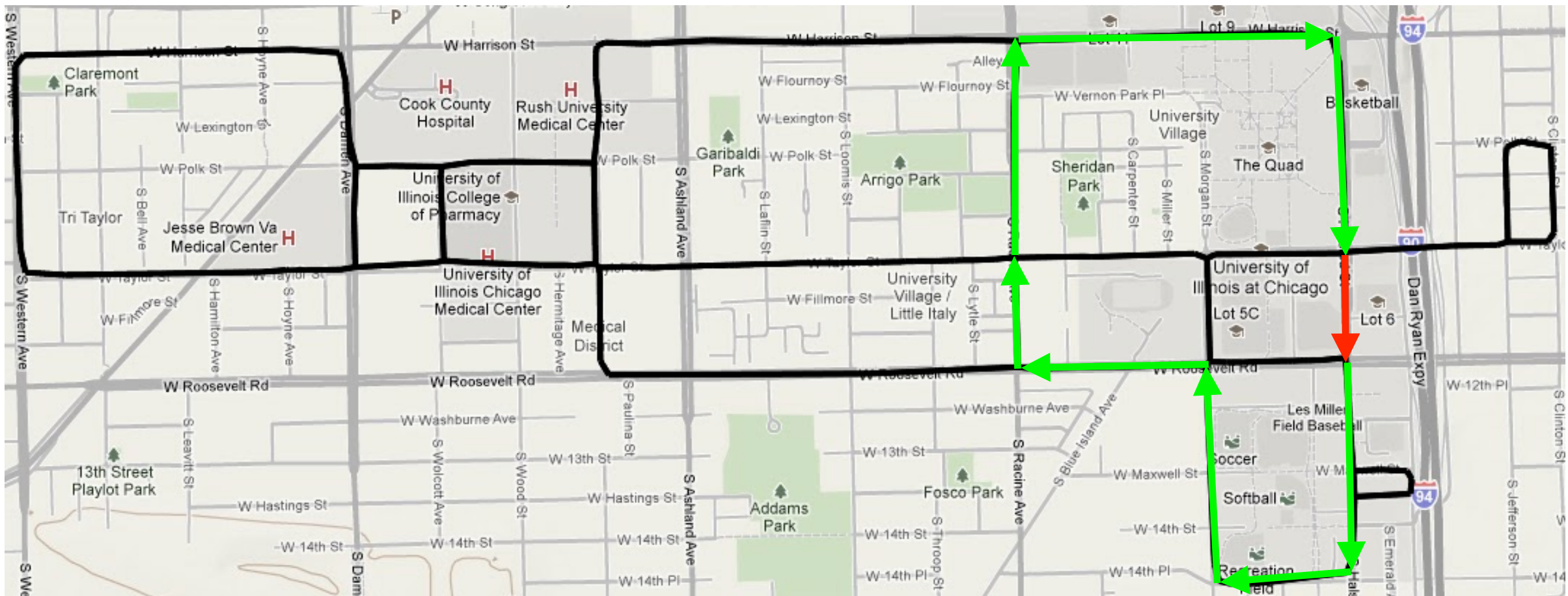
Route extraction

- ▶ 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

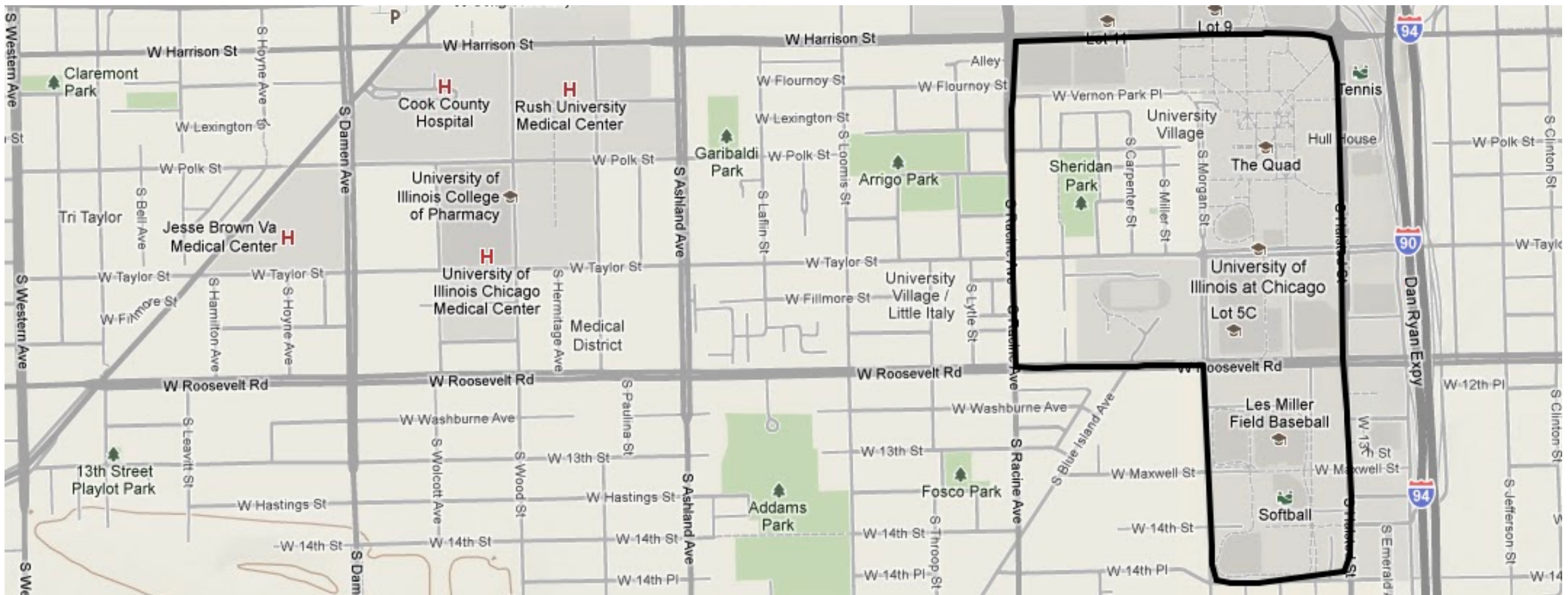
Route extraction



Route extraction



Route extraction

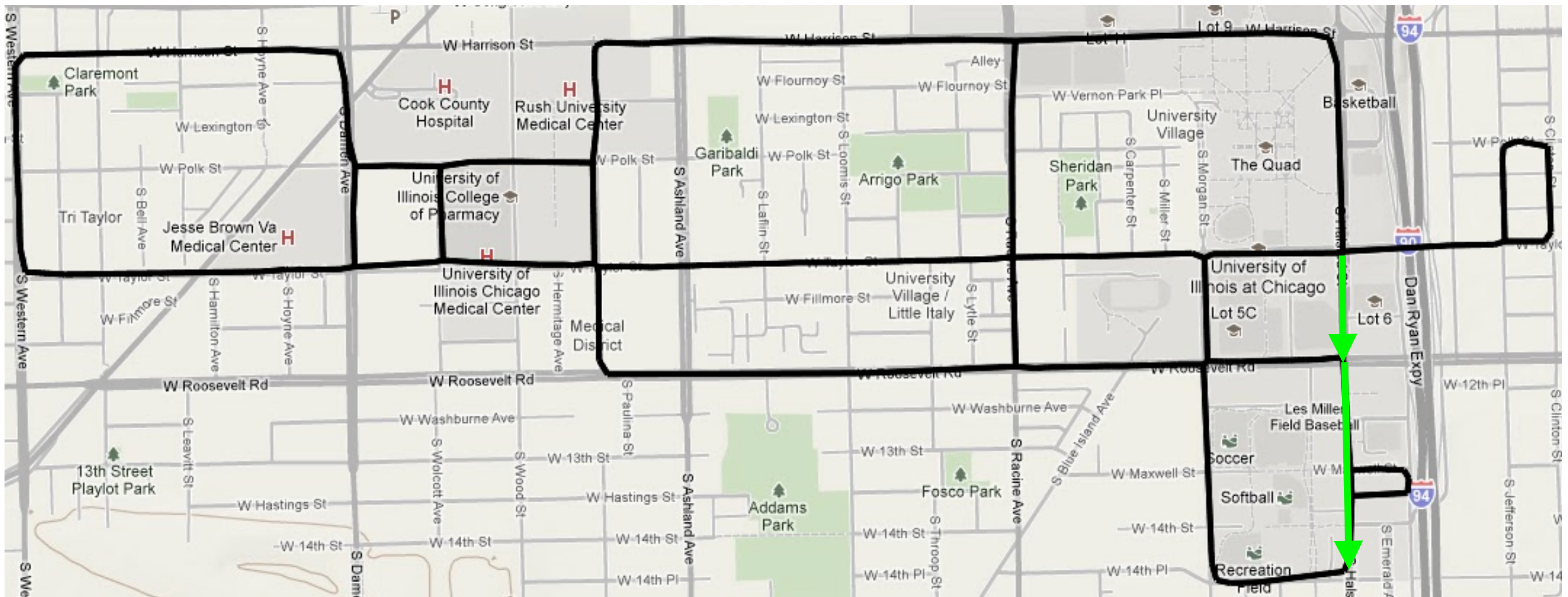


The map displays the University City neighborhood in Chicago, bounded by W Harrison St to the north, W 14th St to the south, S Western Ave to the west, and the Dan Ryan Expressway (I-55) to the east. A thick black line outlines a specific area within the neighborhood, which includes several blocks. Key landmarks and streets shown include:

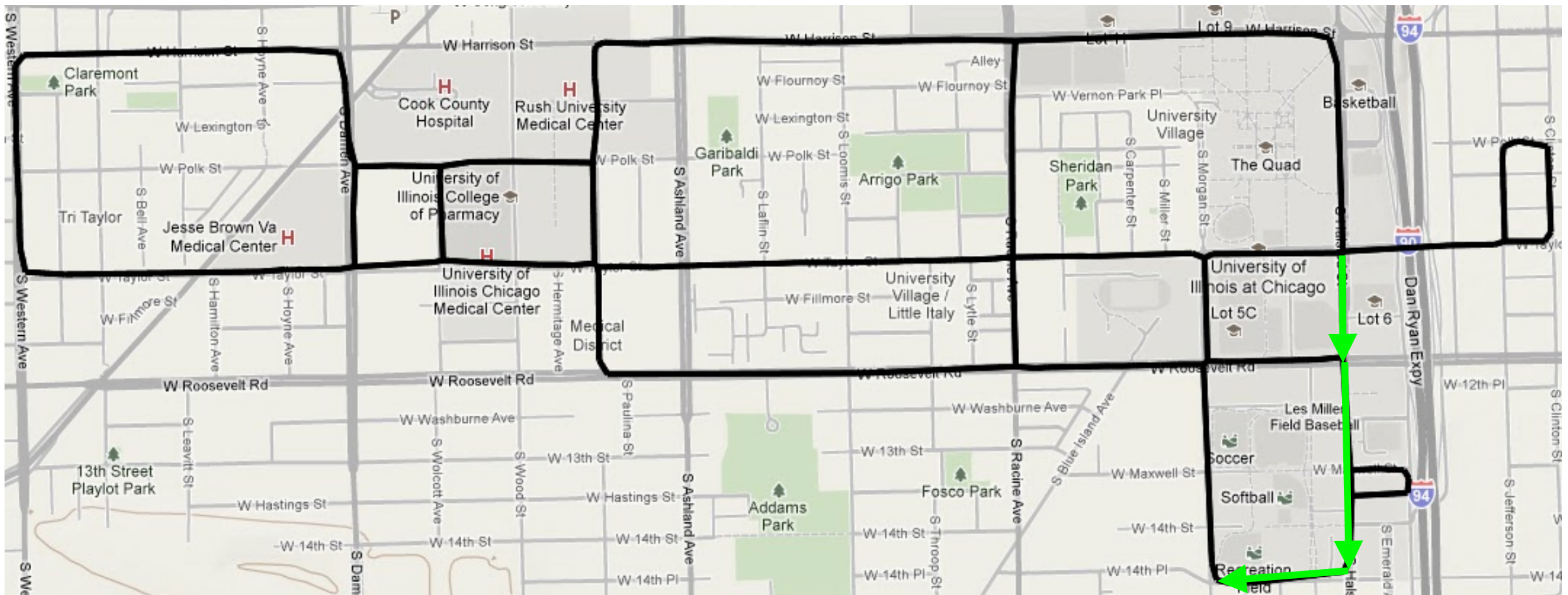
- Streets:** W Harrison St, W Flornoy St, W Lexington St, W Polk St, W Fillmore St, W Roosevelt Rd, W Washburne Ave, W 13th St, W Hastings St, W 14th St, W 14th Pl, S Western Ave, S Hamilton Ave, S Leavitt St, S Ashland Ave, S Paulina St, S Wood St, S Throop St, S Racine Ave, S Belmont Ave, S Dearborn Ave, S Loomis St, S Lavin St, S Morgan St, S Miller St, S Carpenter St, S Belmont Ave, S Dearborn Ave, S Loomis St, S Lavin St, S Morgan St, S Miller St, S Carpenter St.
- Parks and Recreation:** Claremont Park, Garibaldi Park, Arrigo Park, Sheridan Park, Addams Park, Fosco Park, 13th Street Playlot Park, The Quad, Les Miller Field Baseball, Soccer, Softball, Recreation Field.
- Landmarks and Institutions:** Cook County Hospital, Rush University Medical Center, University of Illinois at Chicago, University Village, Little Italy, Medical District, Jesse Brown Va Medical Center, University of Illinois College of Pharmacy, University of Illinois Chicago Medical Center, Lot 5C, Lot 6, Lot 11, Lot 9.
- Transportation:** Dan Ryan Expressway (I-55), I-94, I-55, I-94.

The map shows the University City neighborhood in Chicago, bounded by W Harrison St to the north, W 14th St to the south, S Western Ave to the west, and S Ashland Ave to the east. Key landmarks include Cook County Hospital, Rush University Medical Center, University of Illinois Chicago Medical Center, and University Village. Parks such as Garibaldi Park, Arrigo Park, Sheridan Park, and Addams Park are also shown. A green arrow points to the intersection of W Roosevelt Rd and S Ashland Ave.

Route extraction

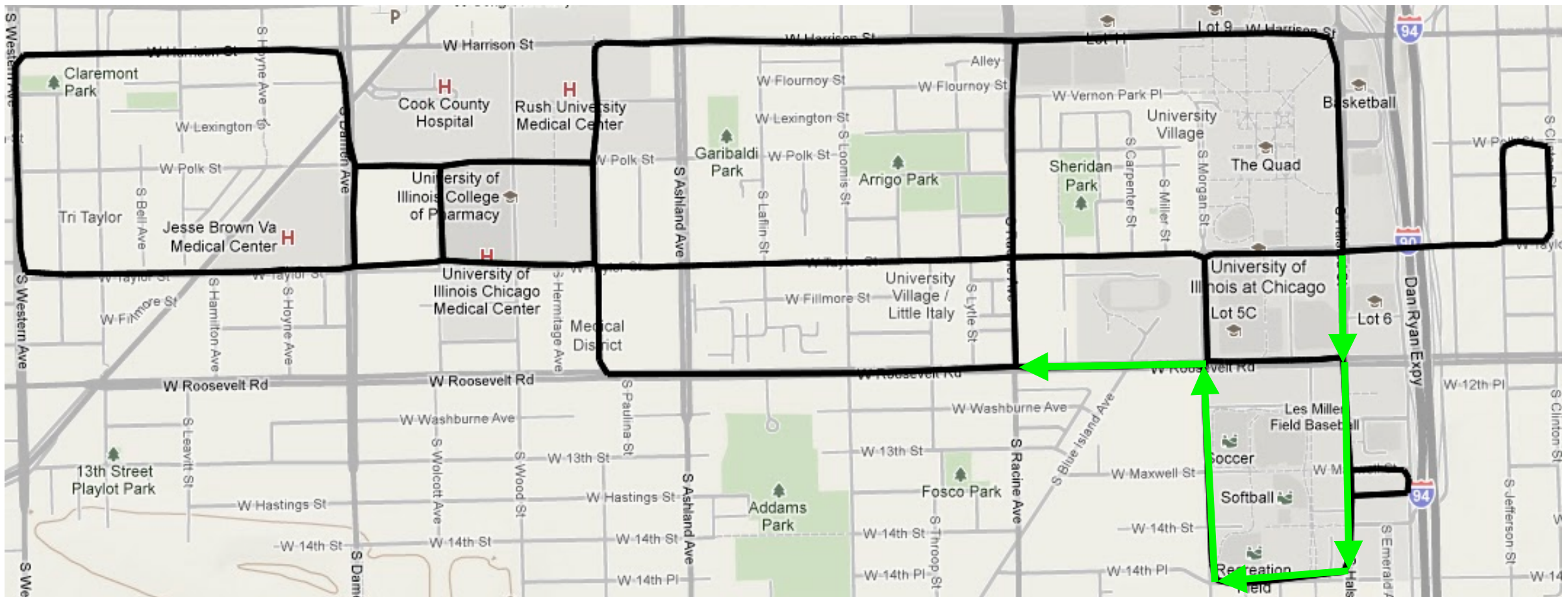


Route extraction

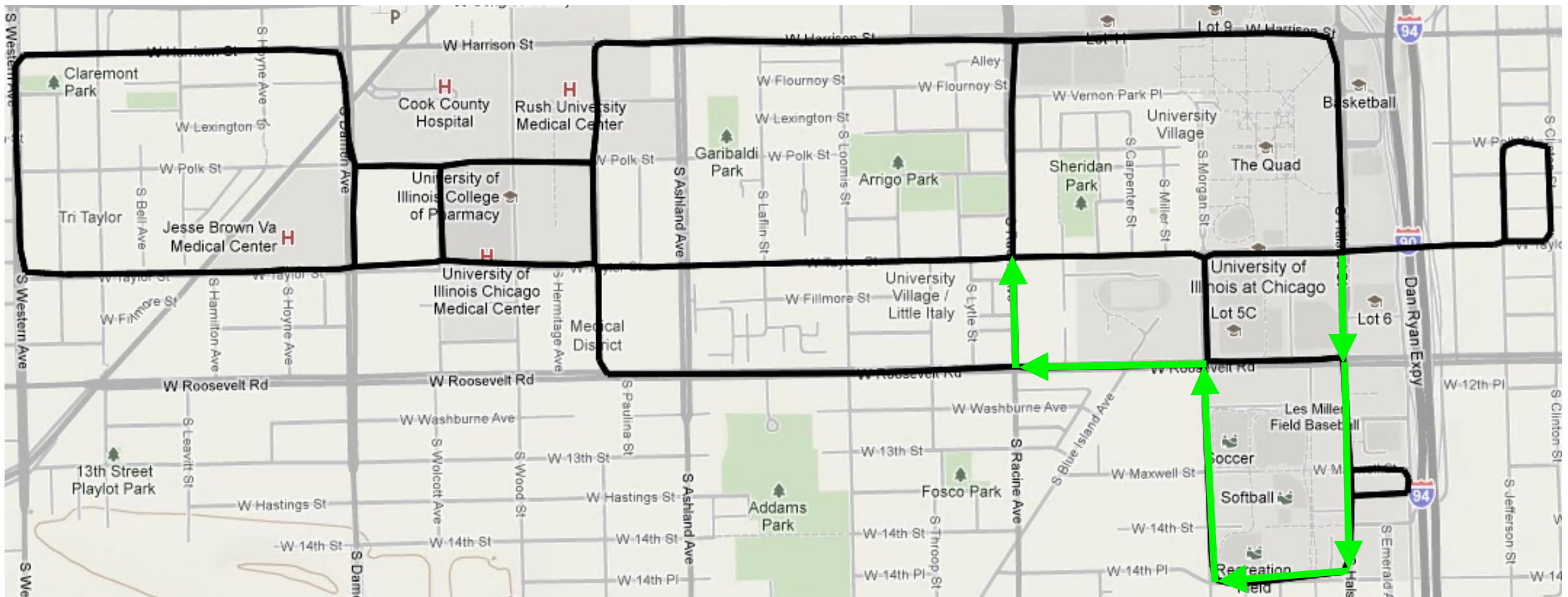


This map shows the University City neighborhood in Chicago, bounded by a thick black line. The neighborhood is situated between W Harrison St to the north and W Roosevelt Rd to the south, and S Western Ave to the west and S Ashland Ave to the east. Key landmarks include Cook County Hospital, Rush University Medical Center, University of Illinois College of Pharmacy, University of Illinois Chicago Medical Center, and the University of Illinois at Chicago. Parks such as Claremont Park, Garibaldi Park, Arrigo Park, Sheridan Park, Addams Park, and Fosco Park are also shown. The map includes a grid of streets and a green arrow pointing to the University of Illinois at Chicago.

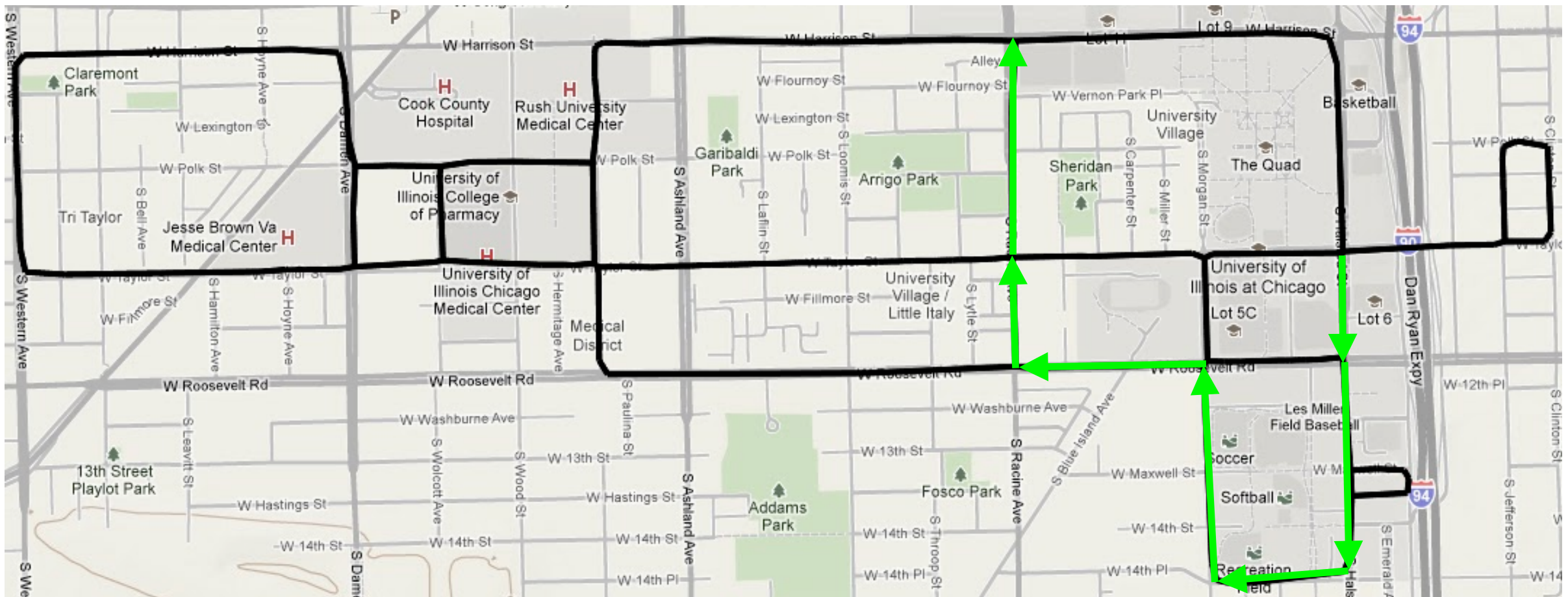
Route extraction



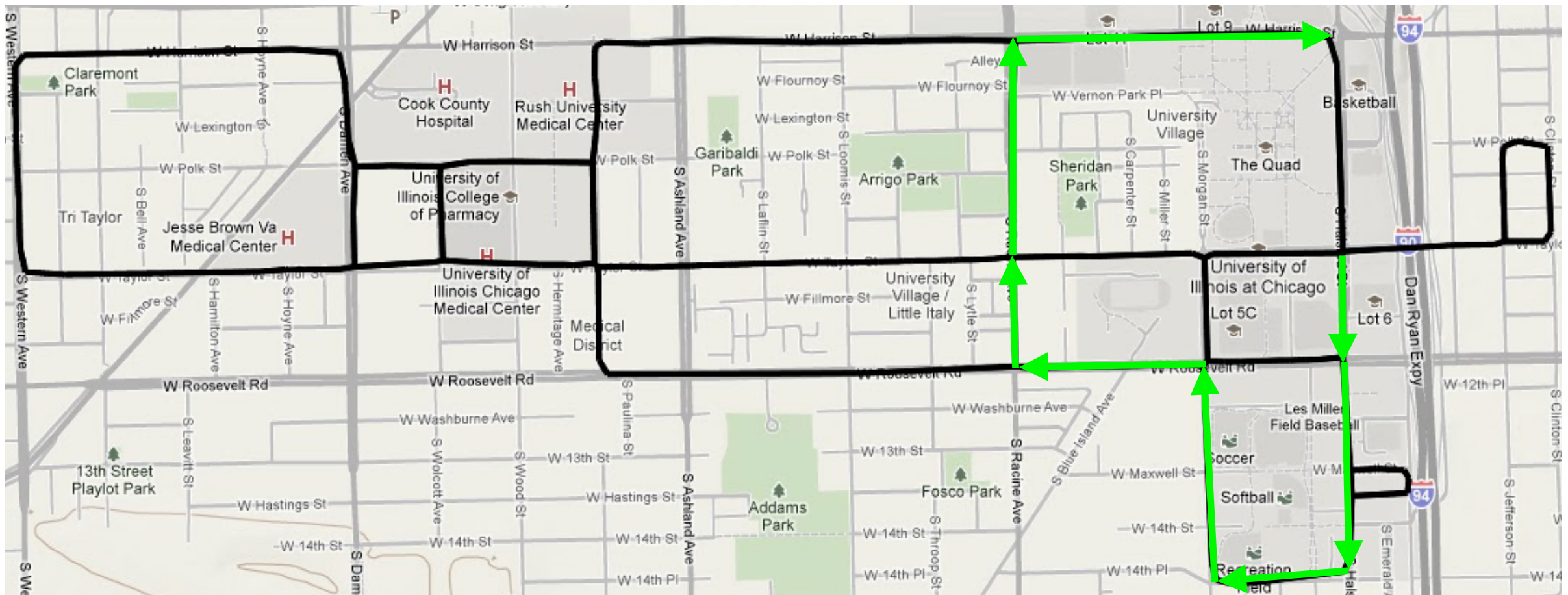
Route extraction



Route extraction

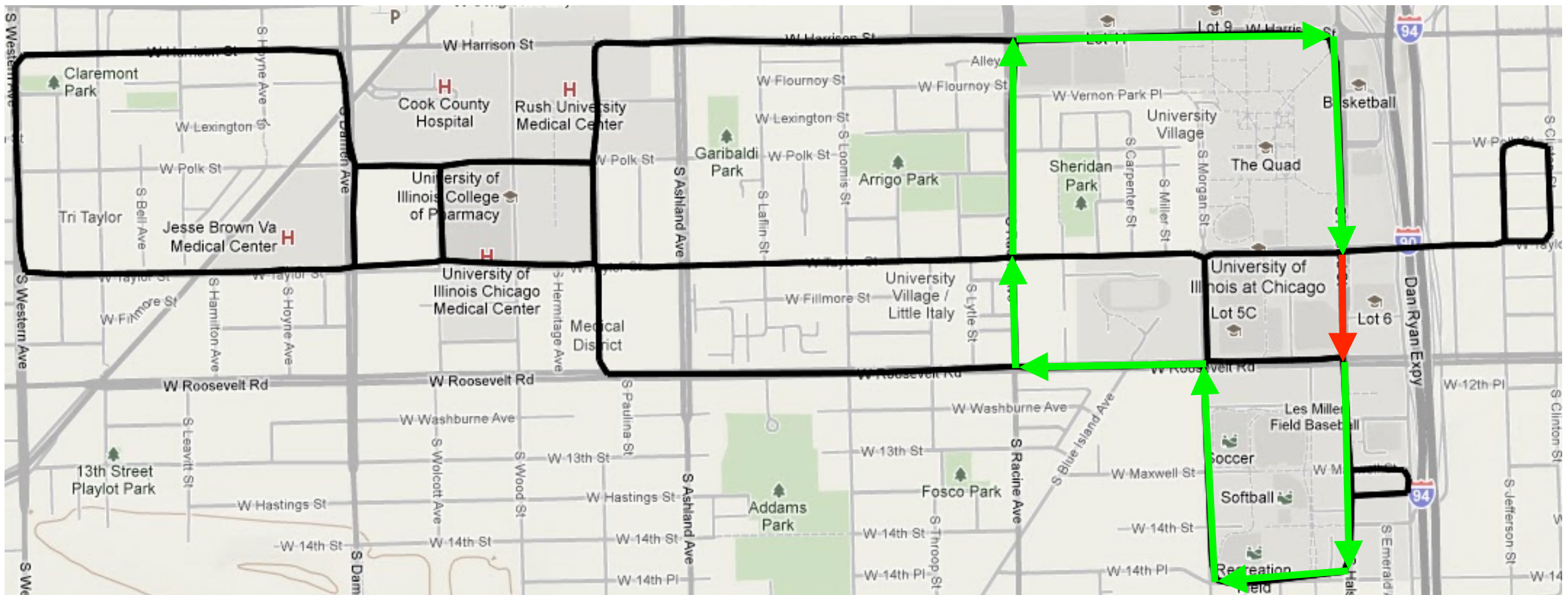


Route extraction

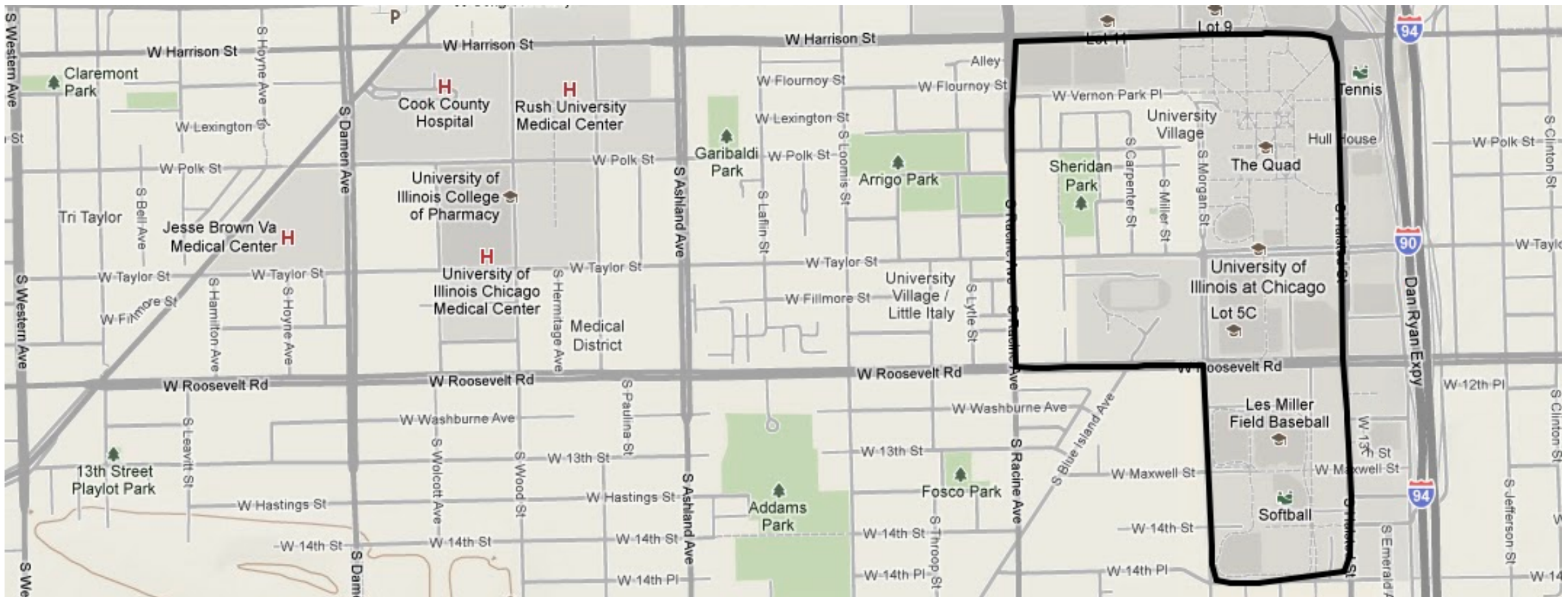


A detailed map of the University City neighborhood in Chicago. The map shows a grid of streets including W Harrison St, W Flounoy St, W Lexington St, W Polk St, W Taylor St, W Fillmore St, W Roosevelt Rd, W Washburne Ave, W-13th St, W Hastings St, W-14th St, S Ashtland Ave, S Loomis St, S Laflin St, S Hermitage Ave, S Paulina St, S Racine Ave, S Throop St, S Belmont Ave, S Morgan St, S Miller St, S Carpenter St, S Dearborn St, S Western Ave, S Leavitt St, S Hamilton Ave, S Hoyne Ave, S Bell Ave, S Clinton St, S Jefferson St, S Emerald Ave, and Dan Ryan Expy. Key landmarks include Cook County Hospital, Rush University Medical Center, University of Illinois College of Pharmacy, Jesse Brown VA Medical Center, University of Illinois Chicago Medical Center, University Village / Little Italy, University Village, The Quad, Sheridan Park, Garibaldi Park, Arrigo Park, Addams Park, Fosco Park, Claremont Park, Tri Taylor, 13th Street Playlot Park, Les Miller Field Baseball, Soccer, Softball, and Recreation field. A green arrow indicates a route starting from the top right, going left along W Harrison St, down S Ashtland Ave, left along W Roosevelt Rd, up S Racine Ave, and right along W-14th St. A black outline highlights a large rectangular area covering most of the map.

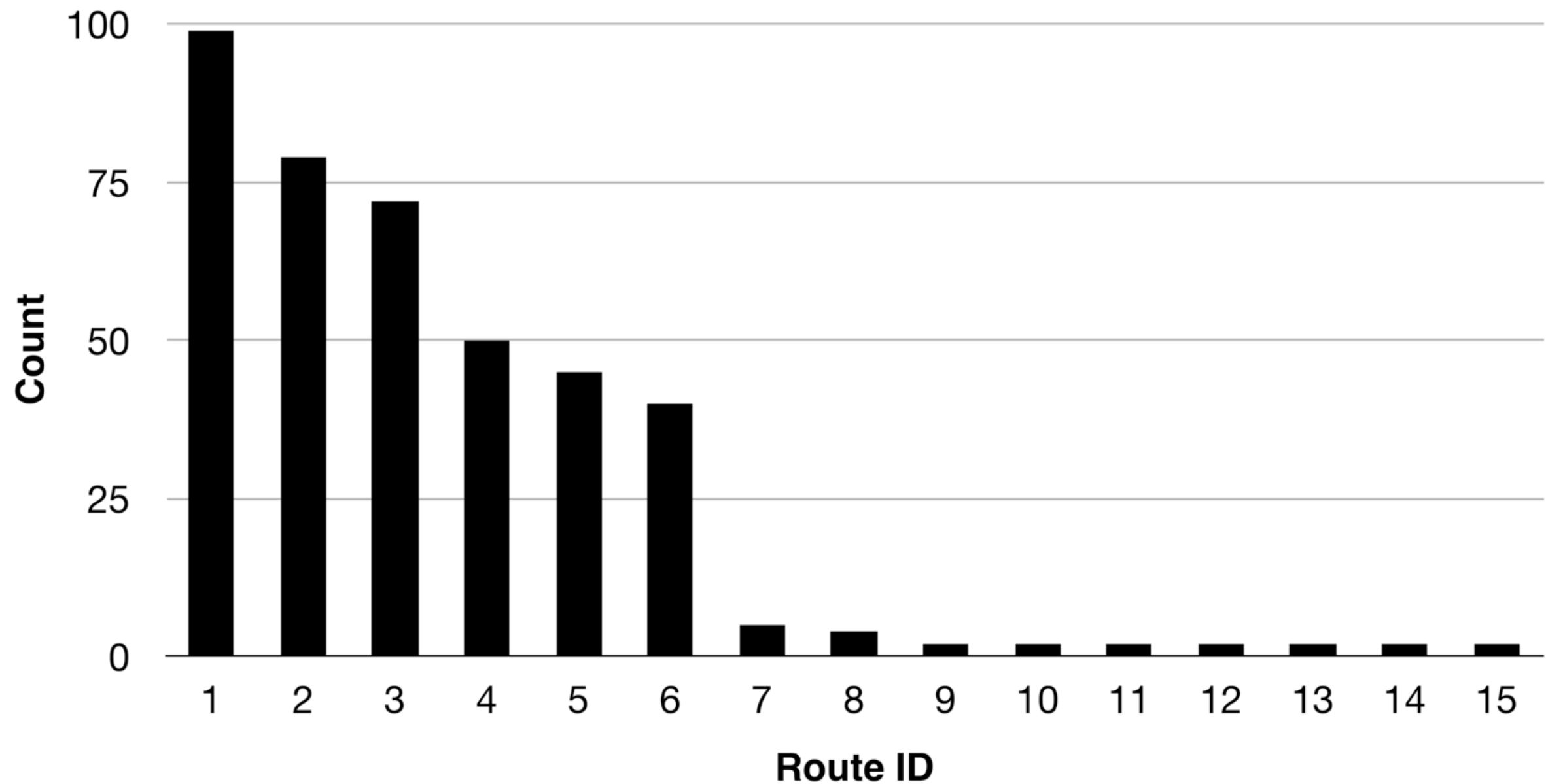
Route extraction



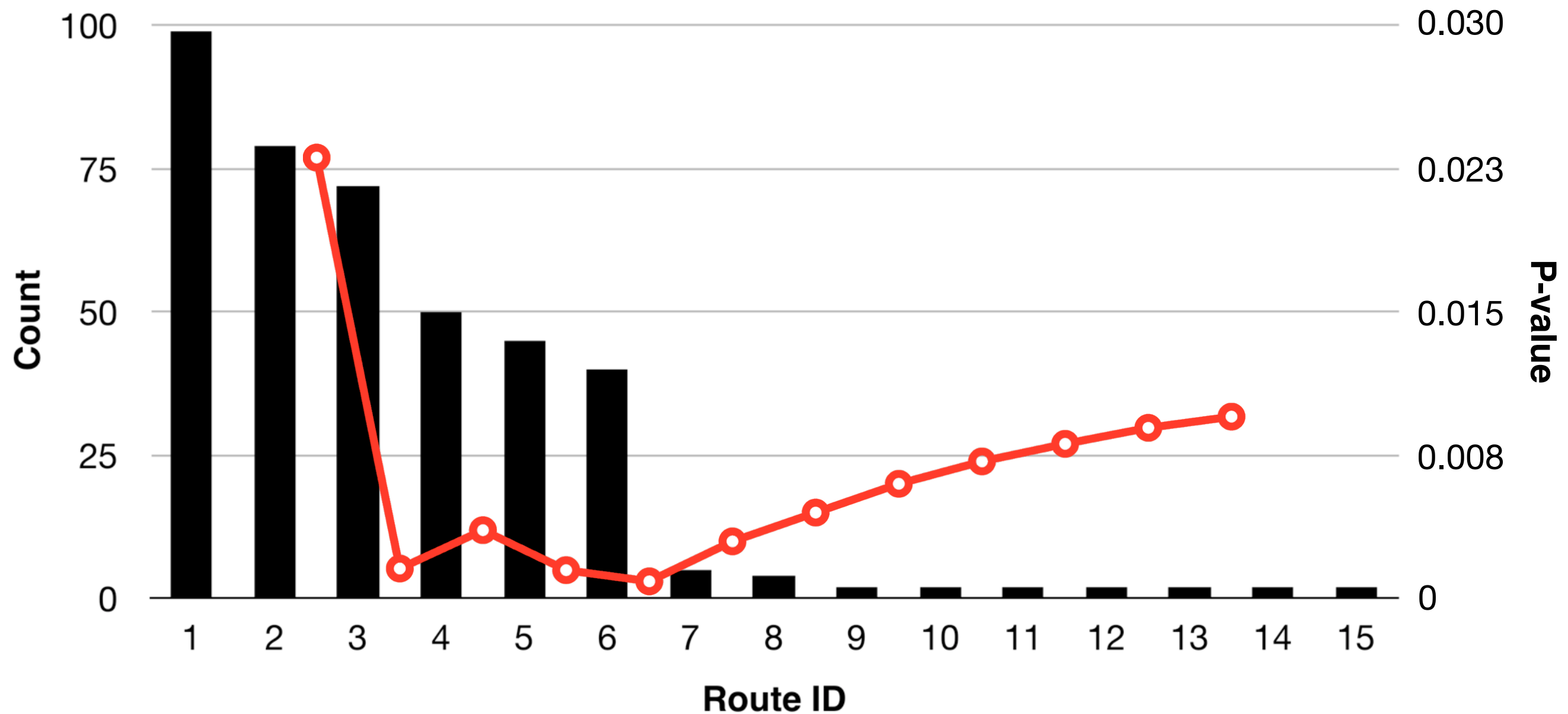
Route extraction



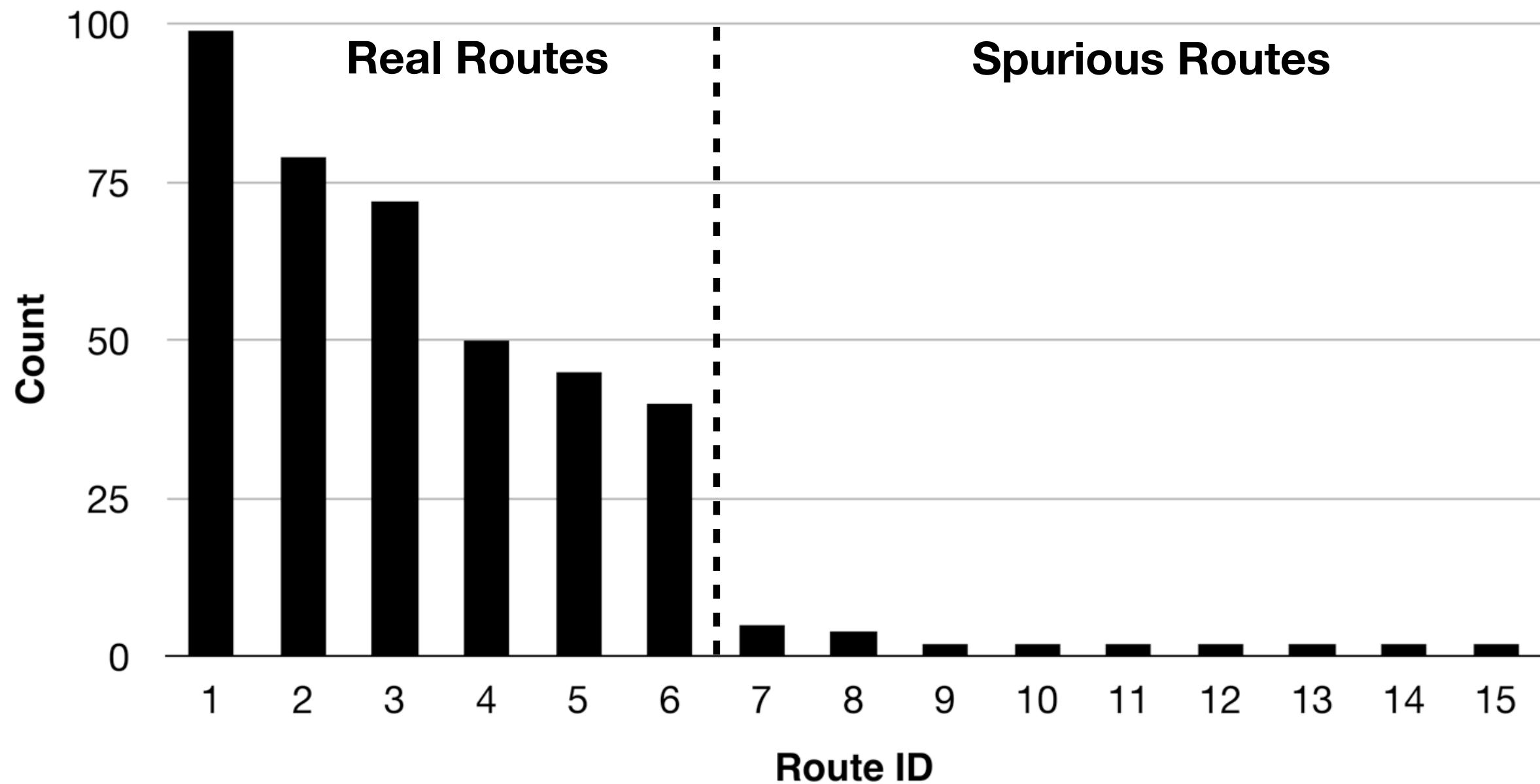
Route extraction results



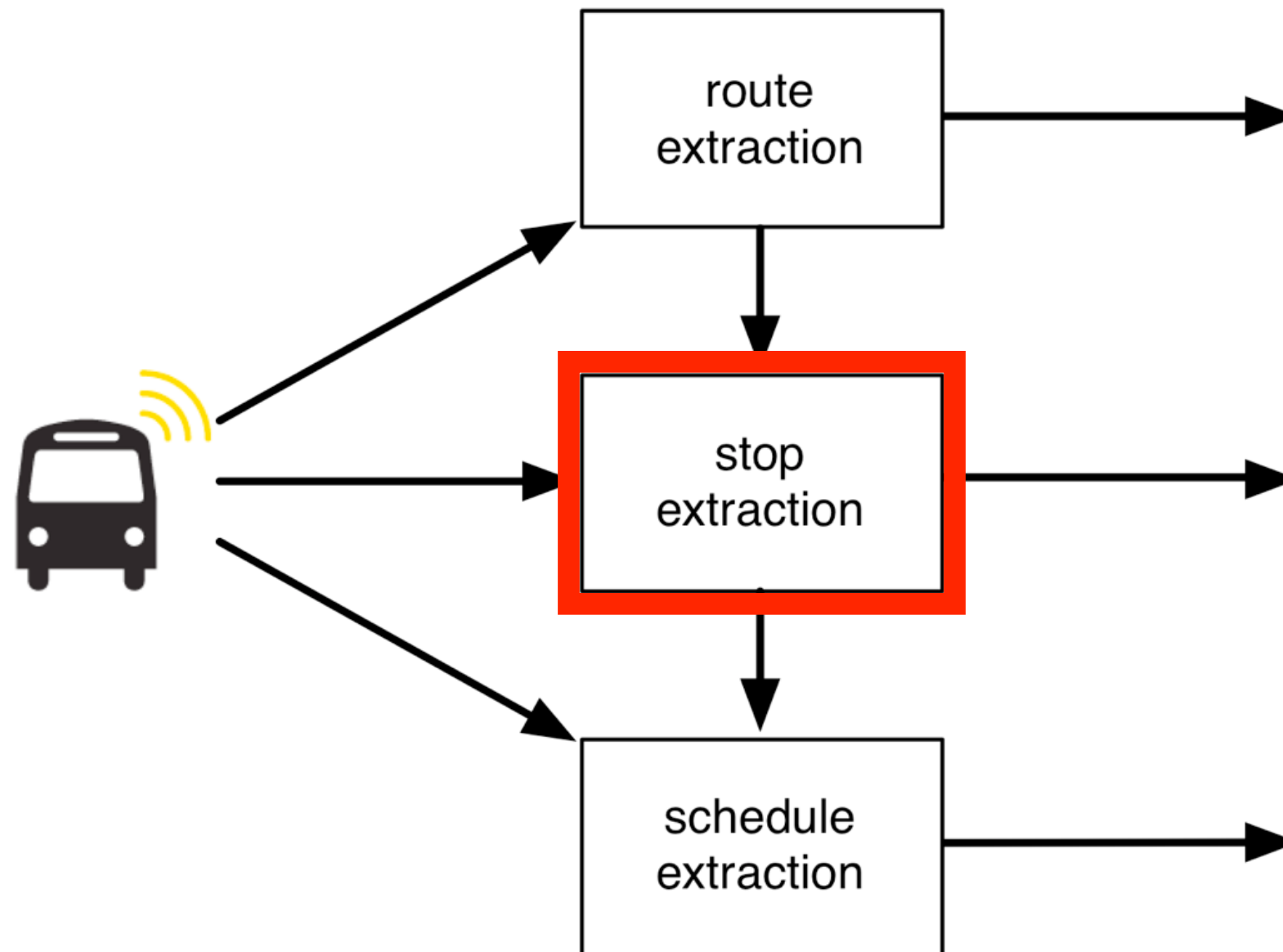
Welch's t -Test



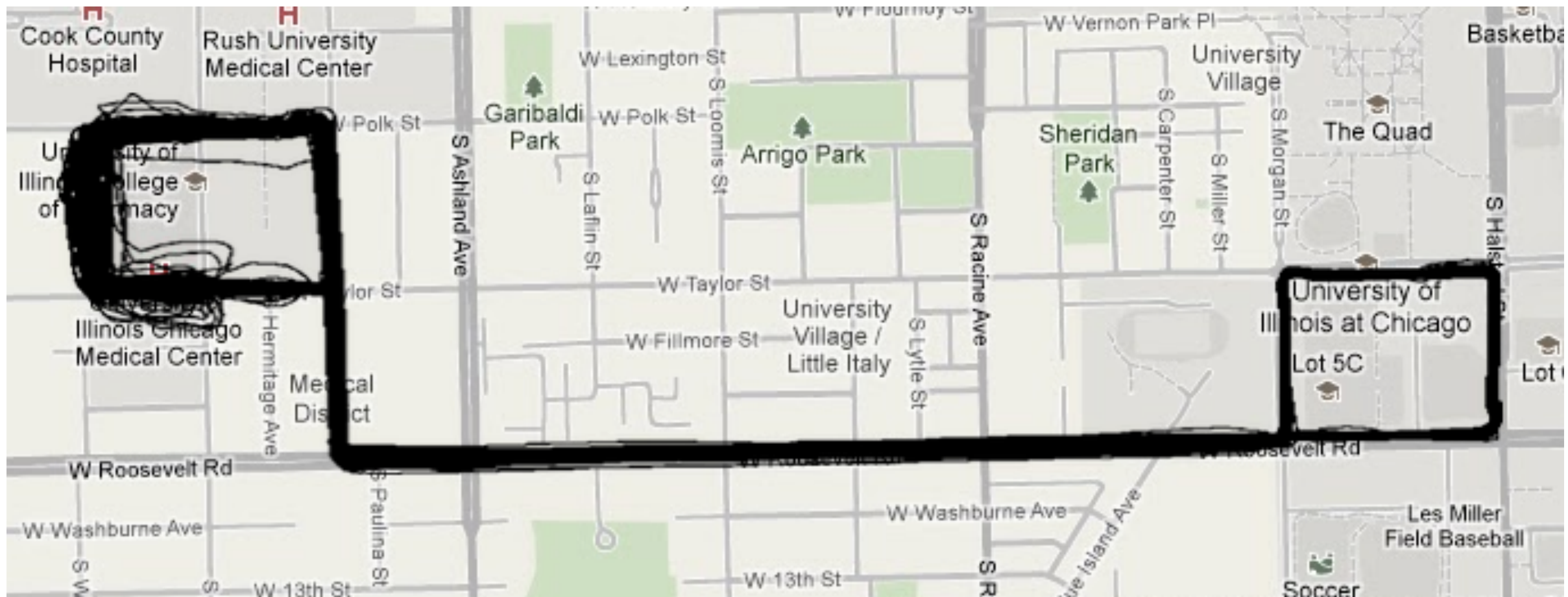
Routes separated



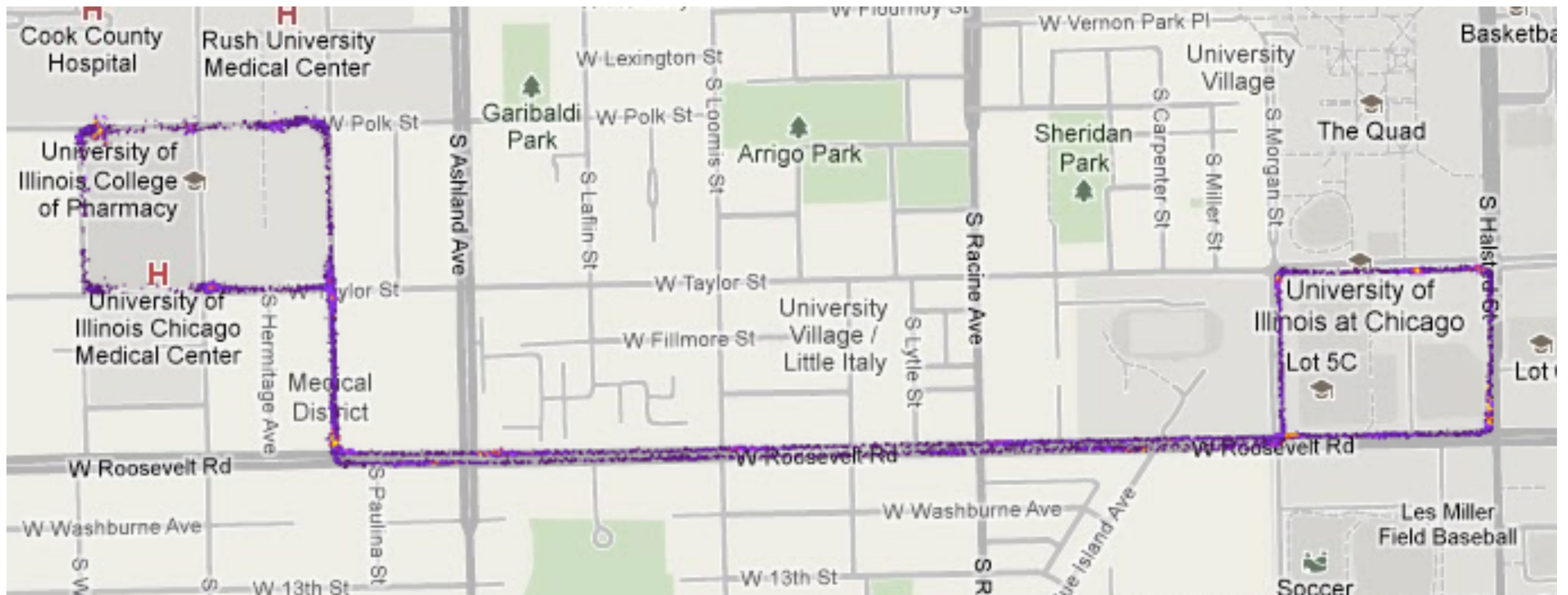
Stop extraction



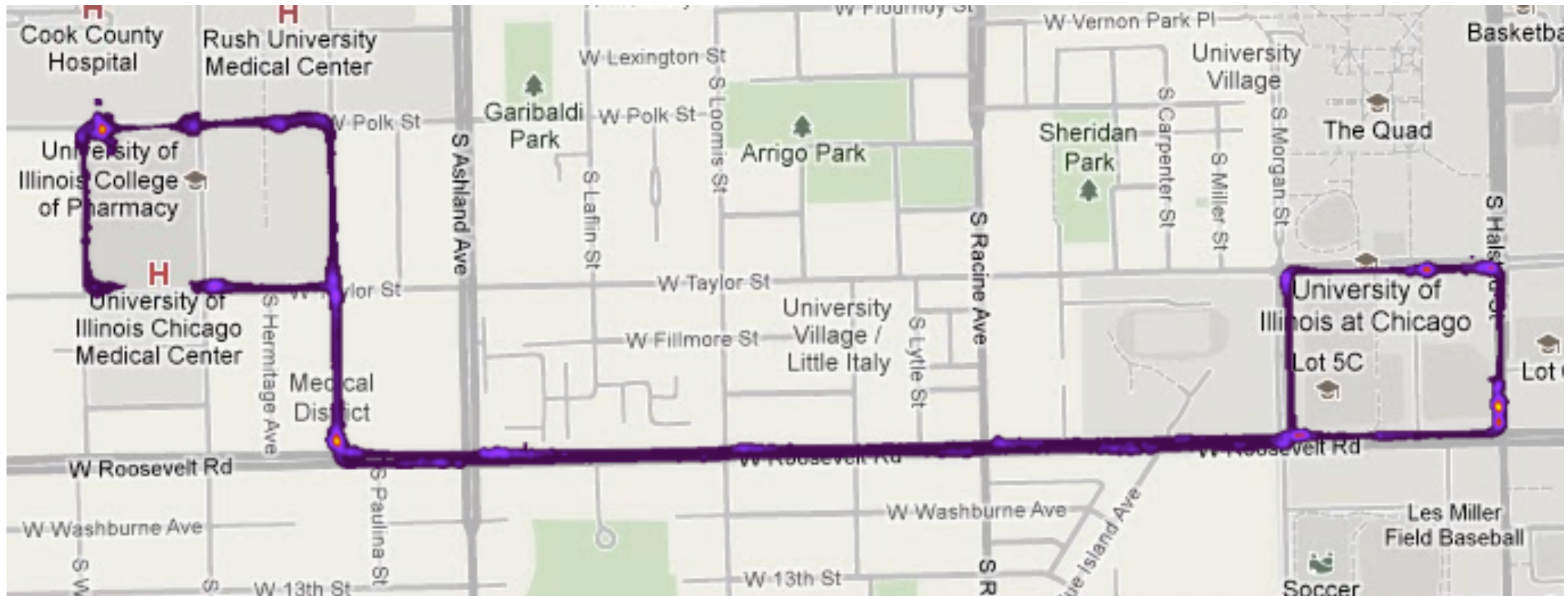
Route-labeled GPS traces



2-D histogram



Point density estimate



Thresholded binary image



Noise in binary image



Noise reduced binary image



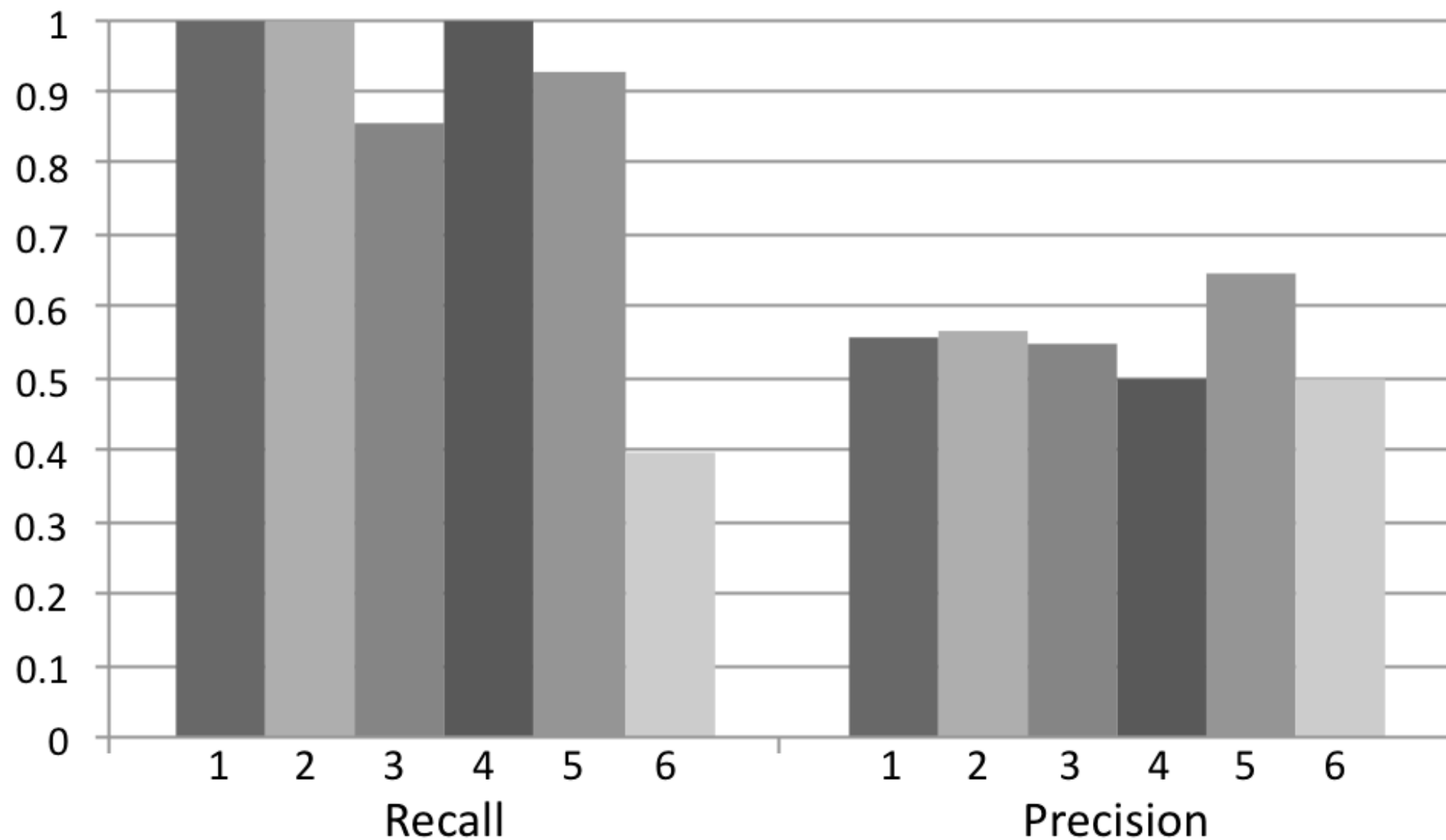
Stop extraction



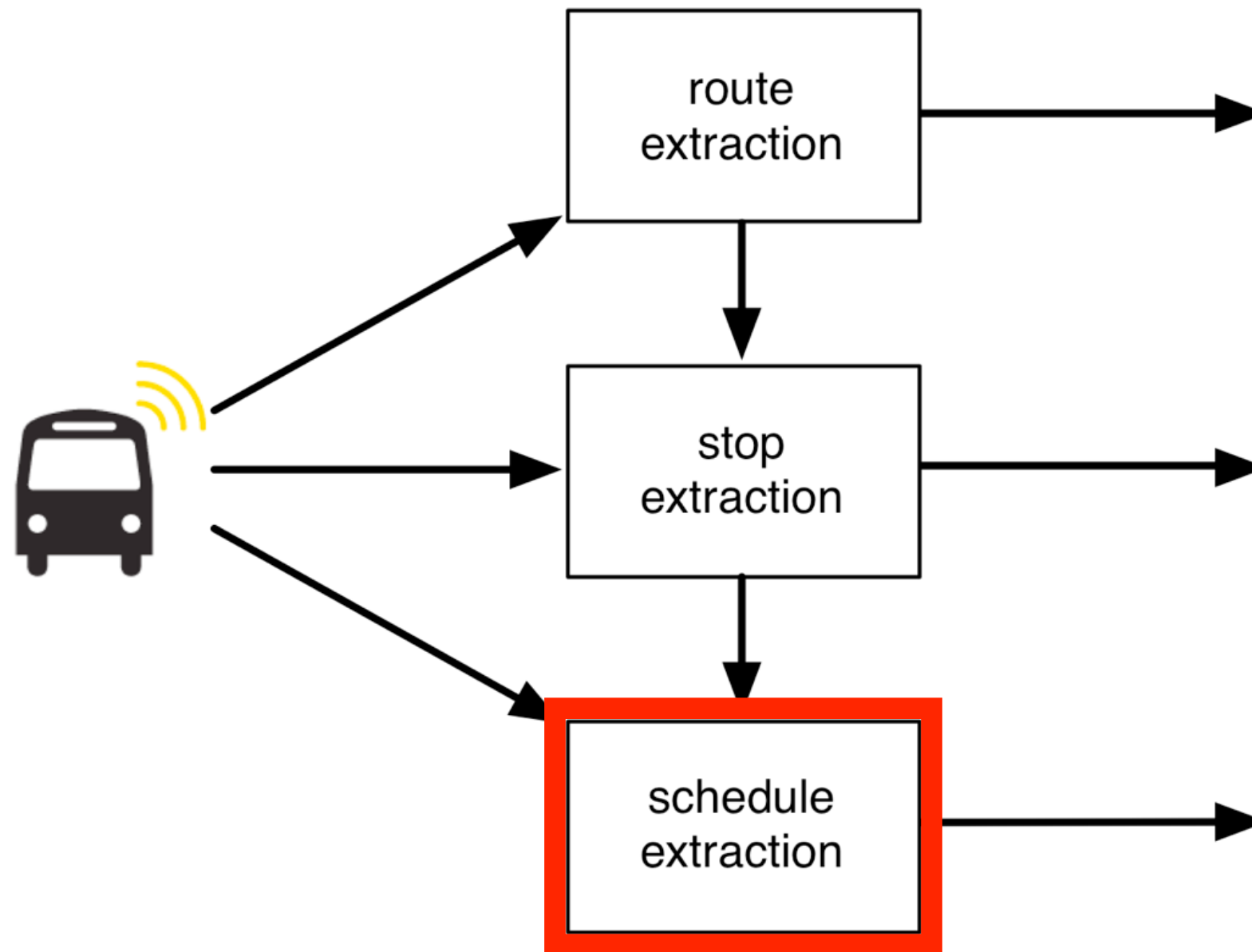
Stop extraction



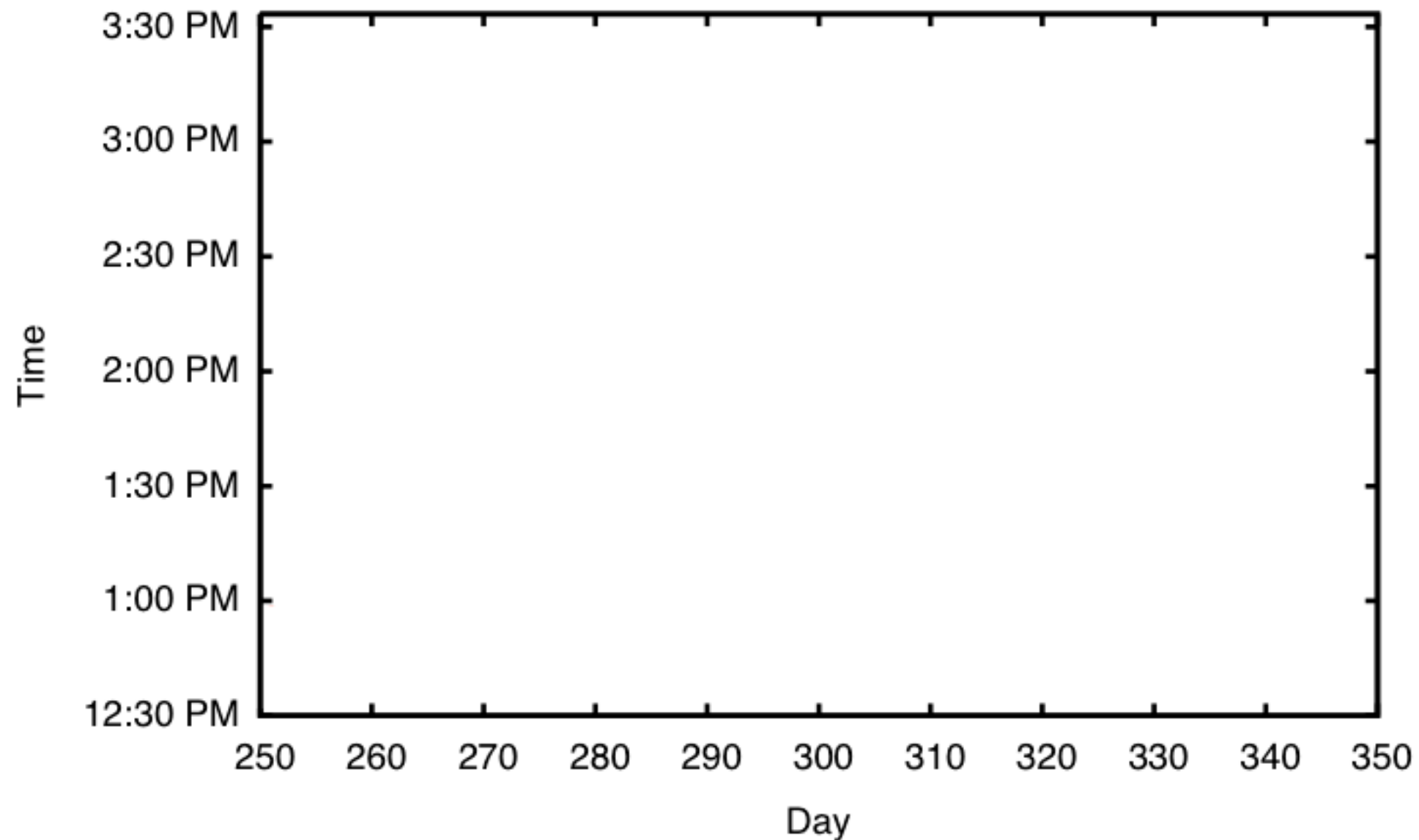
Stop extraction performance



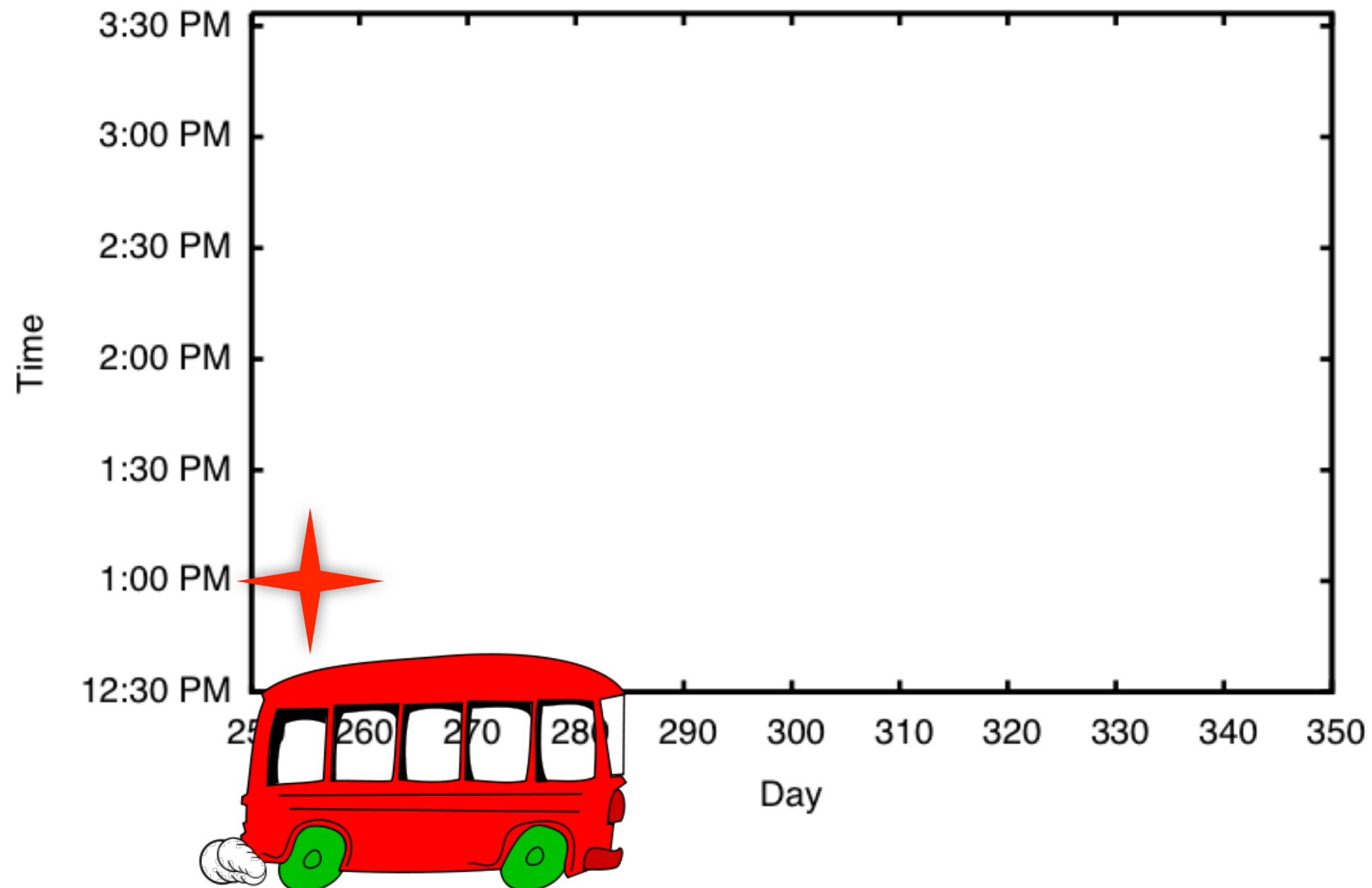
Schedule extraction



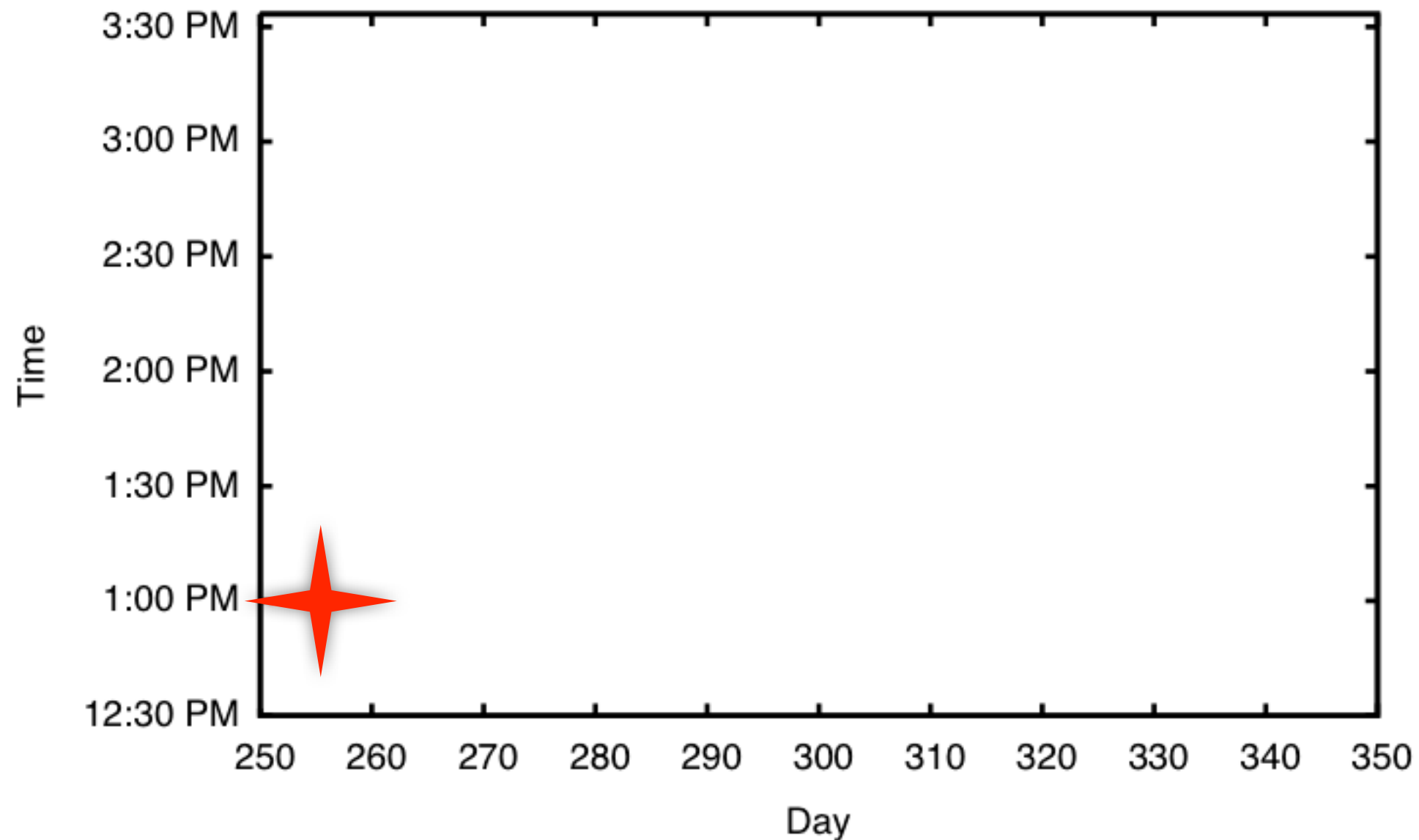
Bus stop arrival times



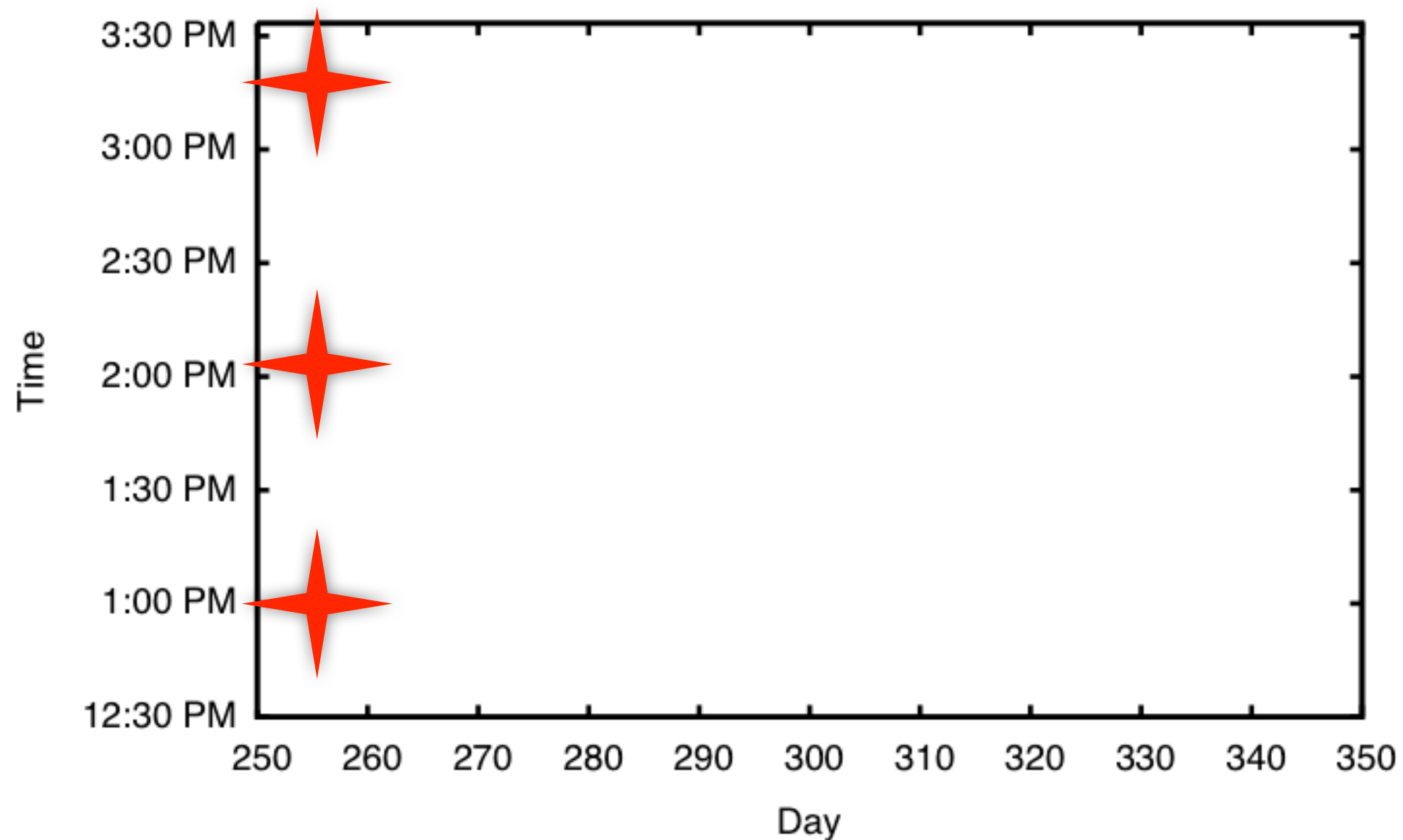
Bus stop arrival times



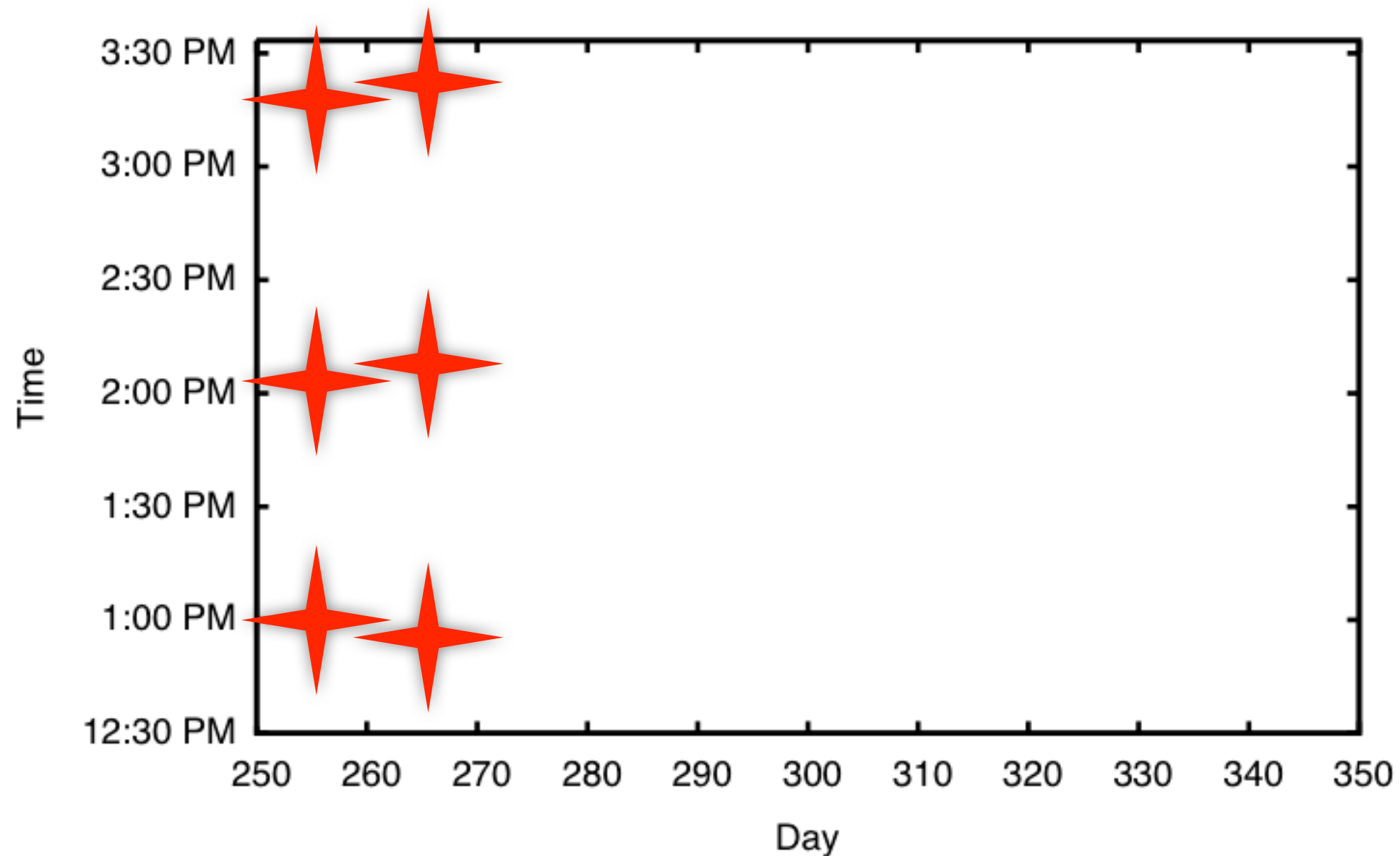
Bus stop arrival times



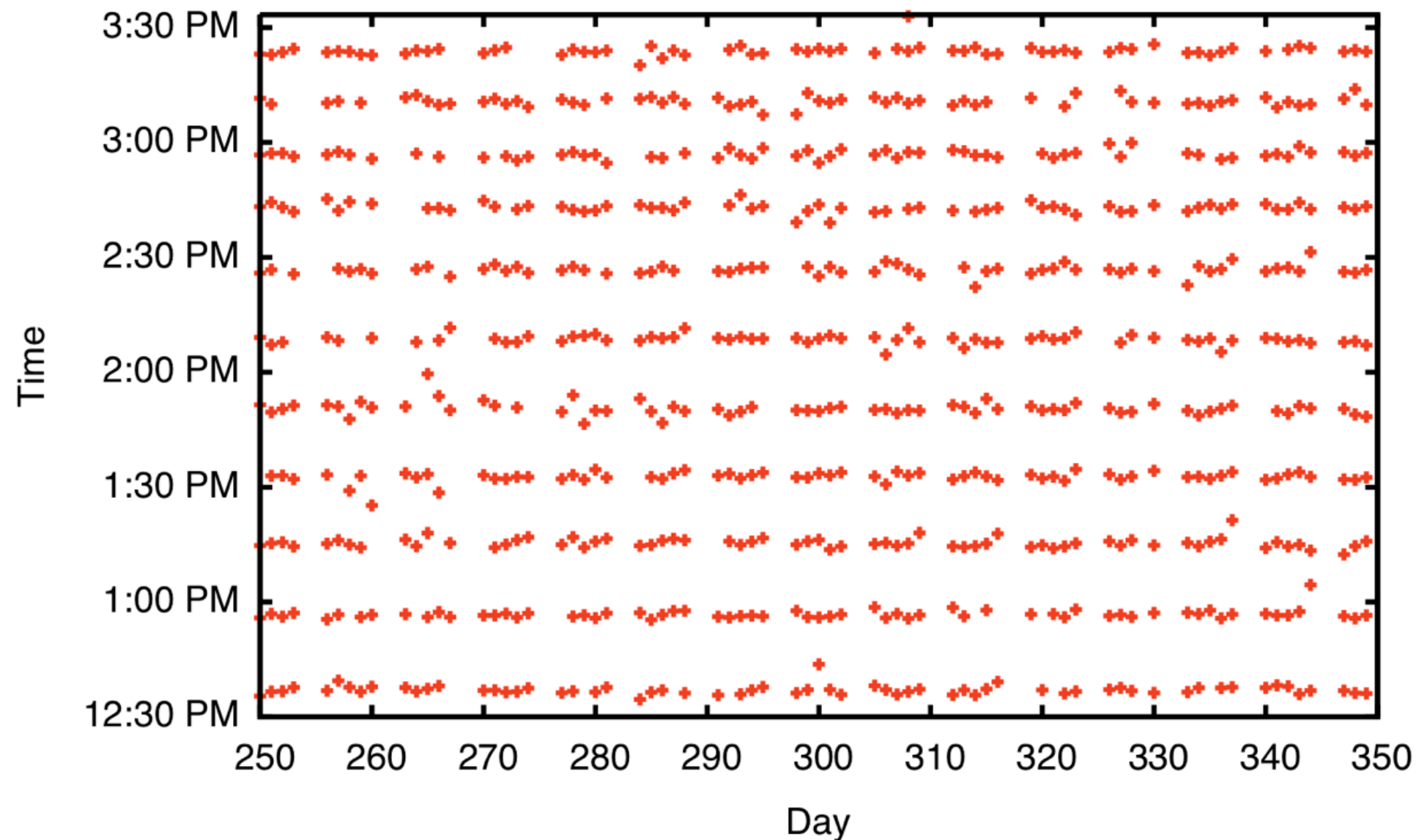
Bus stop arrival times



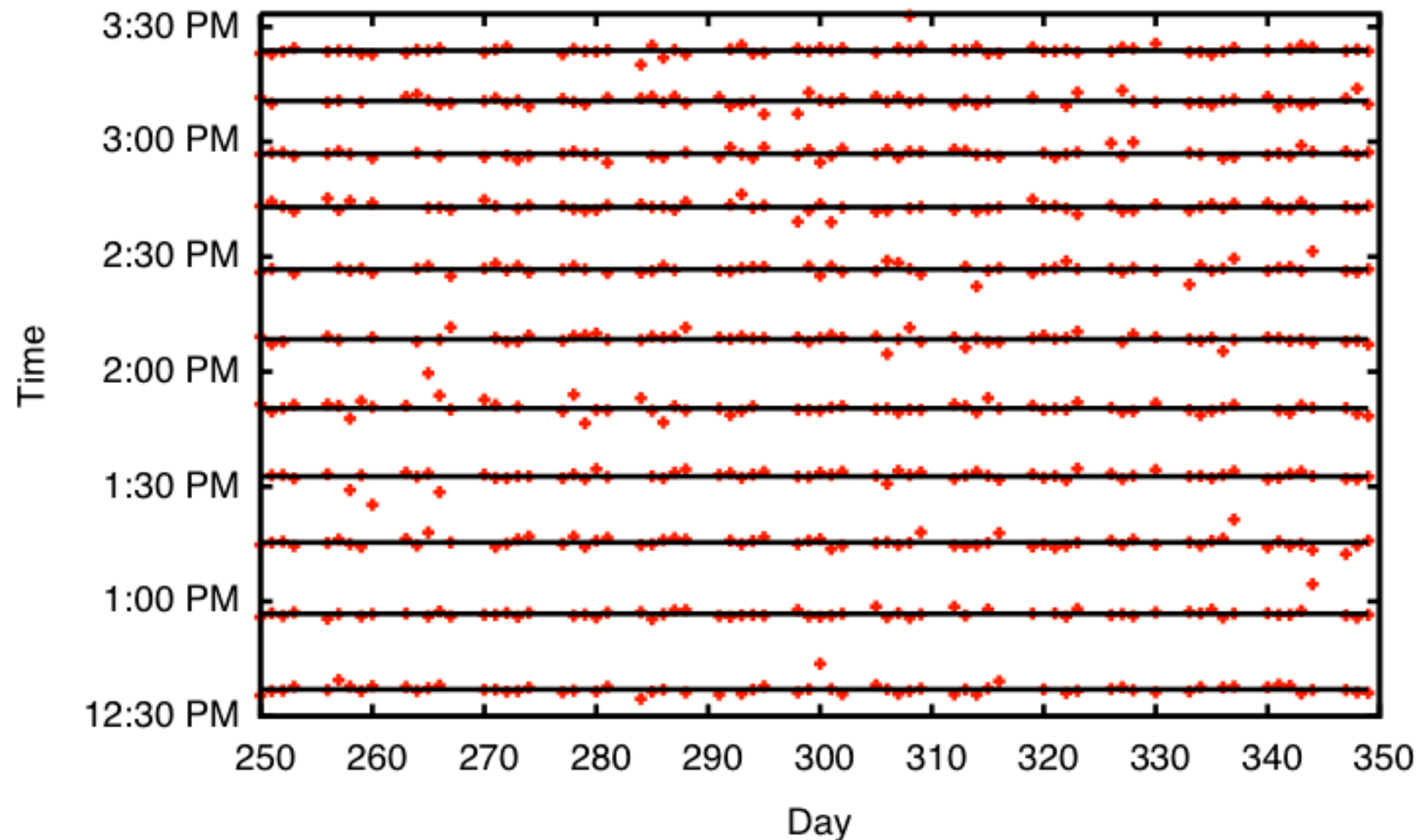
Bus stop arrival times



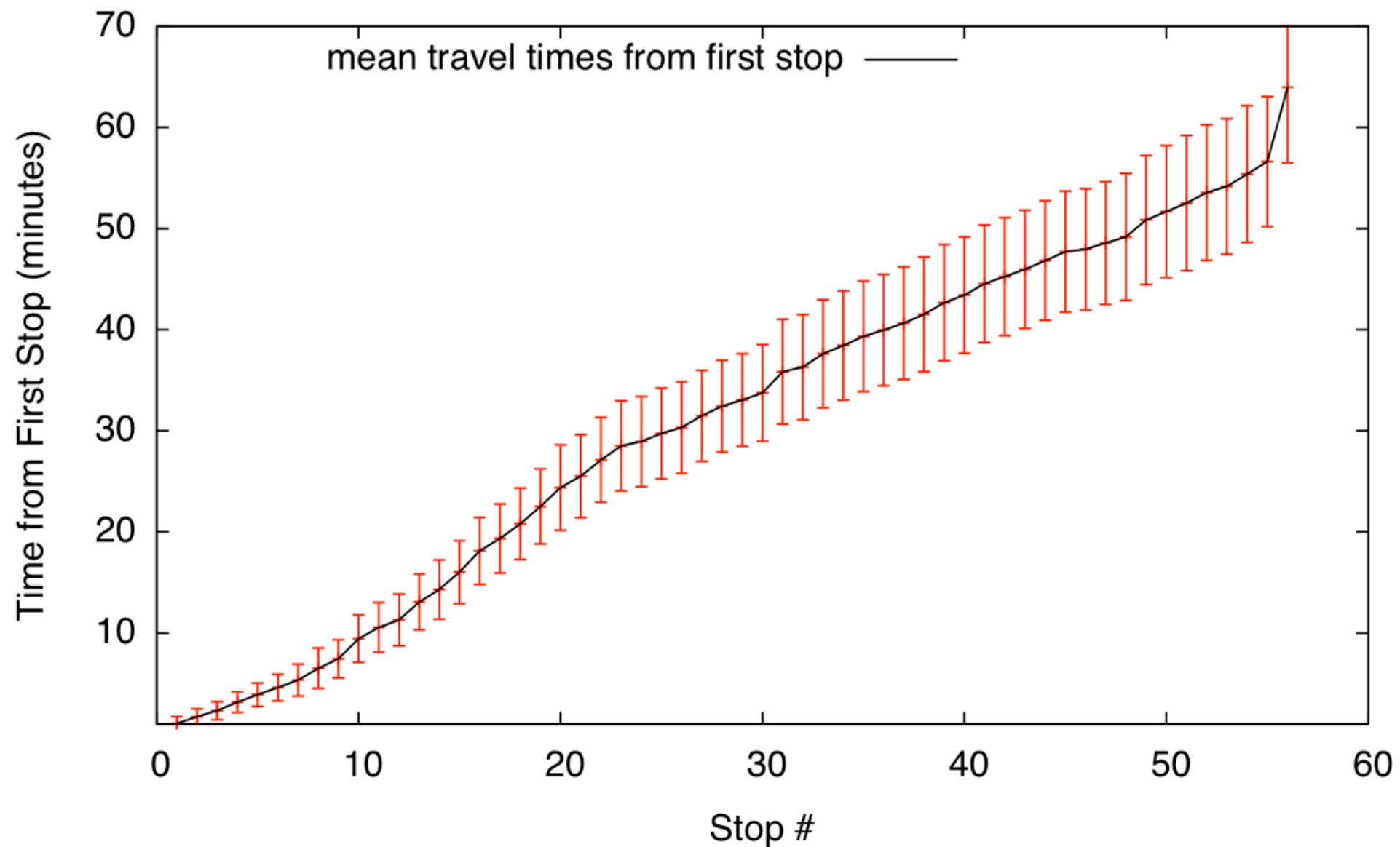
Bus stop arrival times



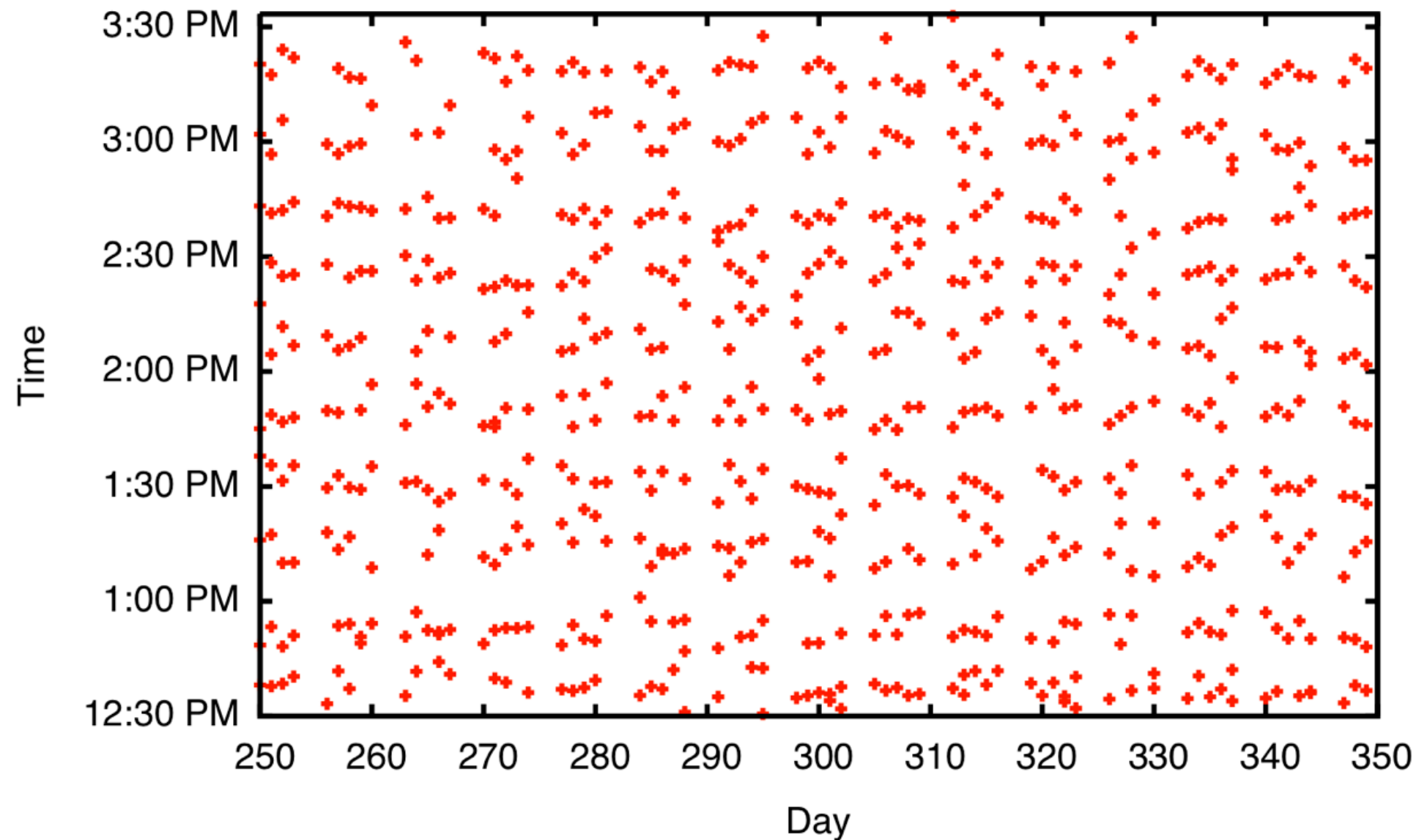
First stop schedule



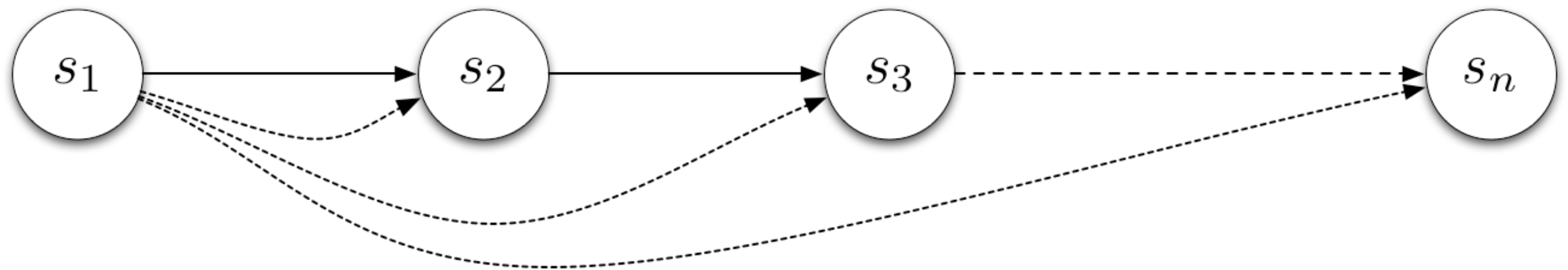
Travel time variance



Last stop arrival times

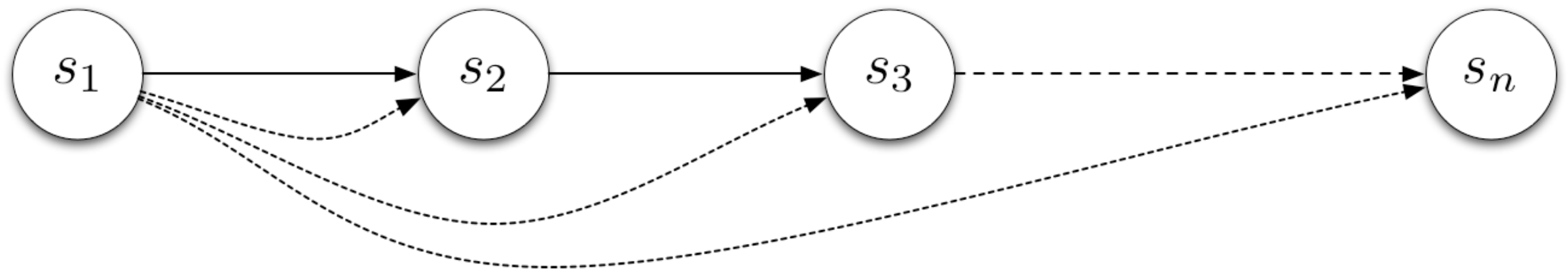


Compute mean travel times



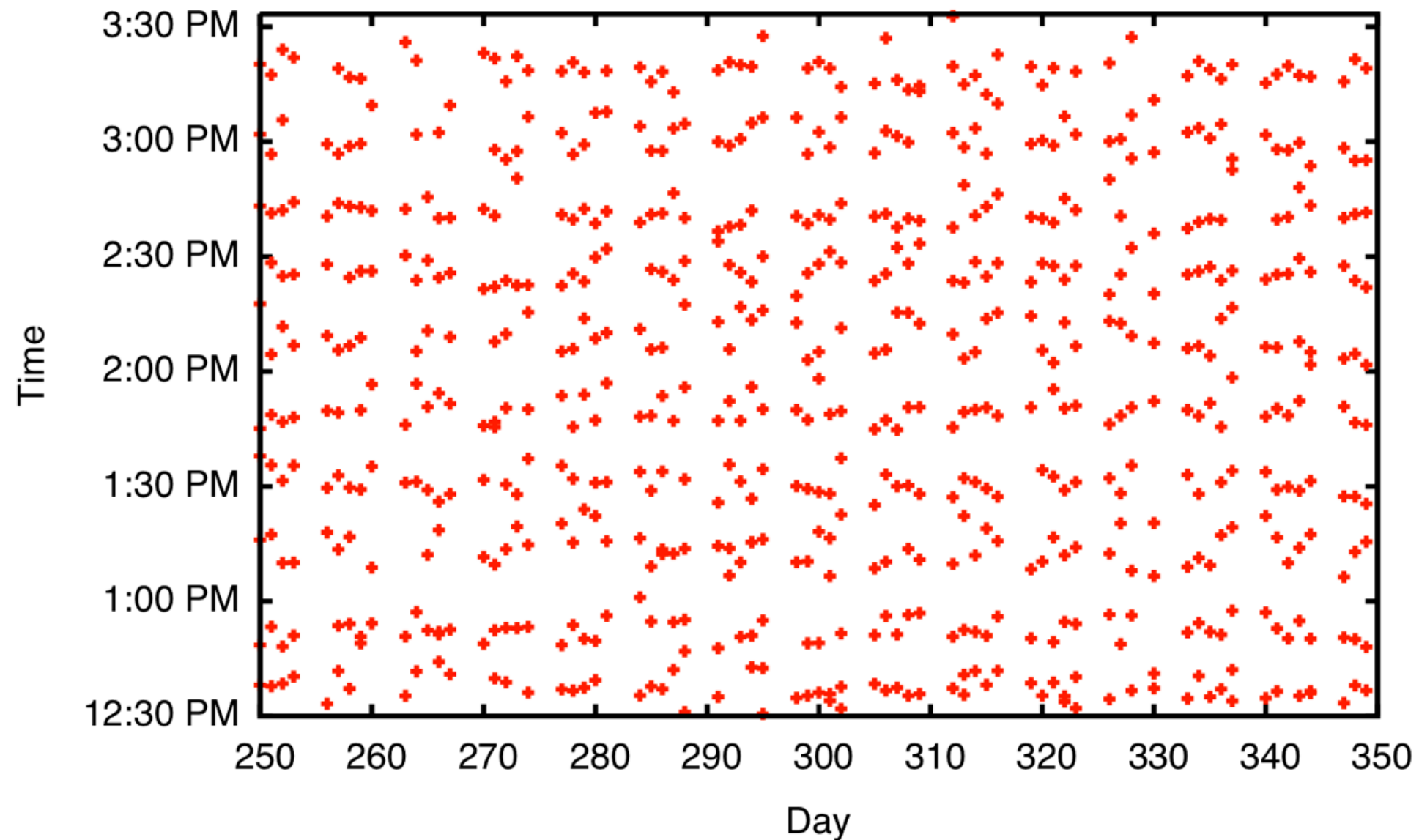
$$travel_time(1, j, t) = \frac{1}{|D|} \sum_D a_j^t - a_1^t$$

Compute downstream schedules

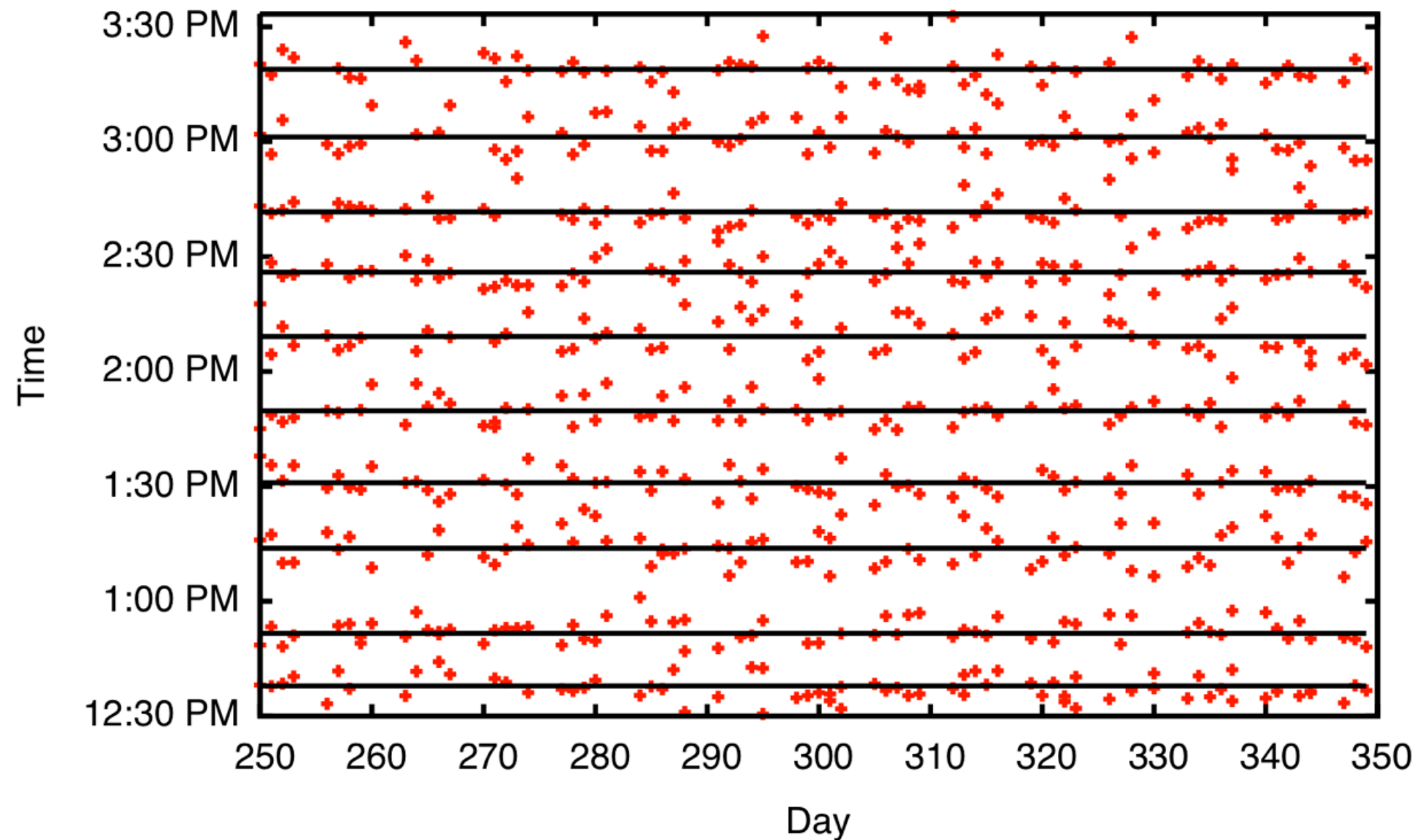


$$k_t^j = k_t^1 + travel_time(1, j, t)$$

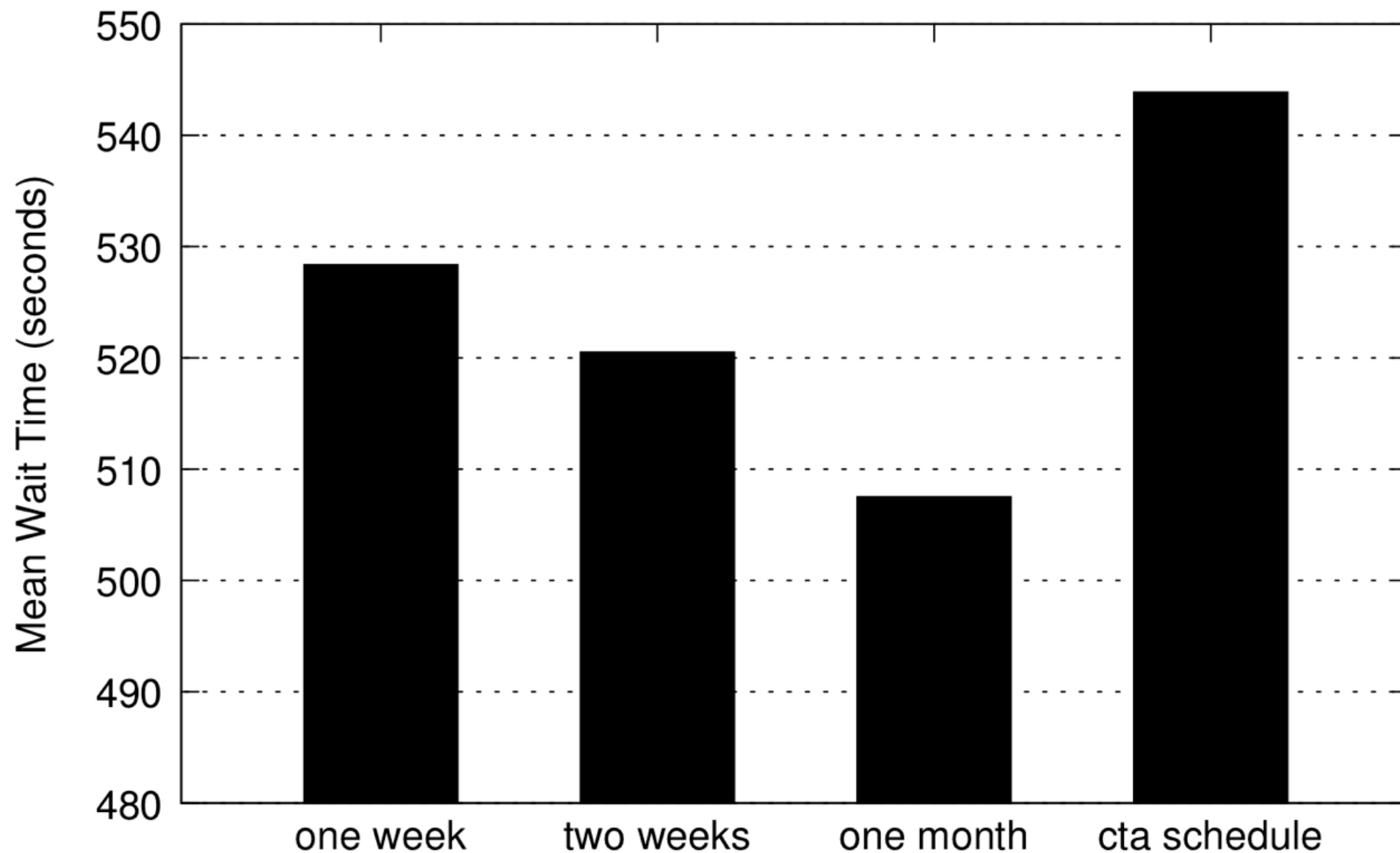
Last stop arrival times



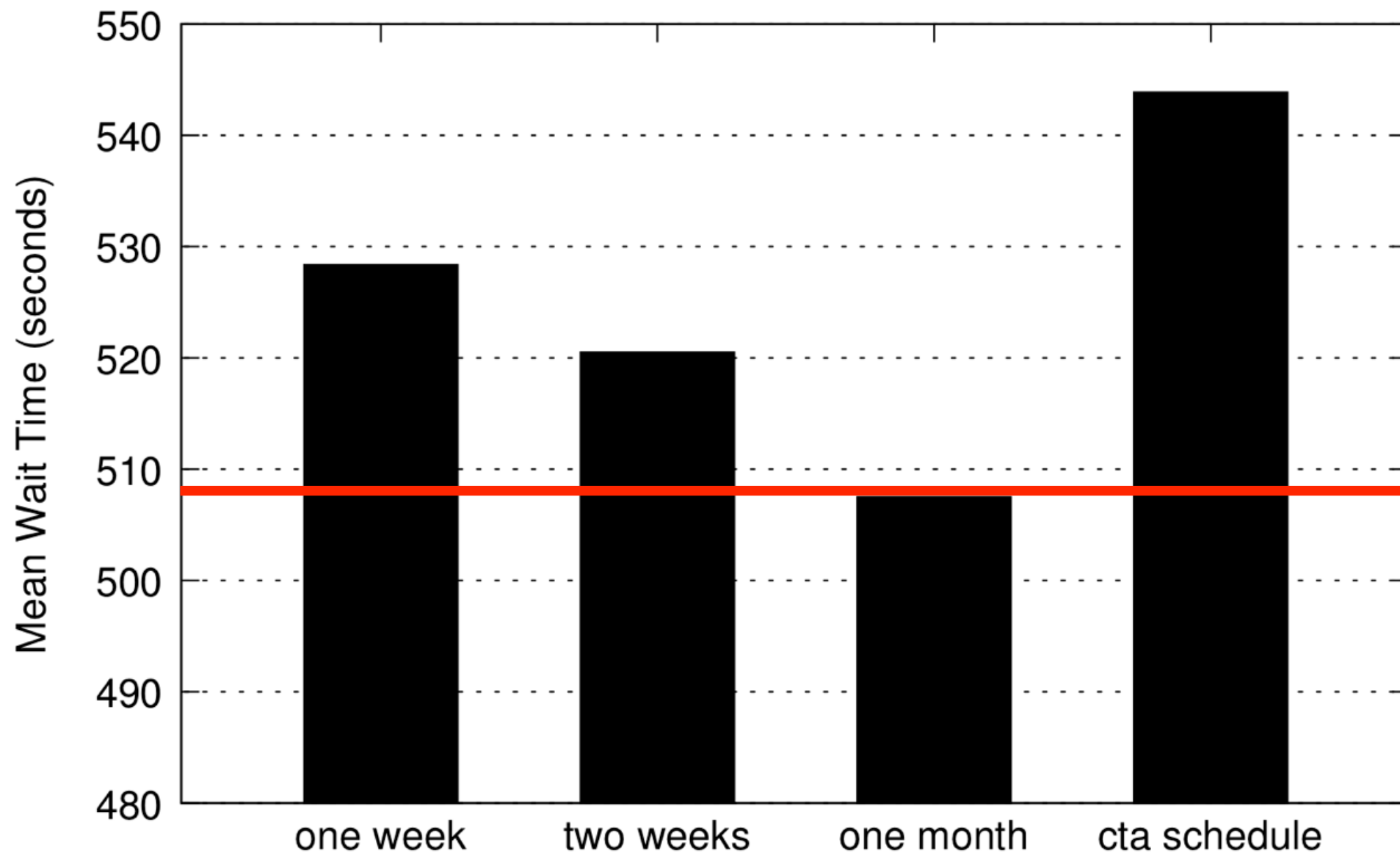
Last stop schedule



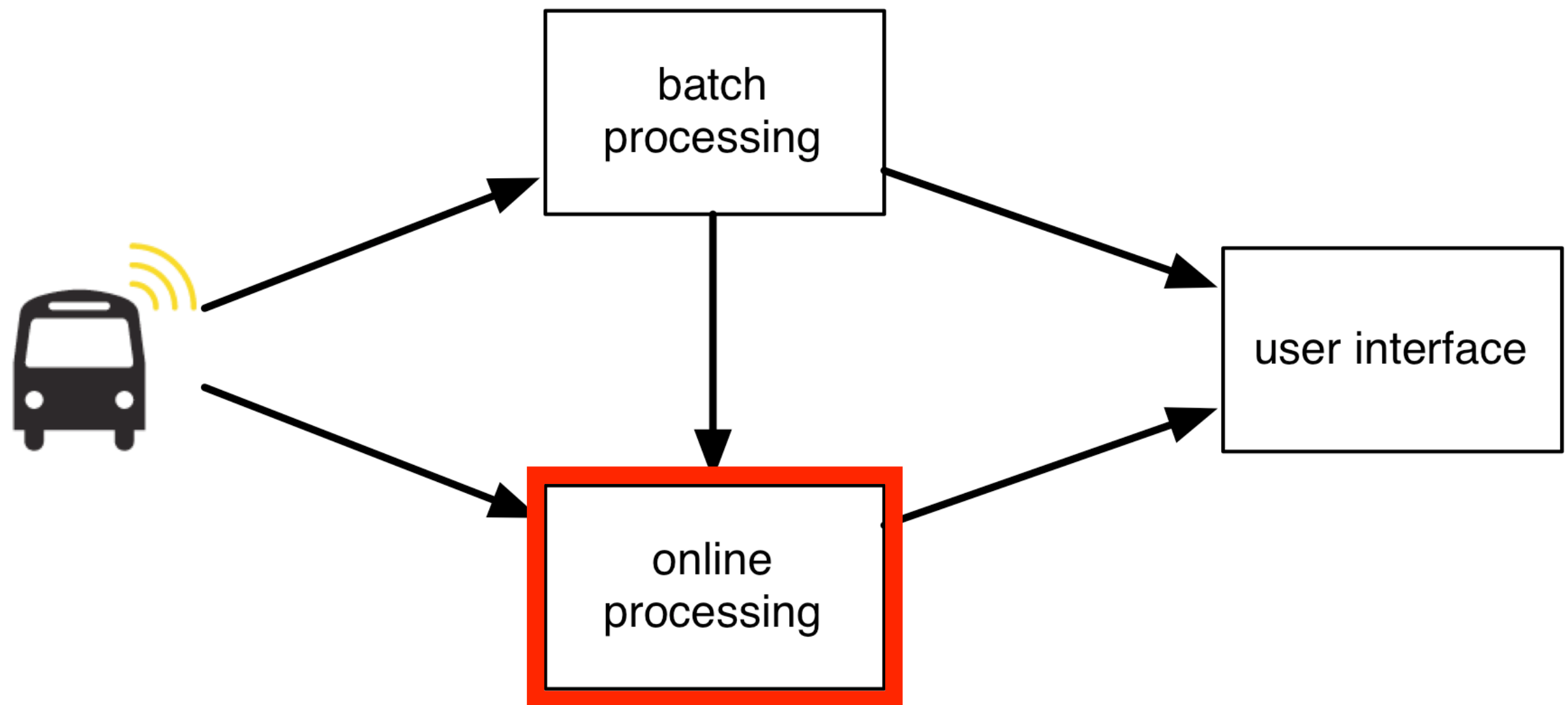
Schedule accuracy



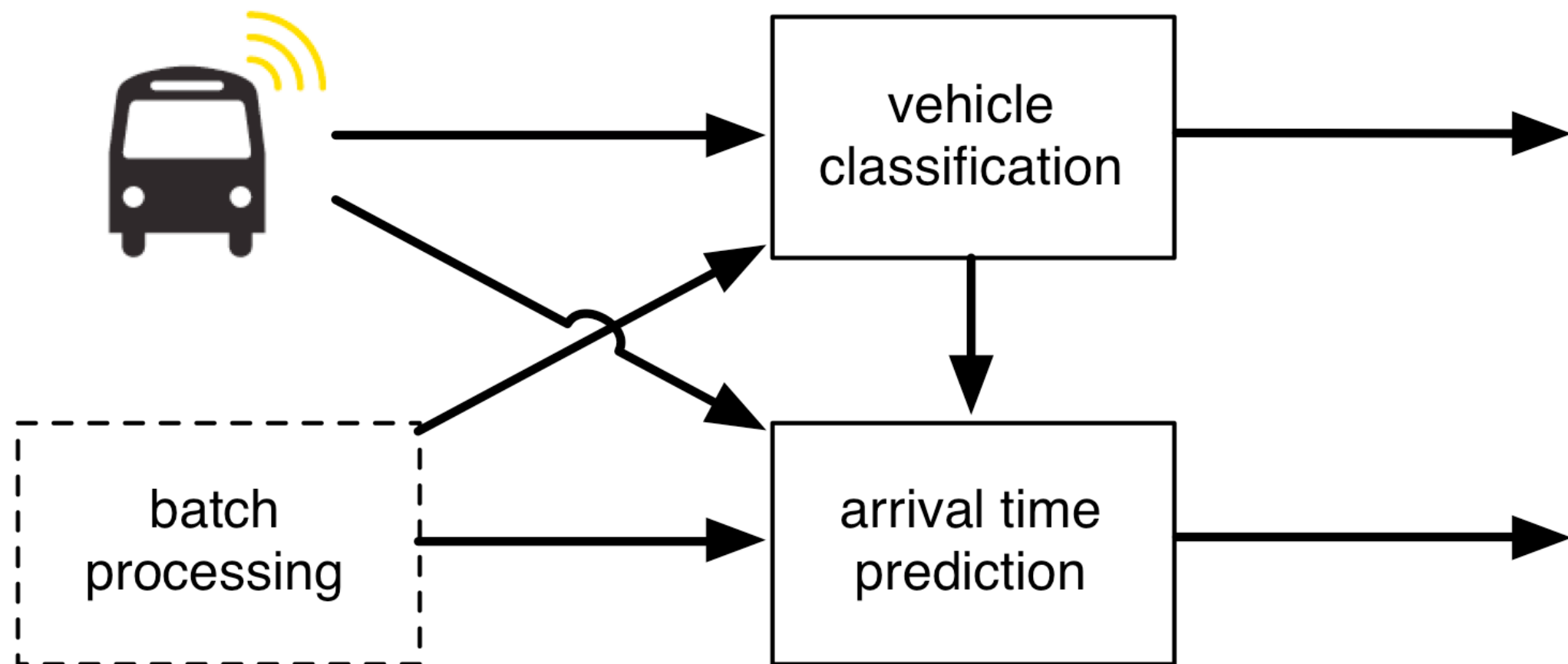
Schedule accuracy



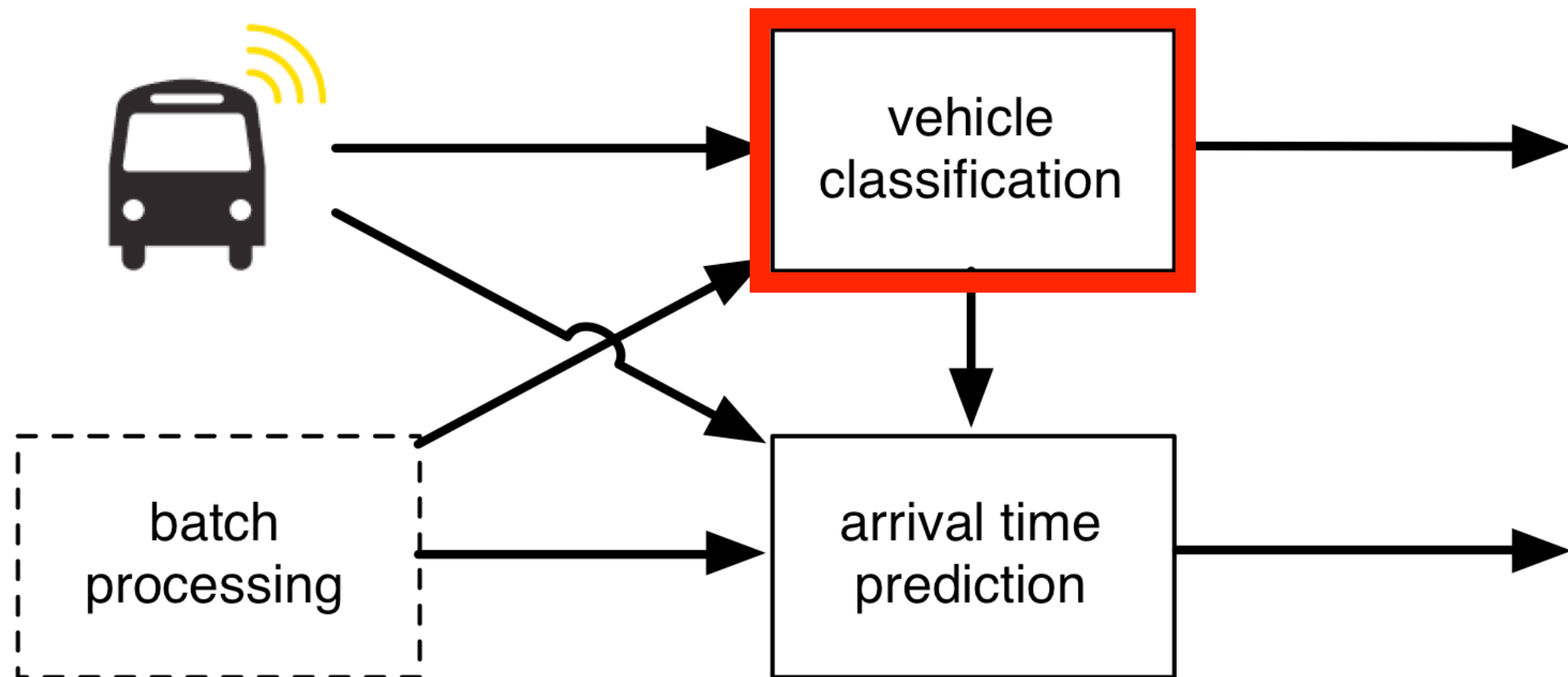
System architecture



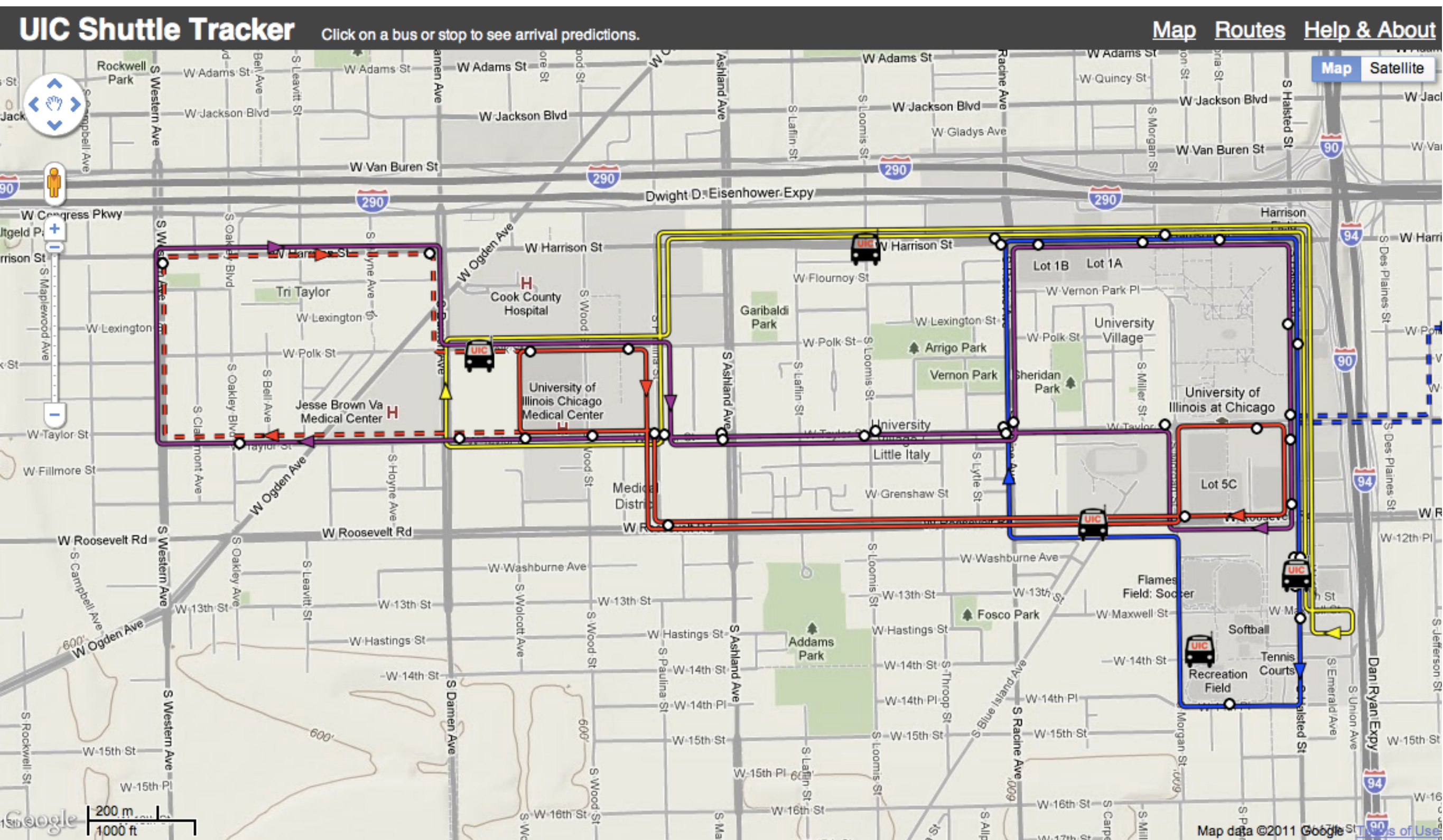
Online processing



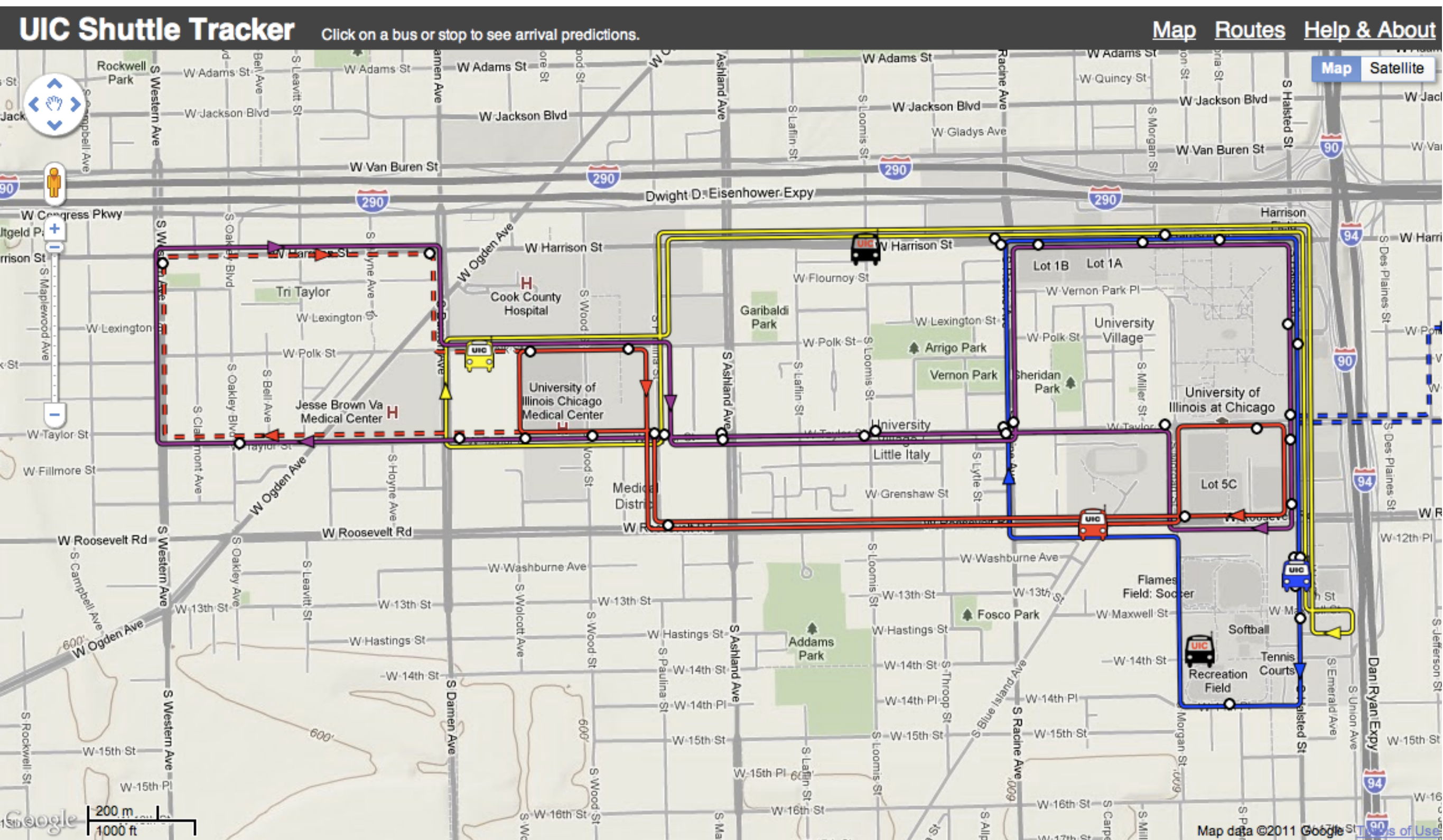
Online processing



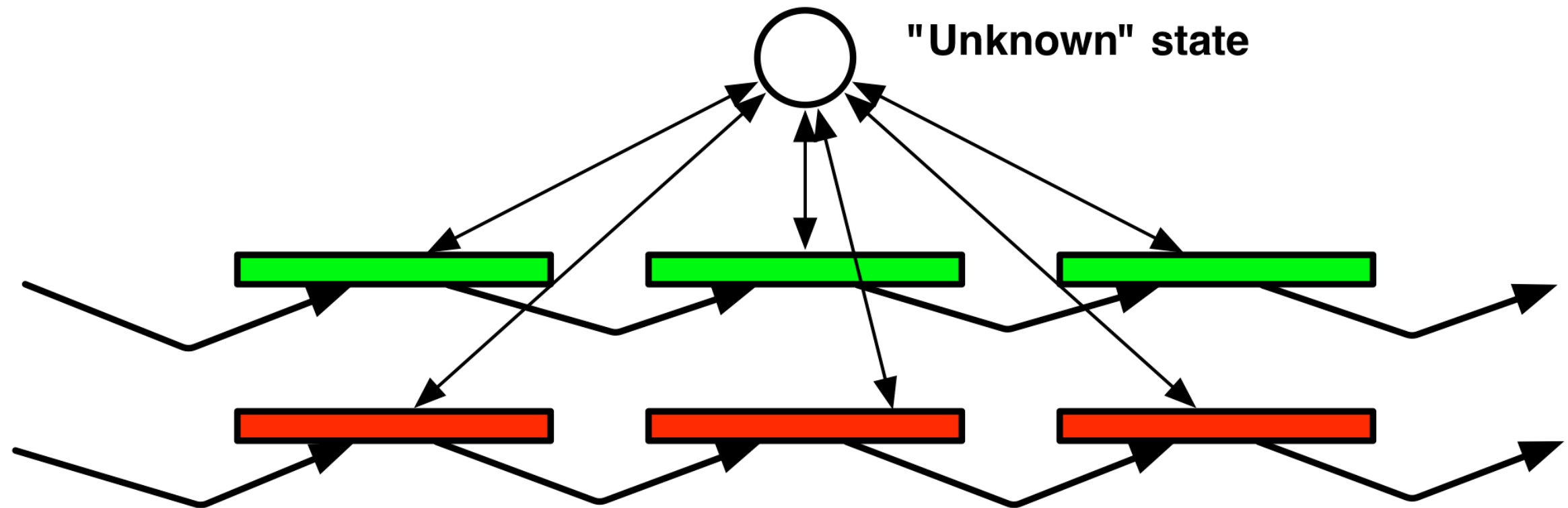
Un-classified buses



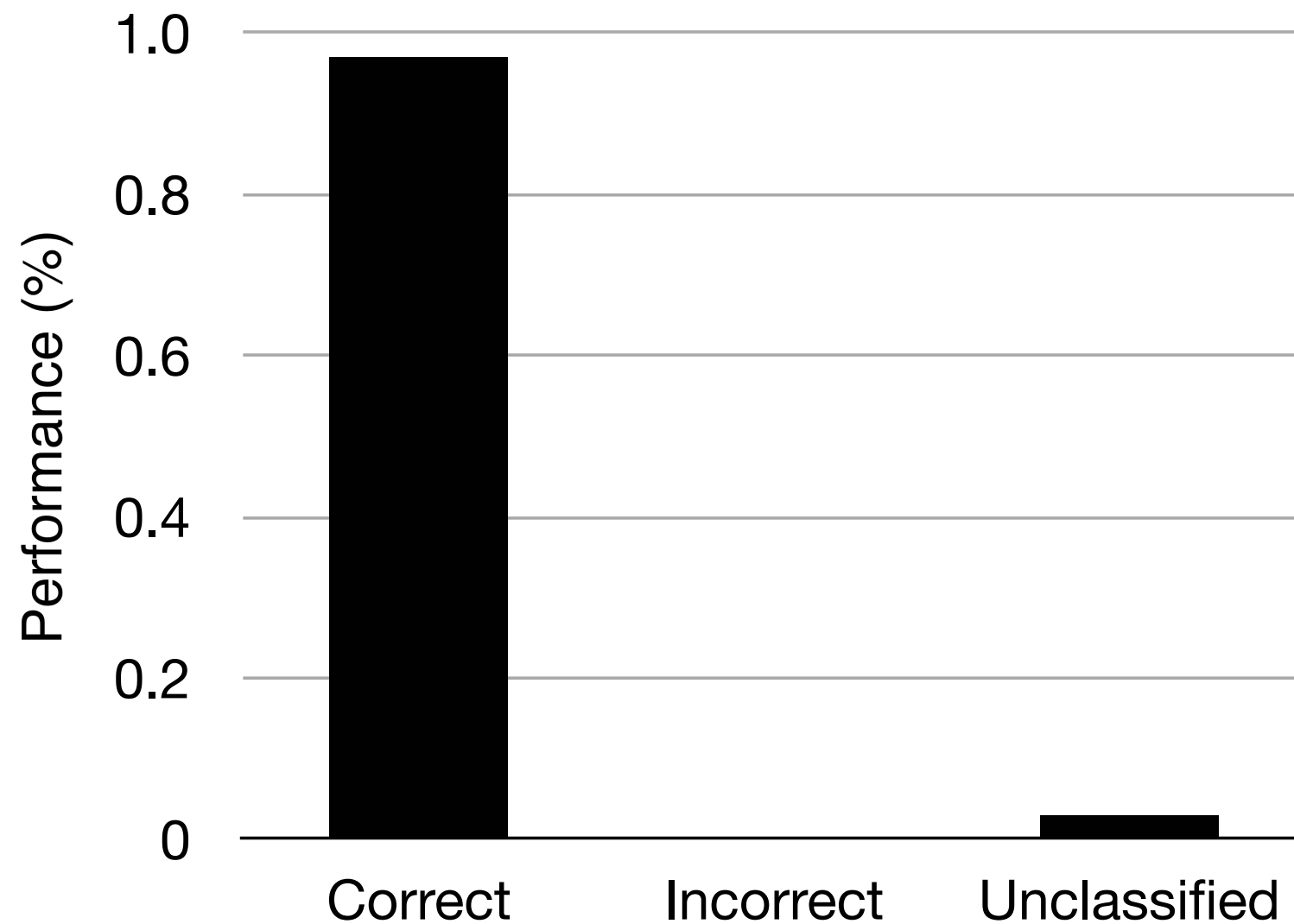
Classified buses



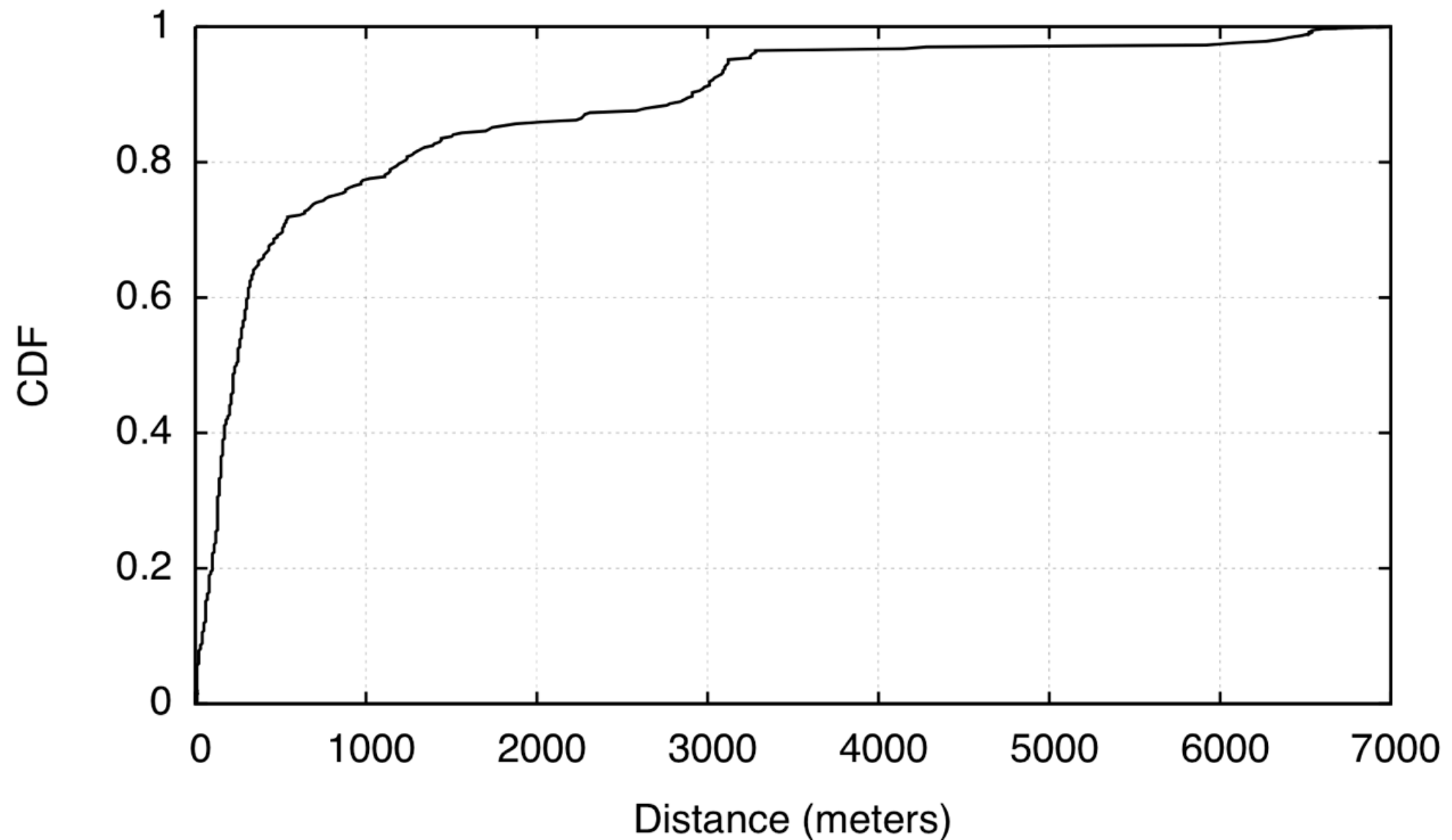
Hidden Markov model



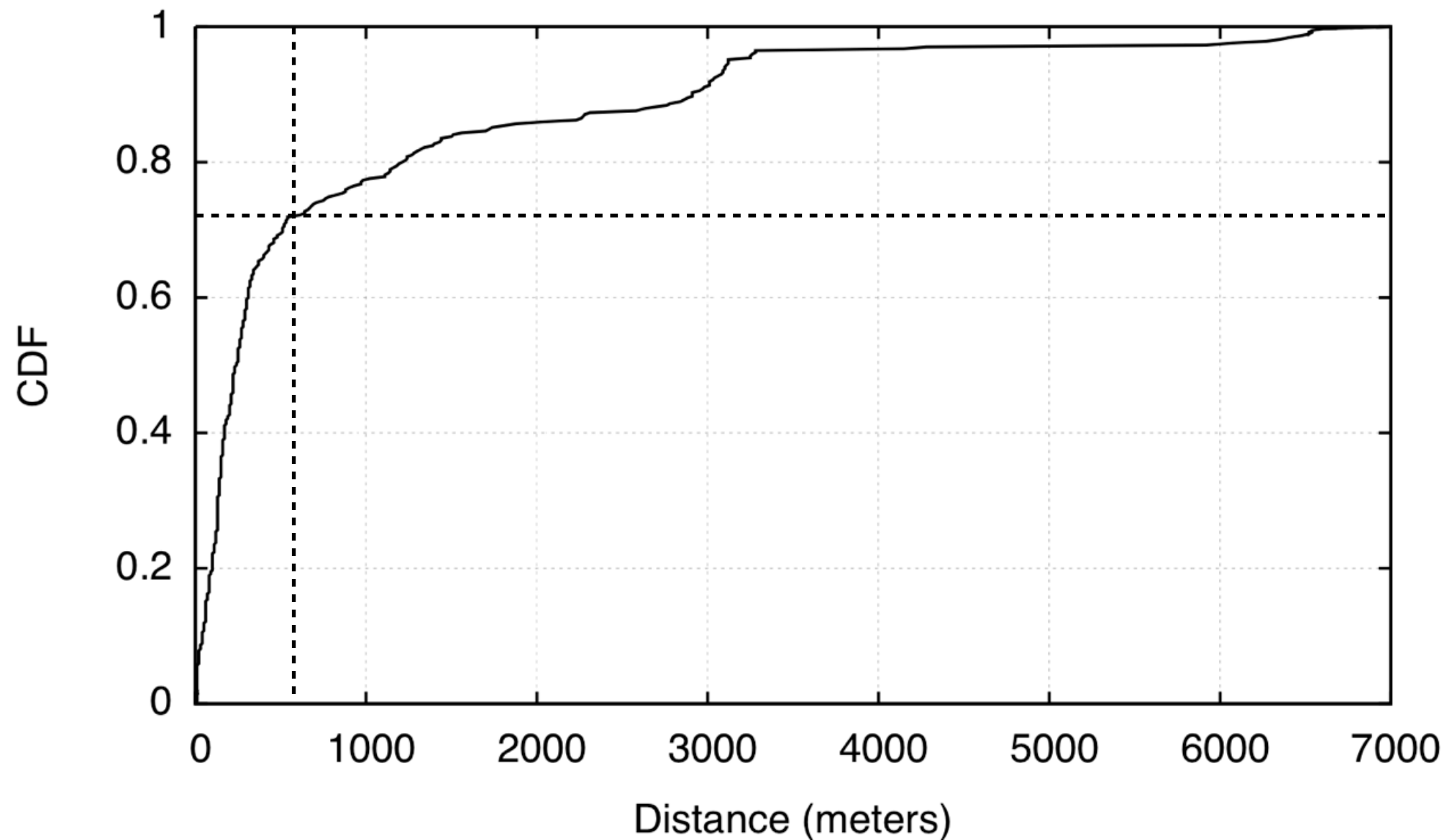
Classification accuracy



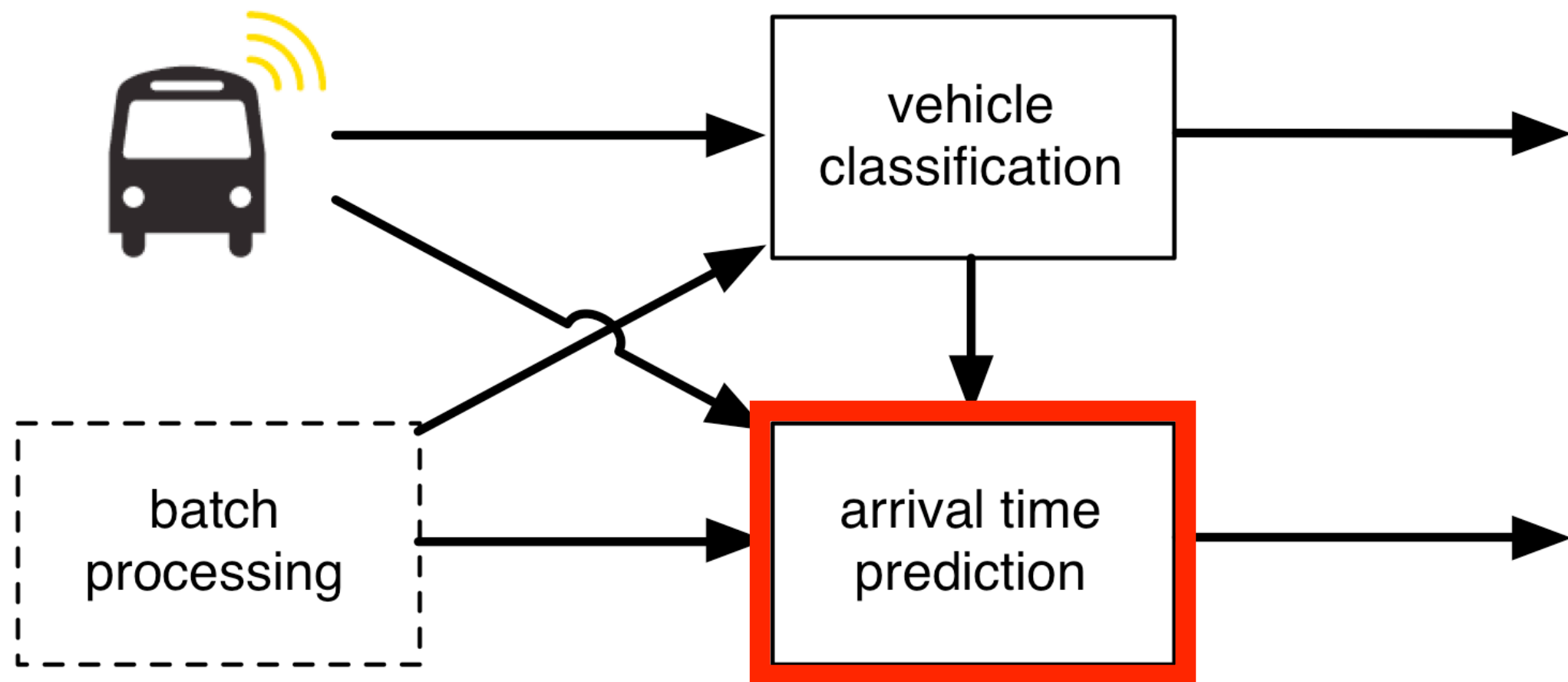
Classification delay



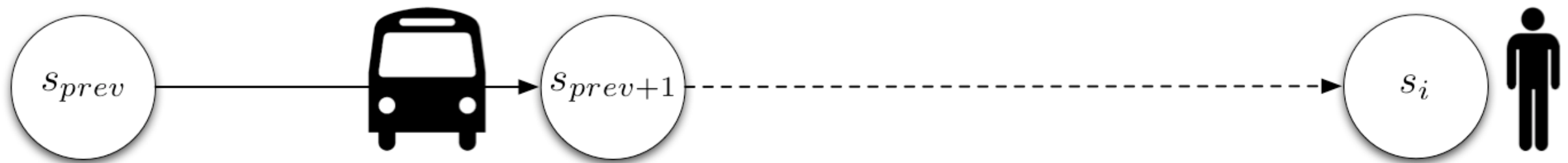
Classification delay



Arrival time prediction

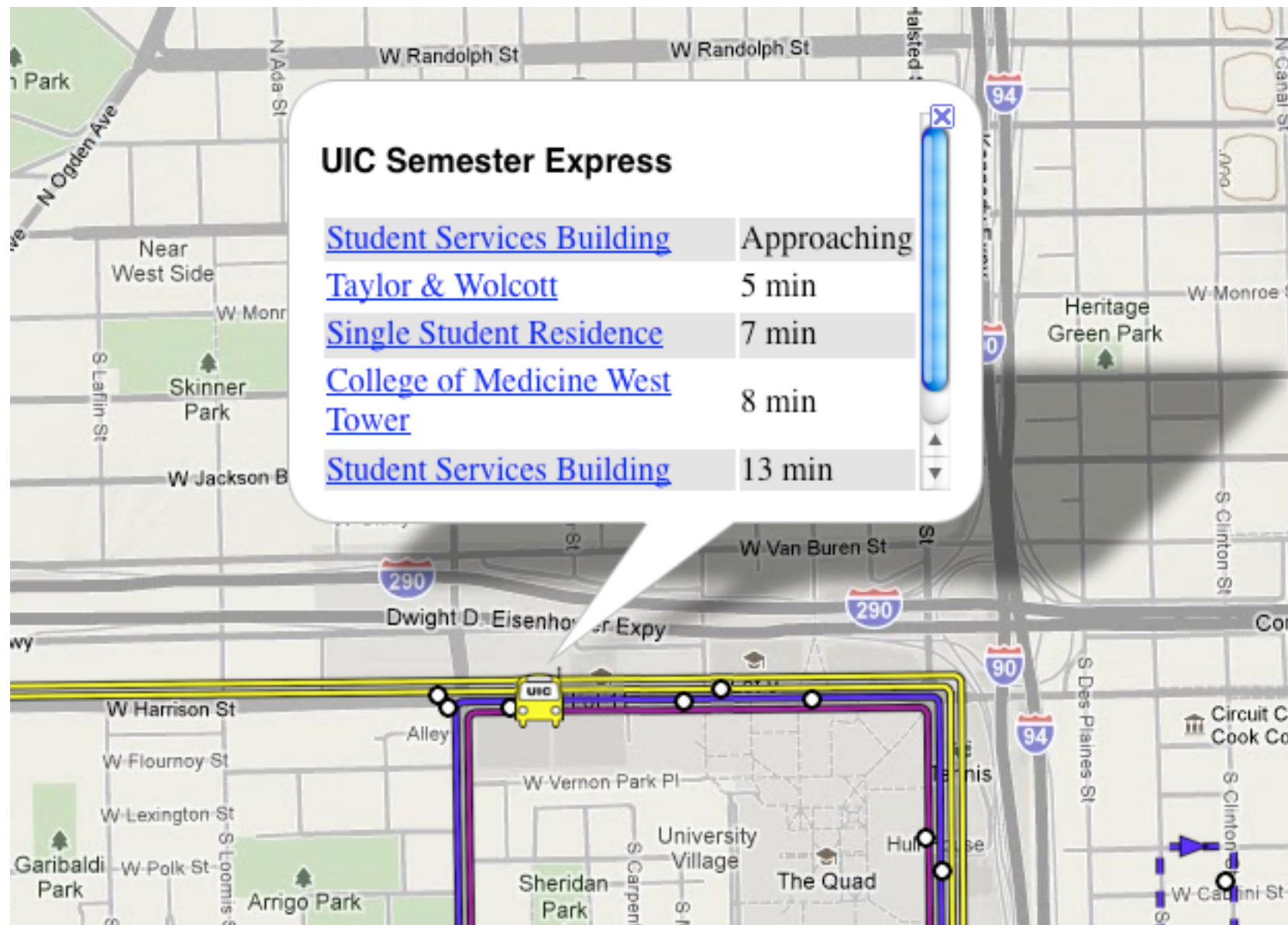


Predicting arrival times

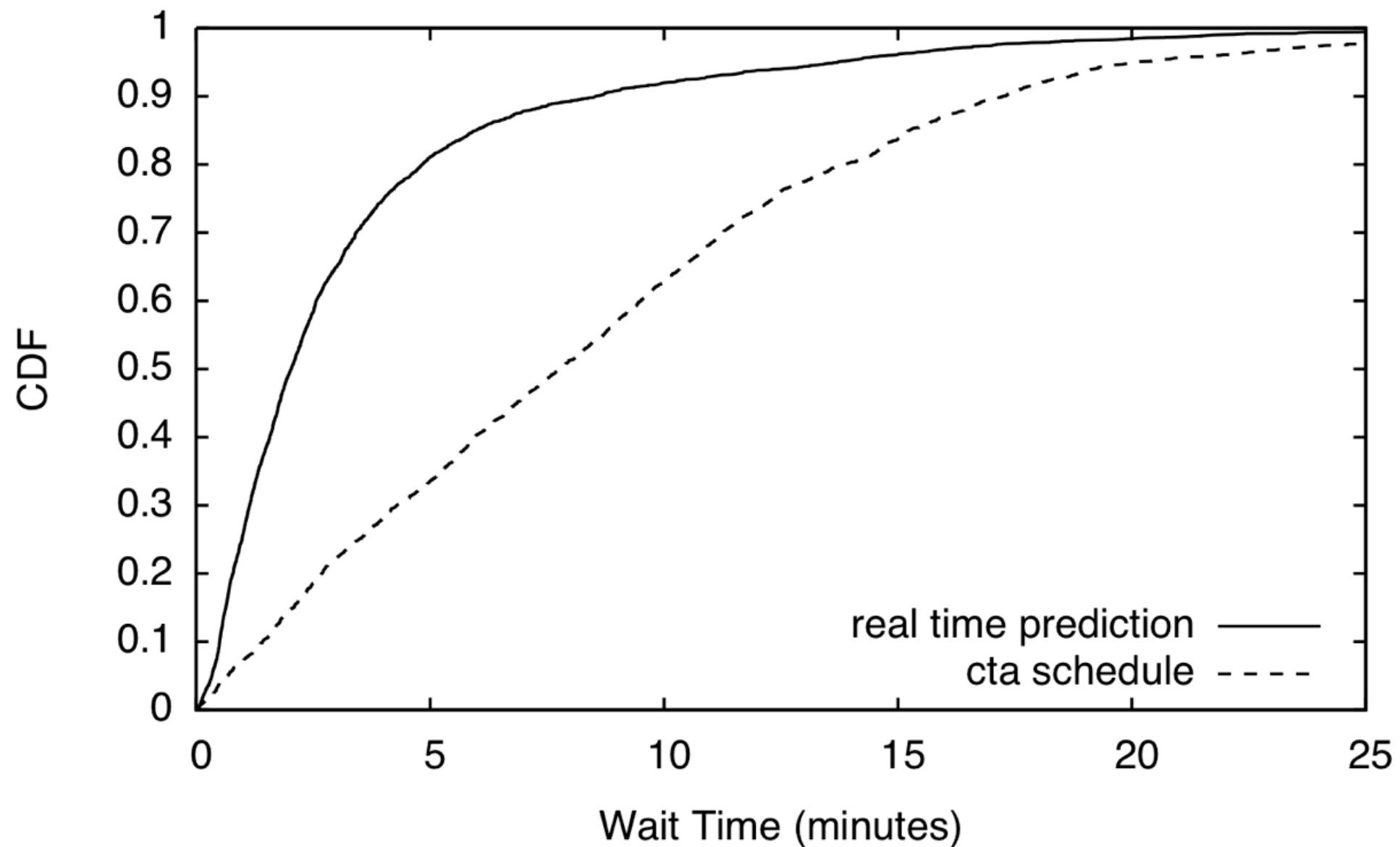


$$time_until_arrival(s_i) = \gamma travel_time(s_{prev+1}, s_i) + (1 - \gamma) travel_time(s_{prev}, s_i)$$

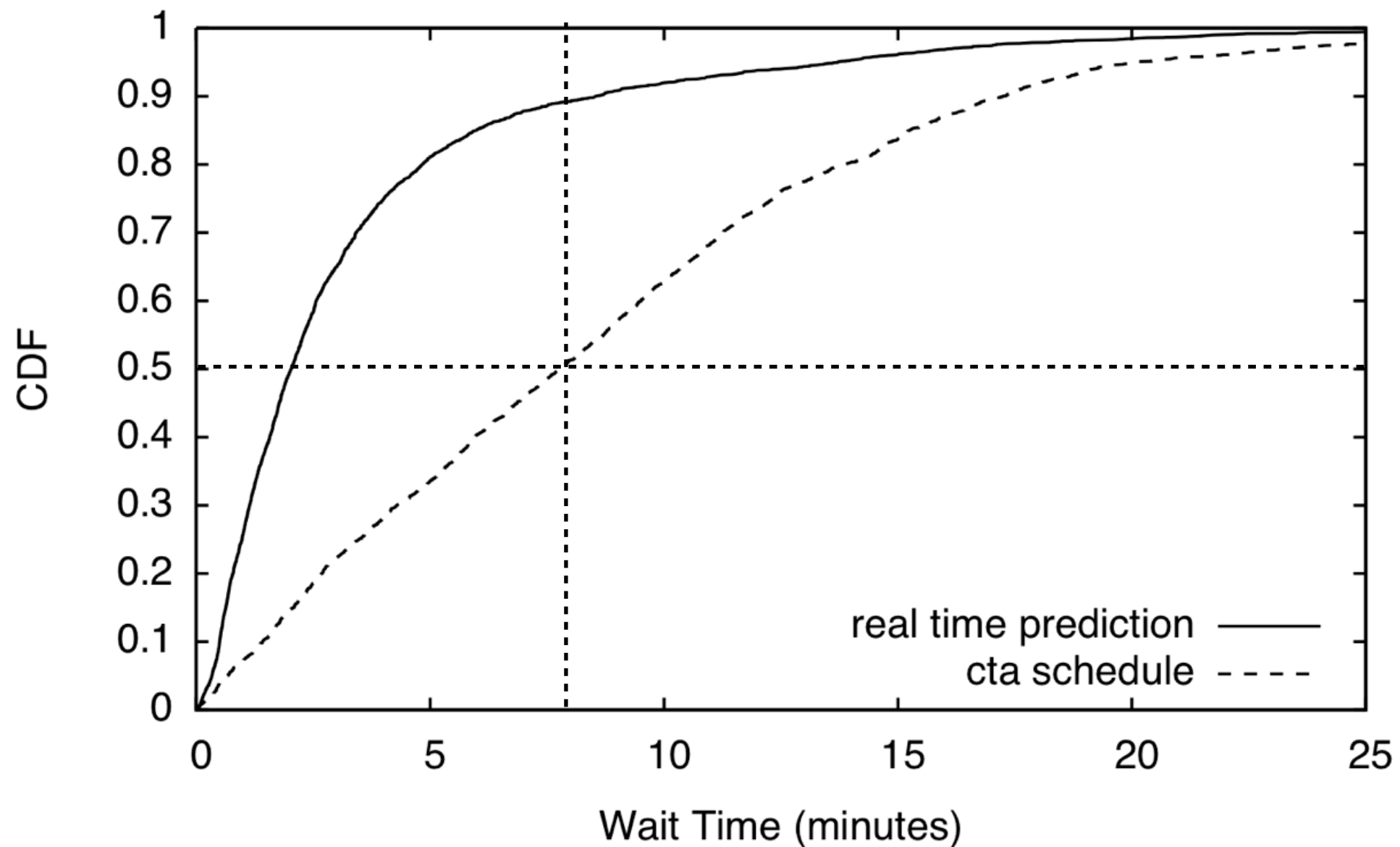
Arrival time predictions



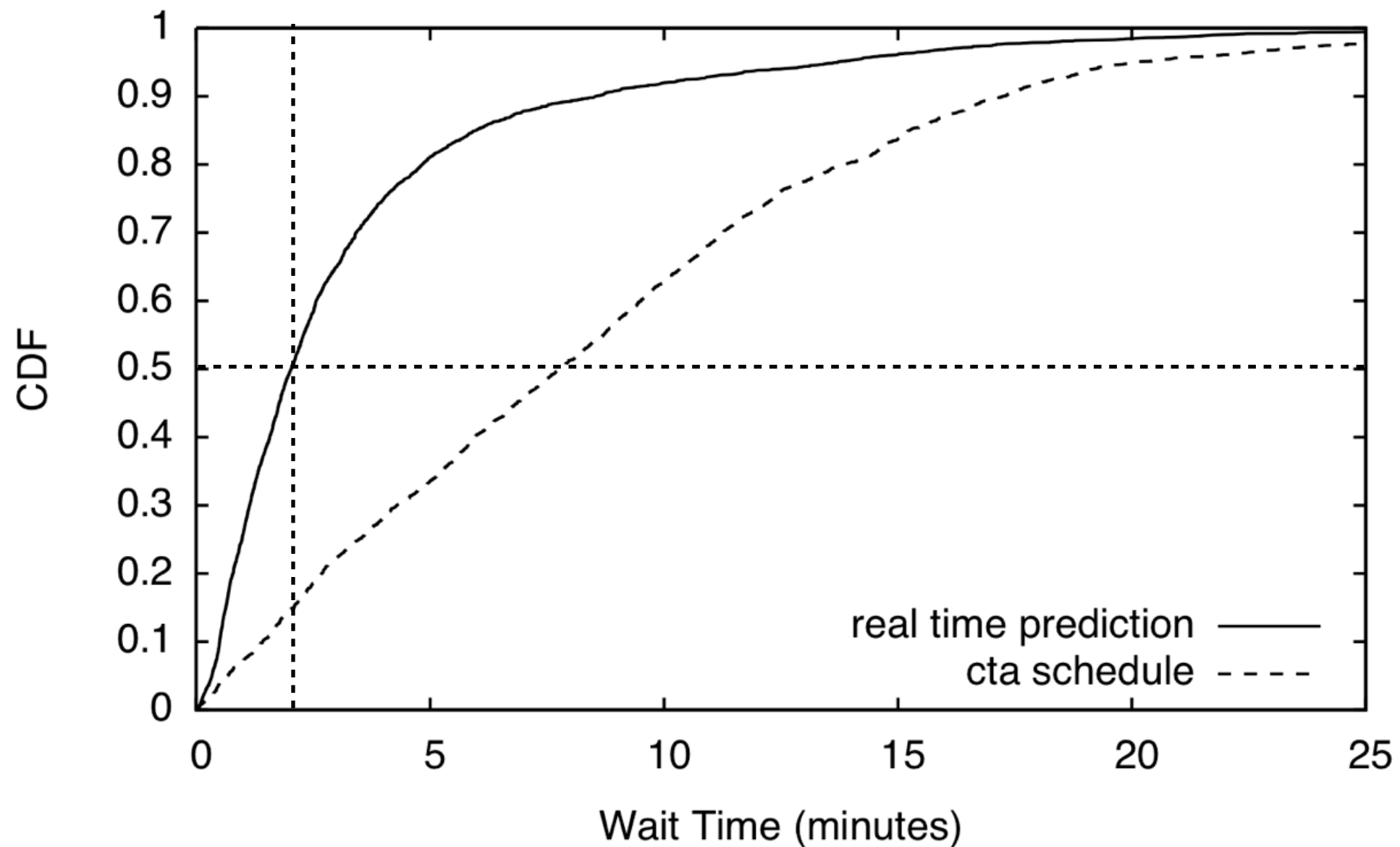
Schedule vs. real-time



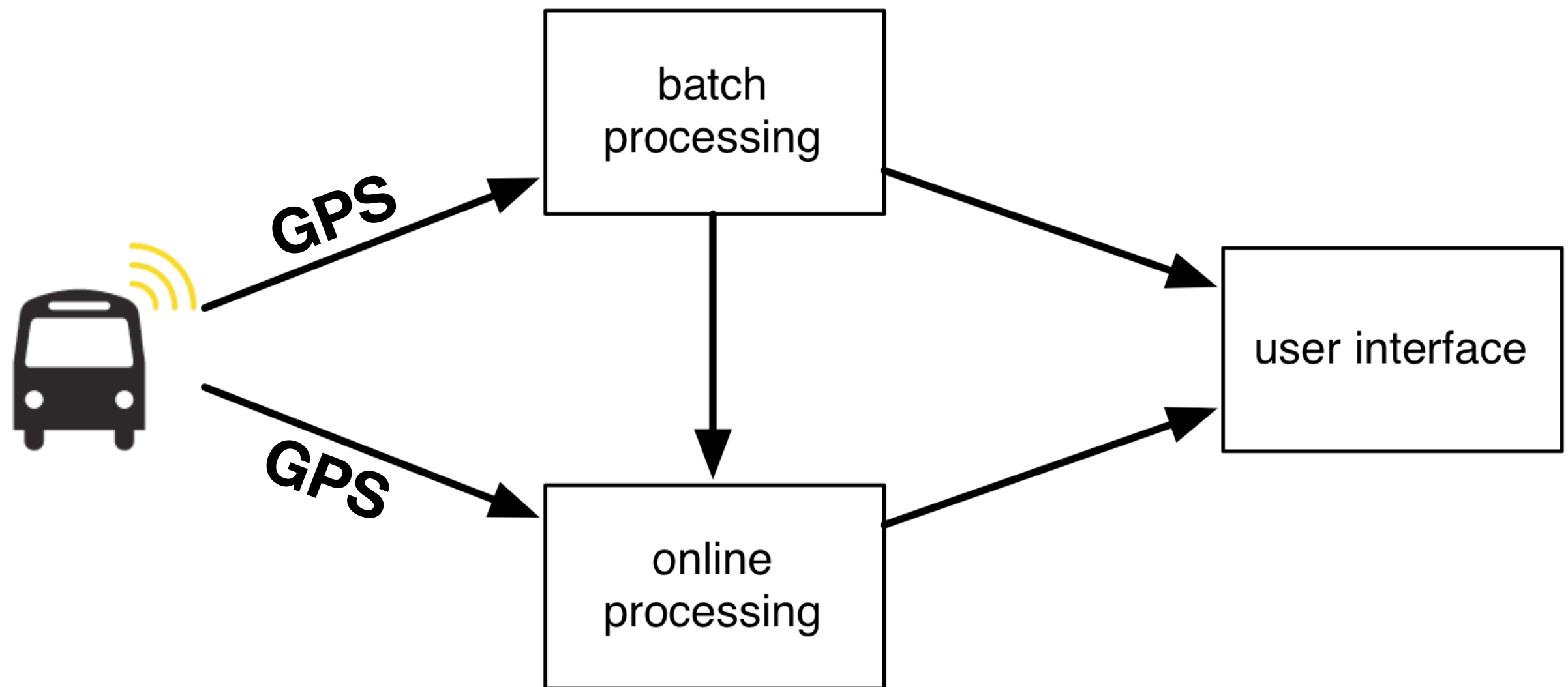
Schedule vs. real-time



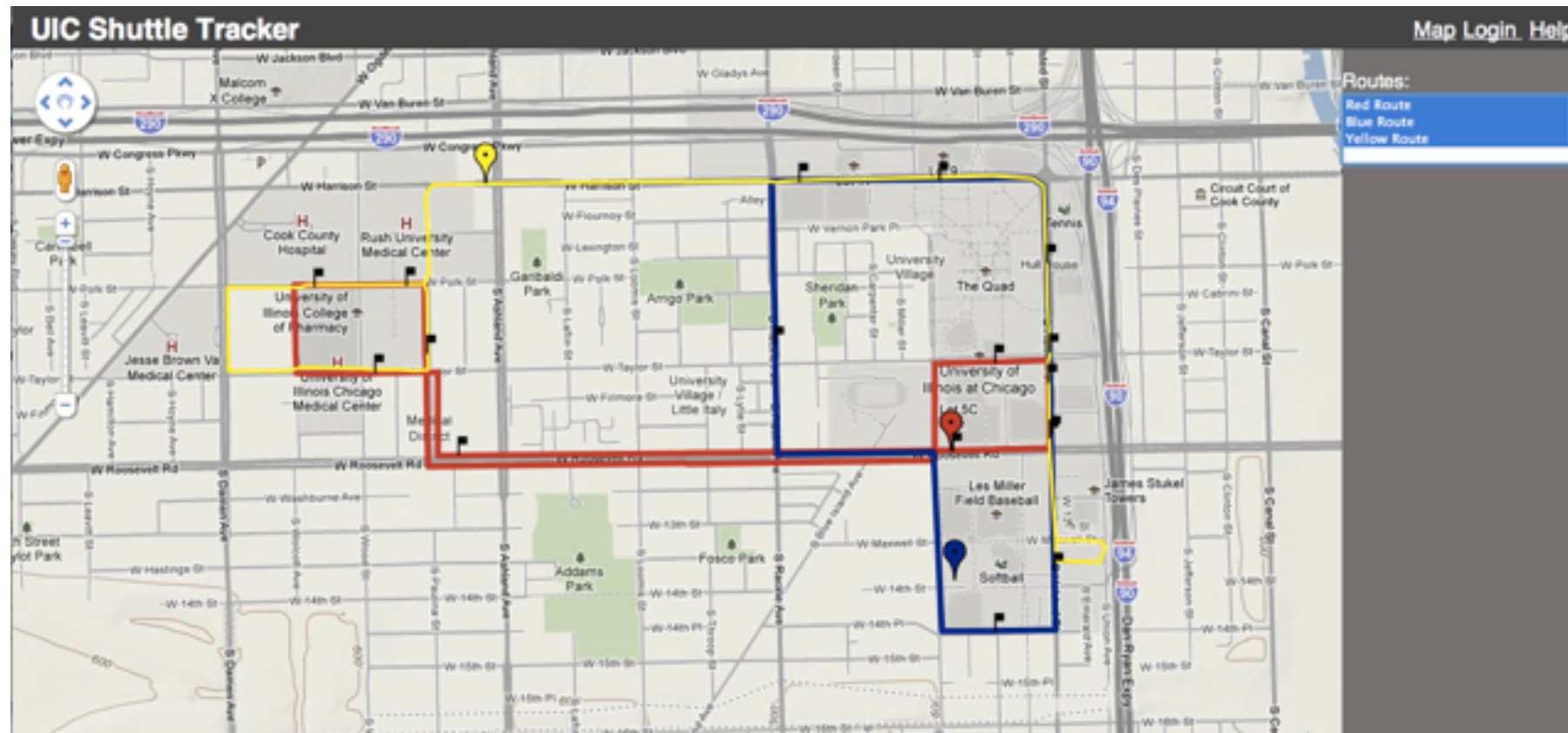
Schedule vs. real-time



System overview



Come and see our demo!



► Thursday, 3:30p-7:30p

Thanks!

Questions?