

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](#)

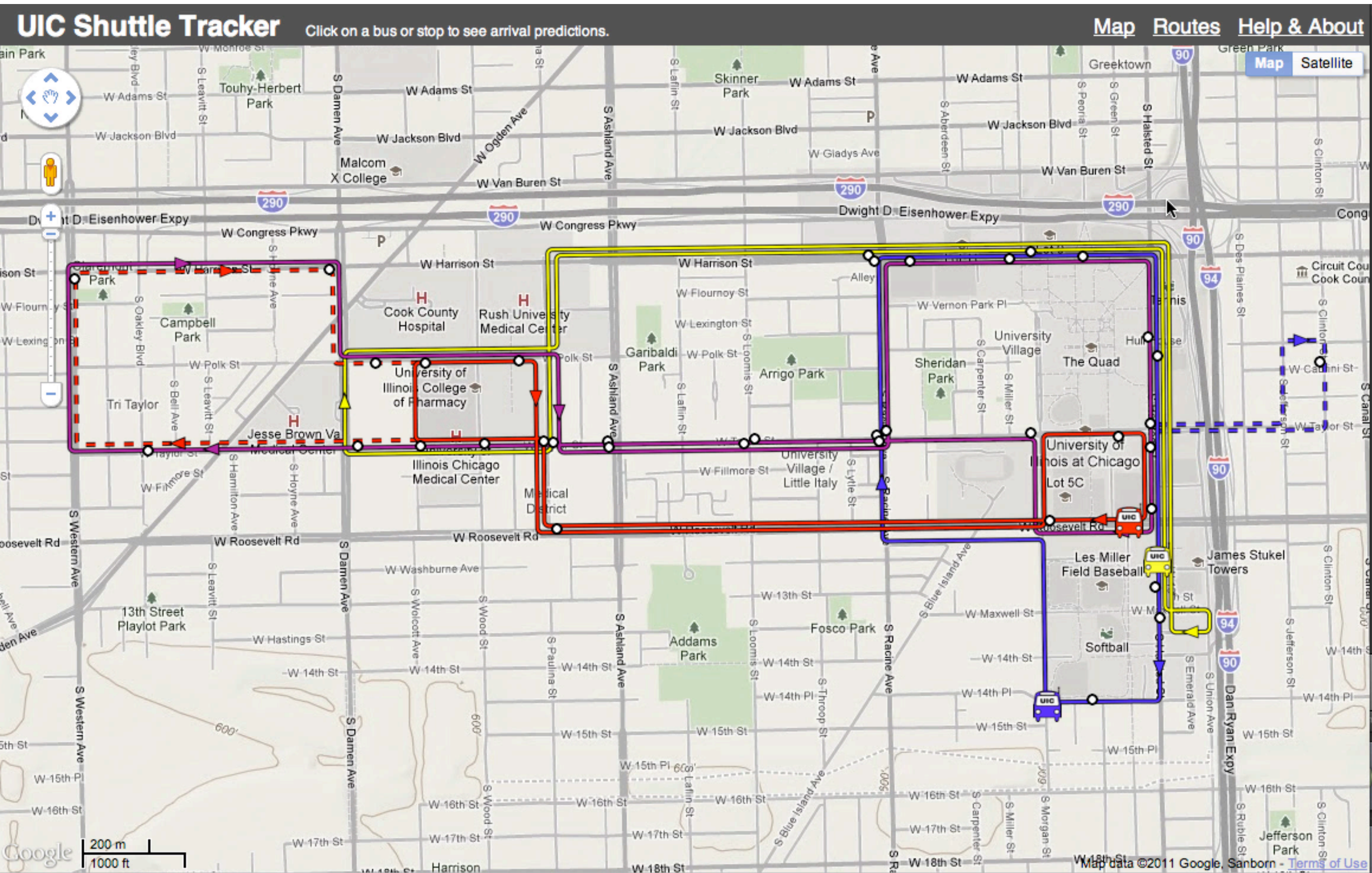
UIC East Side Route

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.

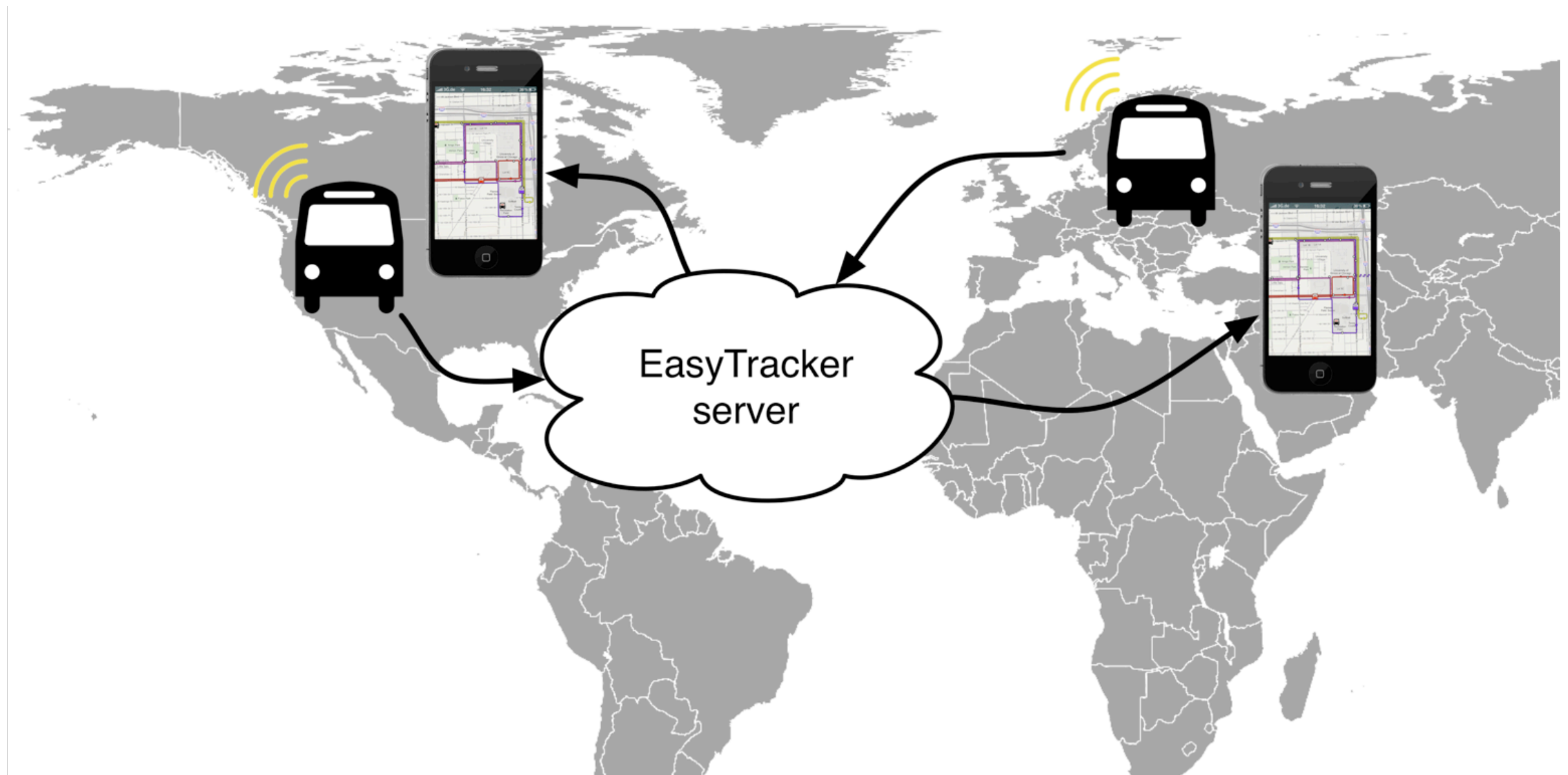
Hours of Operation

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

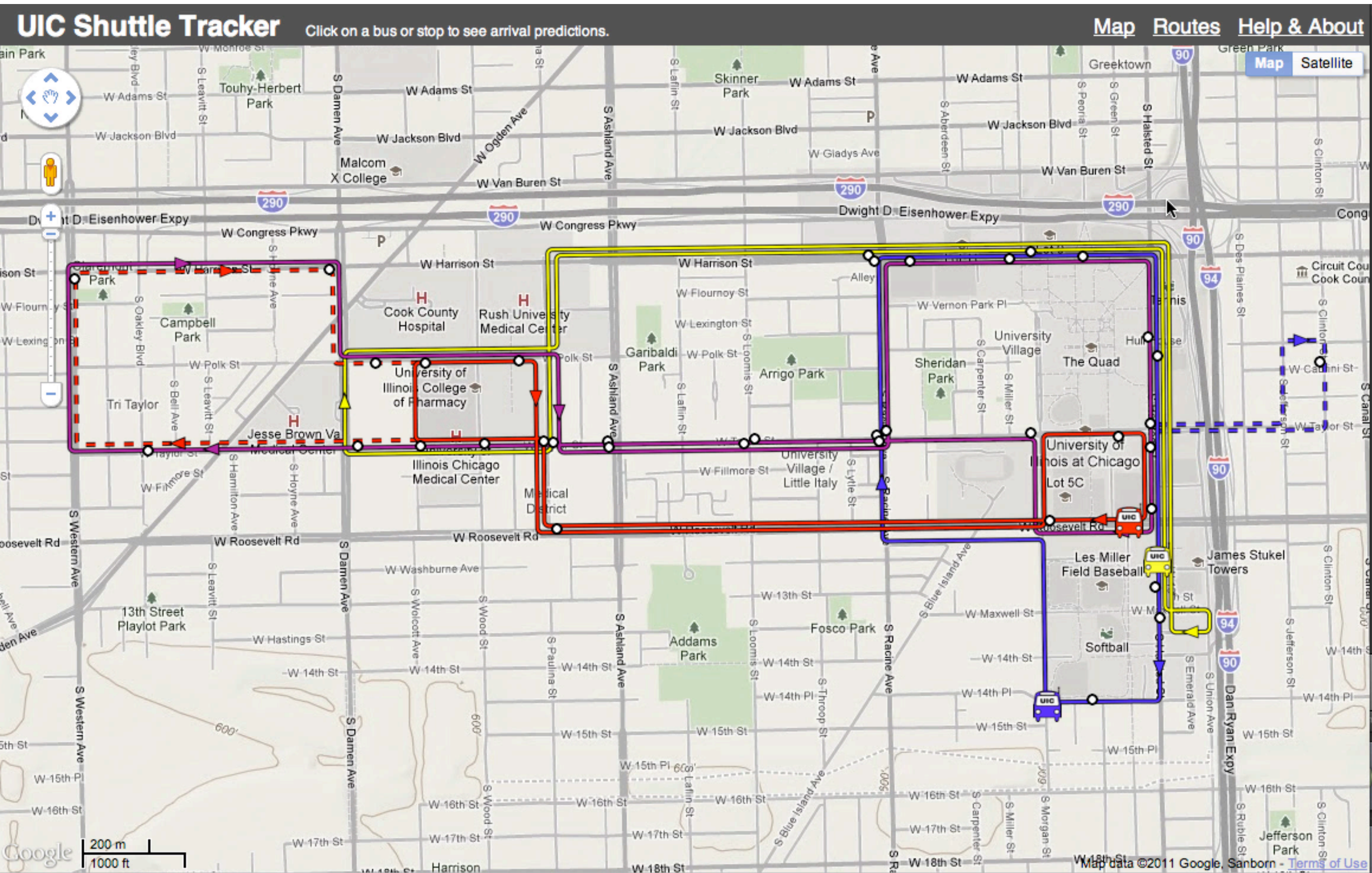
Our shuttle web (after)



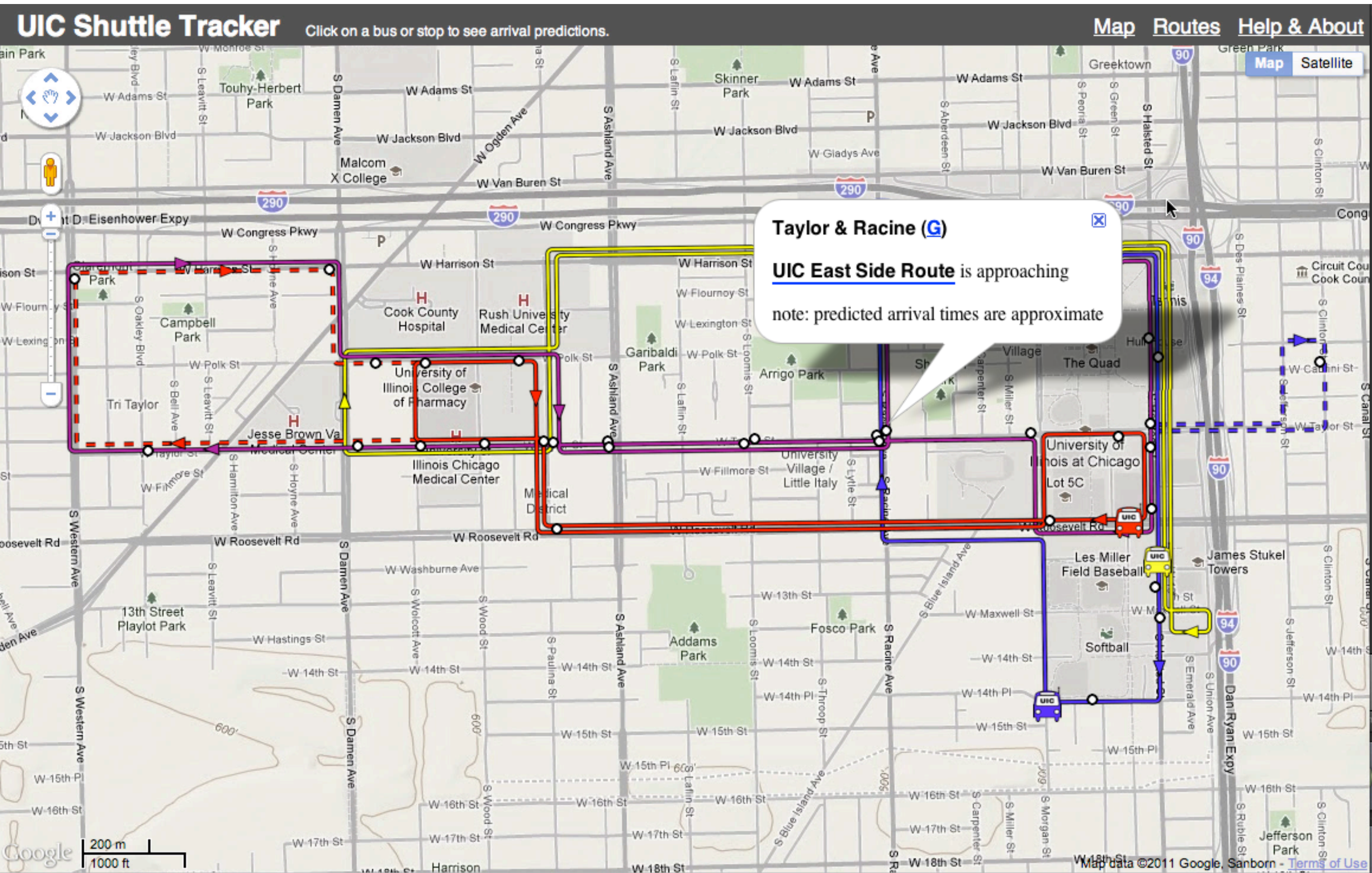
One service for everyone



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



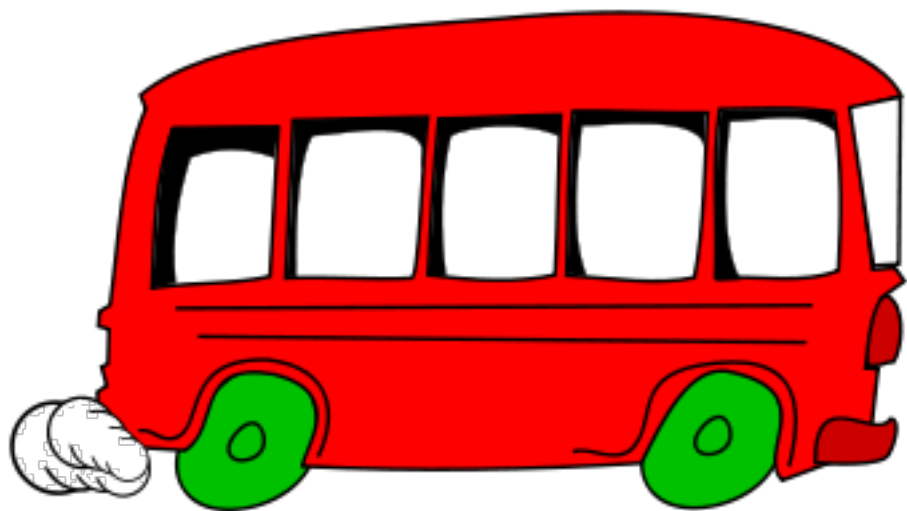
EasyTracker installation

1. Obtain smartphone
2. Install EasyTracker app



EasyTracker installation

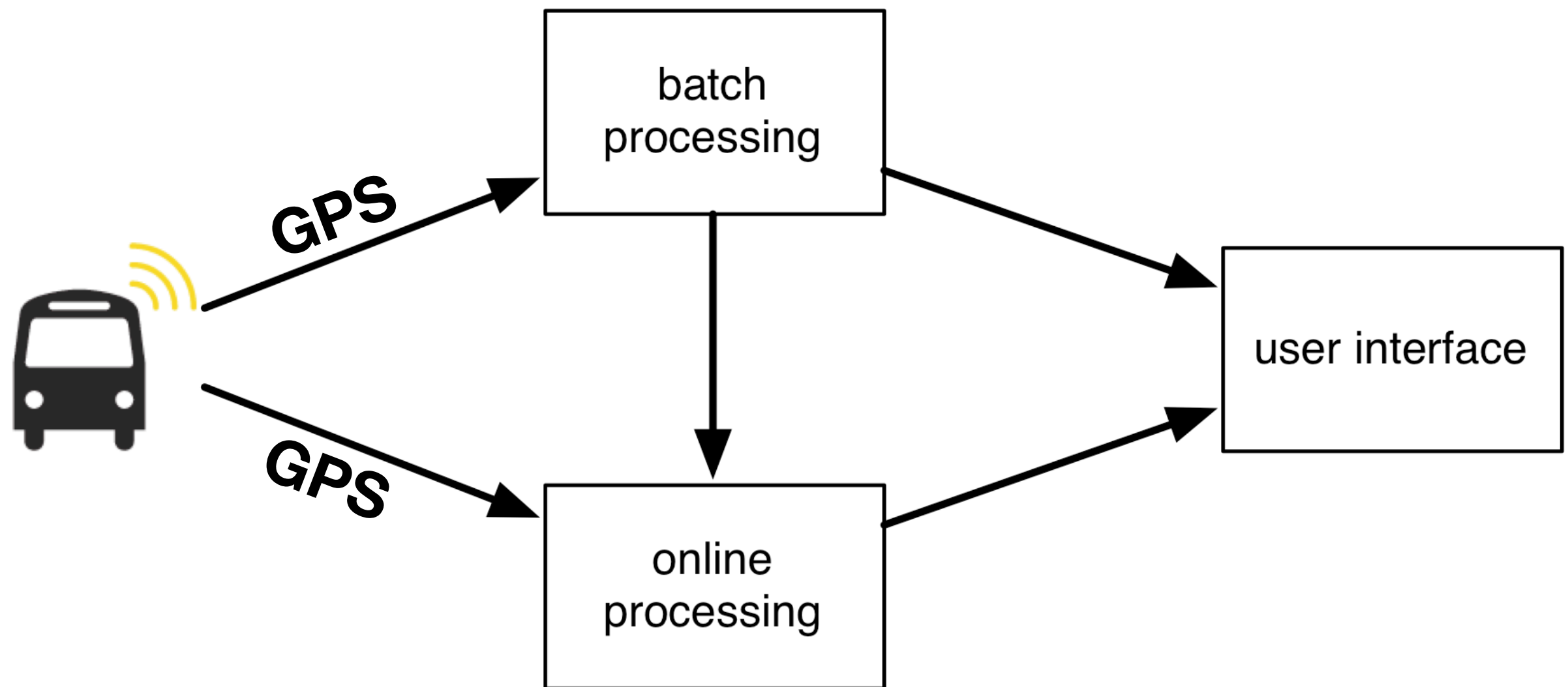
1. Obtain smartphone
2. Install EasyTracker app
3. Stick phone in bus



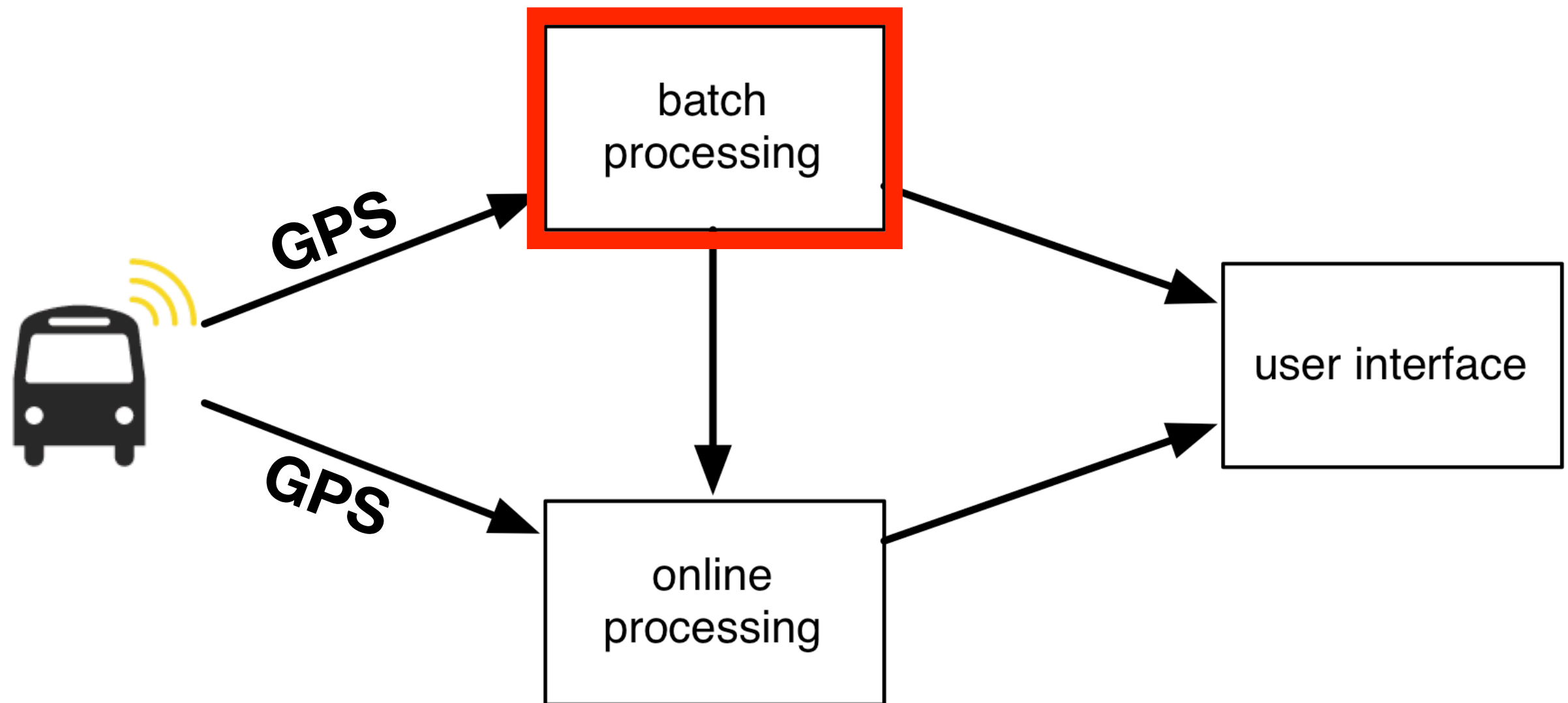
4. Relax



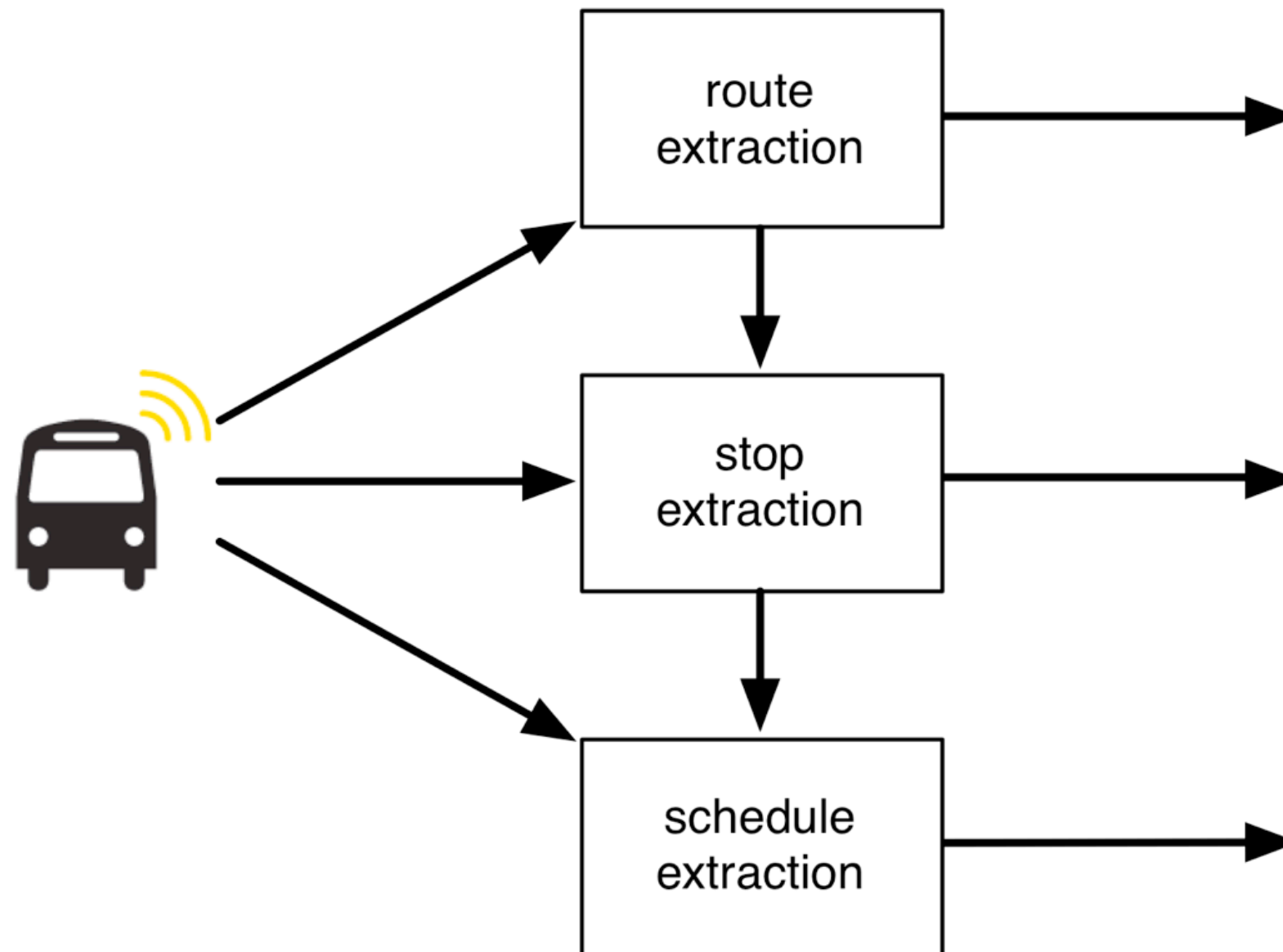
System overview



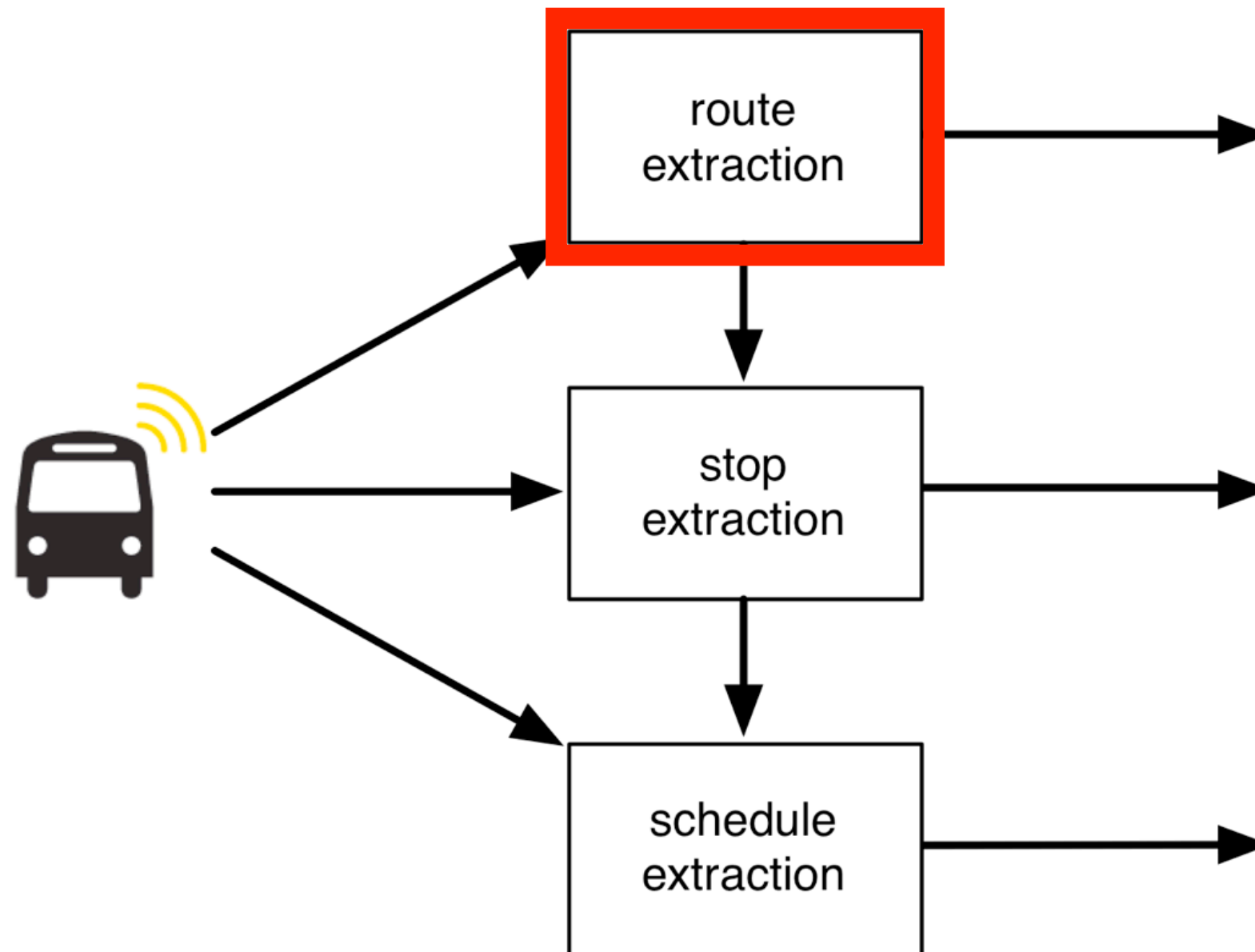
System overview



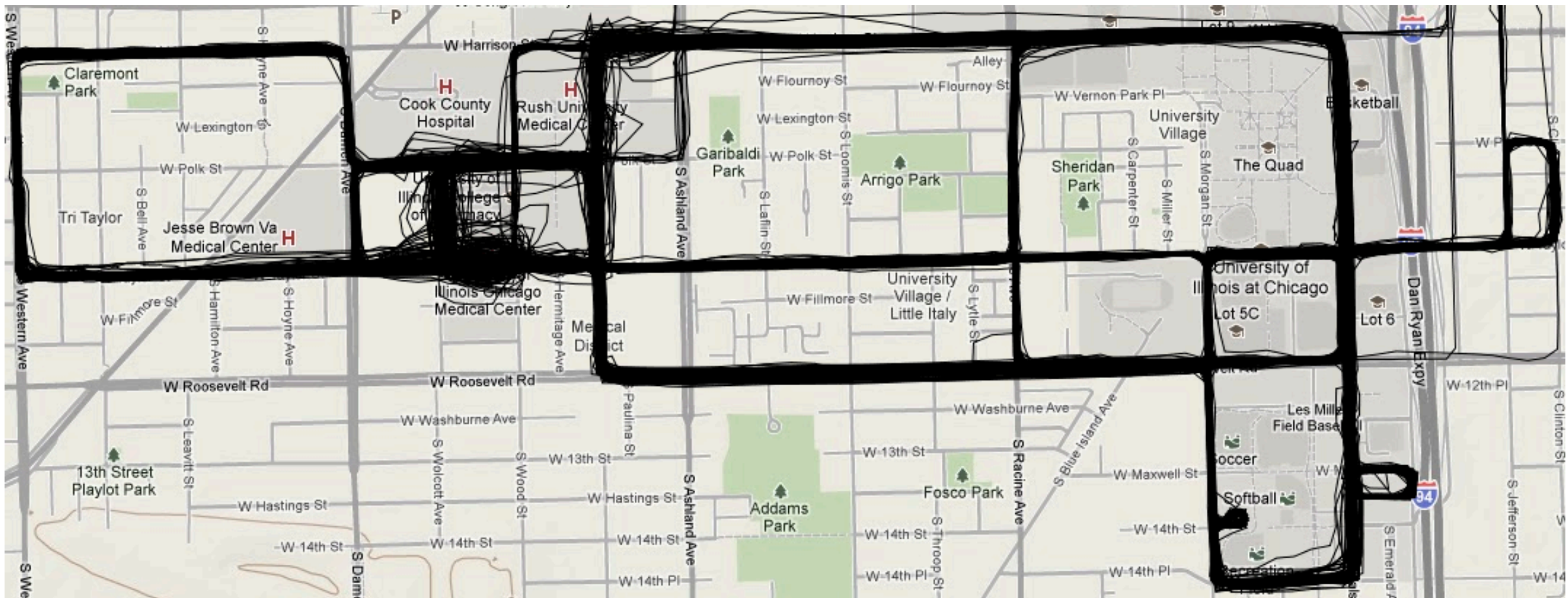
Batch processing



Batch processing



Raw GPS traces



The map displays the University of Illinois at Chicago campus with four distinct walking routes marked by colored lines and arrows. The routes are as follows:

- Red Route:** Starts at the top left, goes east along W Harrison St, then south along S Ashland Ave, and ends at the bottom left near W 14th St.
- Yellow Route:** Starts at the top left, goes east along W Harrison St, then south along S Ashland Ave, and ends at the bottom right near W 14th St.
- Purple Route:** Starts at the top left, goes east along W Harrison St, then south along S Ashland Ave, and ends at the bottom right near W 14th St.
- Blue Route:** Starts at the top right, goes west along W Harrison St, then south along S Ashland Ave, and ends at the bottom right near W 14th St.

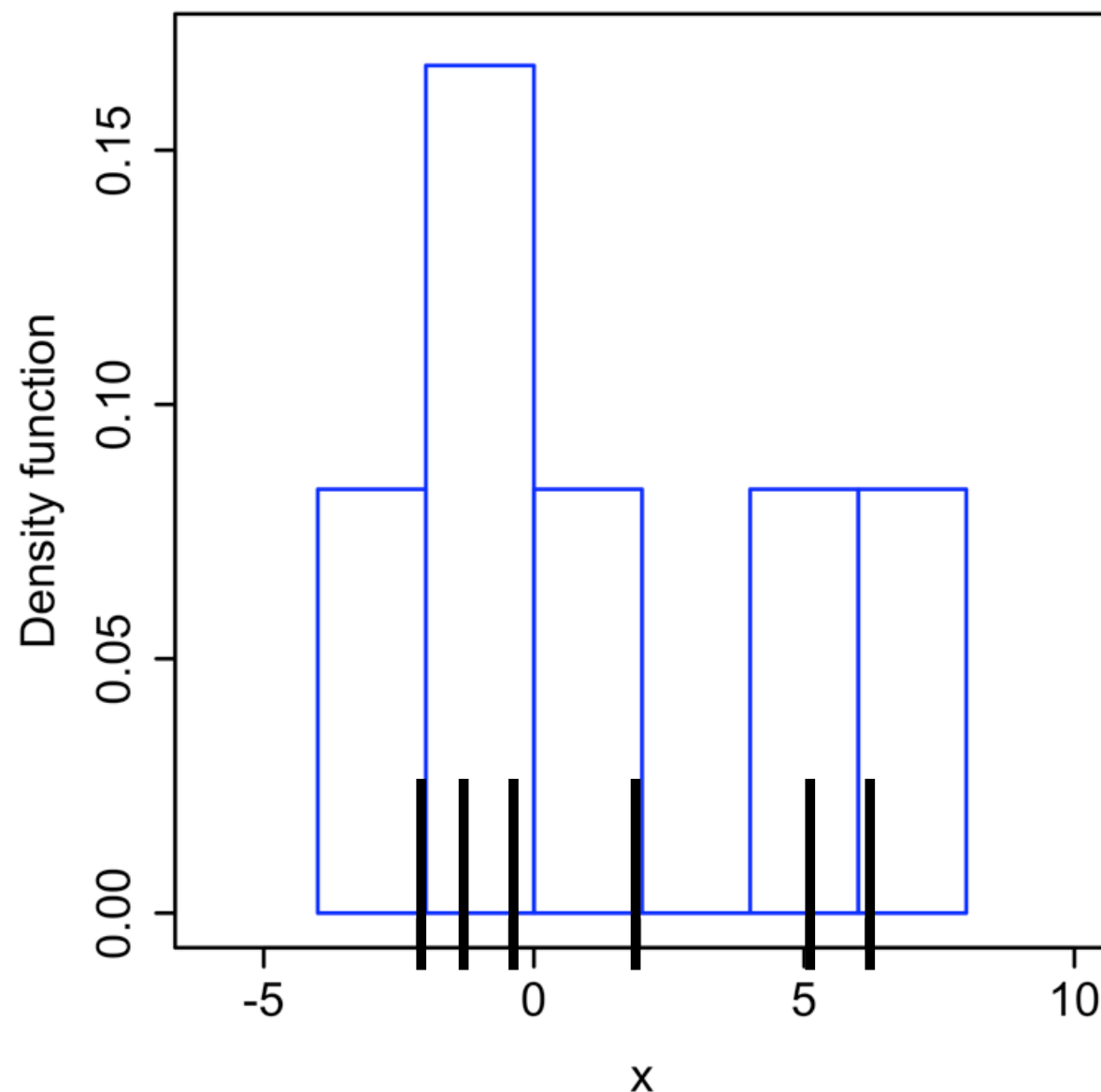
Key landmarks and streets shown on the map include:

- Streets:** W Harrison St, W Flourney 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, W 14th Pl, S Western Ave, S Bell Ave, S Hamilton Ave, S Hoyne Ave, S Paulina St, S Wood St, S Ashland Ave, S Racine Ave, S Blue Island Ave, S Emerald Ave, S Jefferson St, S Clinton St, S Morgan St, S Miller St, S Carpenter St, S Lytle St, S Throop St.
- Landmarks:** Cook County Hospital, Rush University Medical Center, University of Illinois College of Pharmacy, Illinois Chicago Medical Center, Garibaldi Park, Arrigo Park, Sheridan Park, Addams Park, Fosco Park, University Village, The Quad, University of Illinois at Chicago Lot 5C, Les Miller Field Baseball, Soccer, Softball, Recreation Field.
- Highways:** I-94, I-55, I-54.

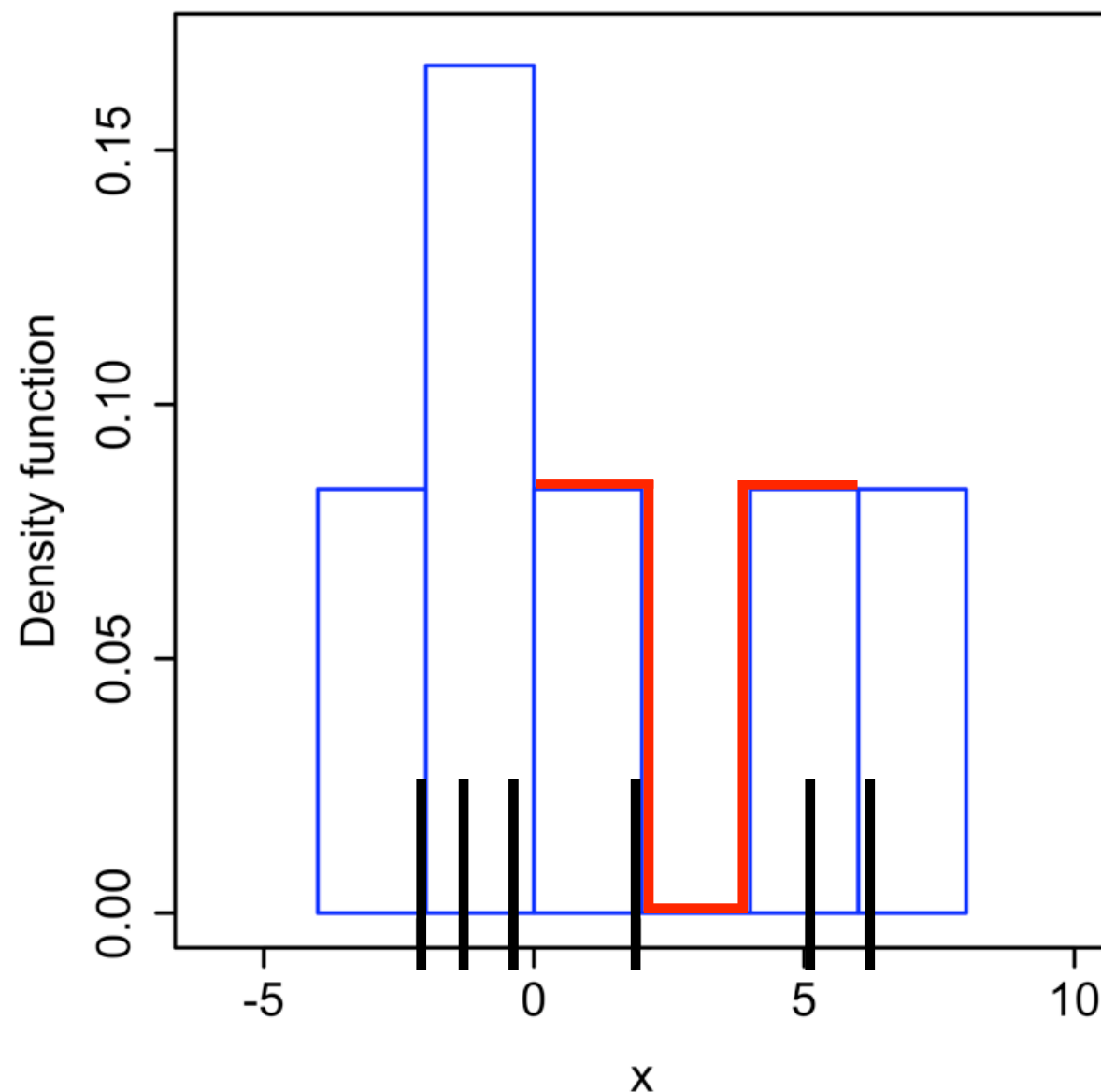
The map displays the University City neighborhood in Chicago, bounded by W Harrison St to the north and W 14th St to the south. A thick black line outlines a specific area within the neighborhood, likely the study area for the research. This outlined area includes the University Village, the Quad, and the University of Illinois at Chicago (UIC) campus. Key landmarks and streets visible include:

- Streets:** W Harrison St, W Floumoy 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 Bell Ave, S Hamilton Ave, S Hoyne Ave, S Leavitt St, S Dearborn Ave, S Ashland Ave, S Paulina St, S Racine Ave, S Throop St, S Belmont Ave, S Morgan St, S Miller St, S Carpenter St, S Loomis St, S Laflin St, S Lytle St, S Dearborn Ave, S Belmont Ave, S Morgan St, S Miller St, S Carpenter St, S Loomis St, S Laflin St, S Lytle St.
- Parks:** Claremont Park, Garibaldi Park, Arrigo Park, Sheridan Park, Addams Park, Fosco Park, 13th Street Playlot Park.
- Medical Centers:** Cook County Hospital, Rush University Medical Center, Jesse Brown VA Medical Center, Illinois Chicago Medical Center.
- Other Landmarks:** University Village, The Quad, University of Illinois at Chicago (UIC) campus, Lot 5C, Lot 6, Les Mills Field Base, Soccer, Softball, Basketball.
- Highways:** I-55 (Dan Ryan Expwy), I-94 (Semiexpwy).

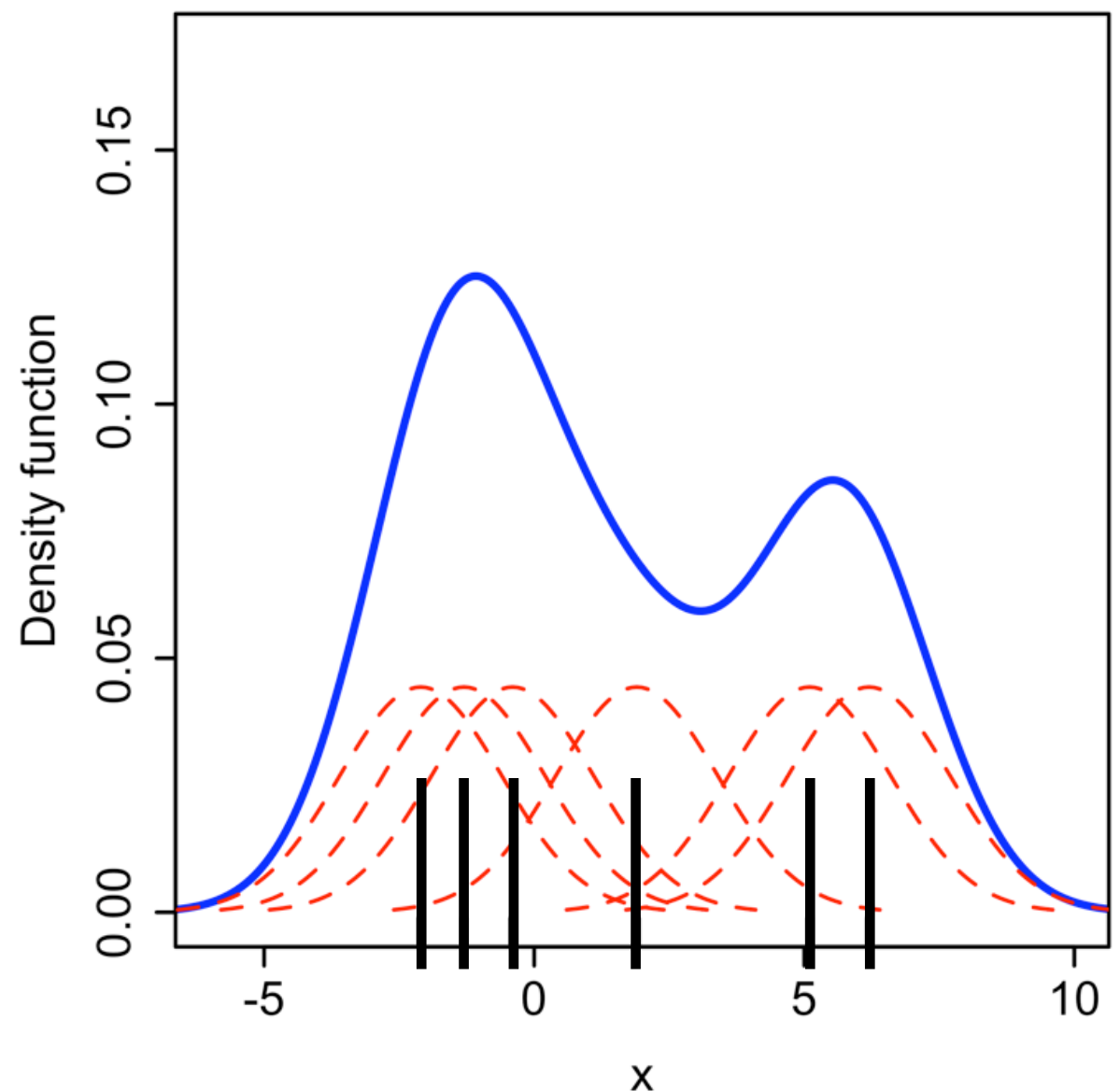
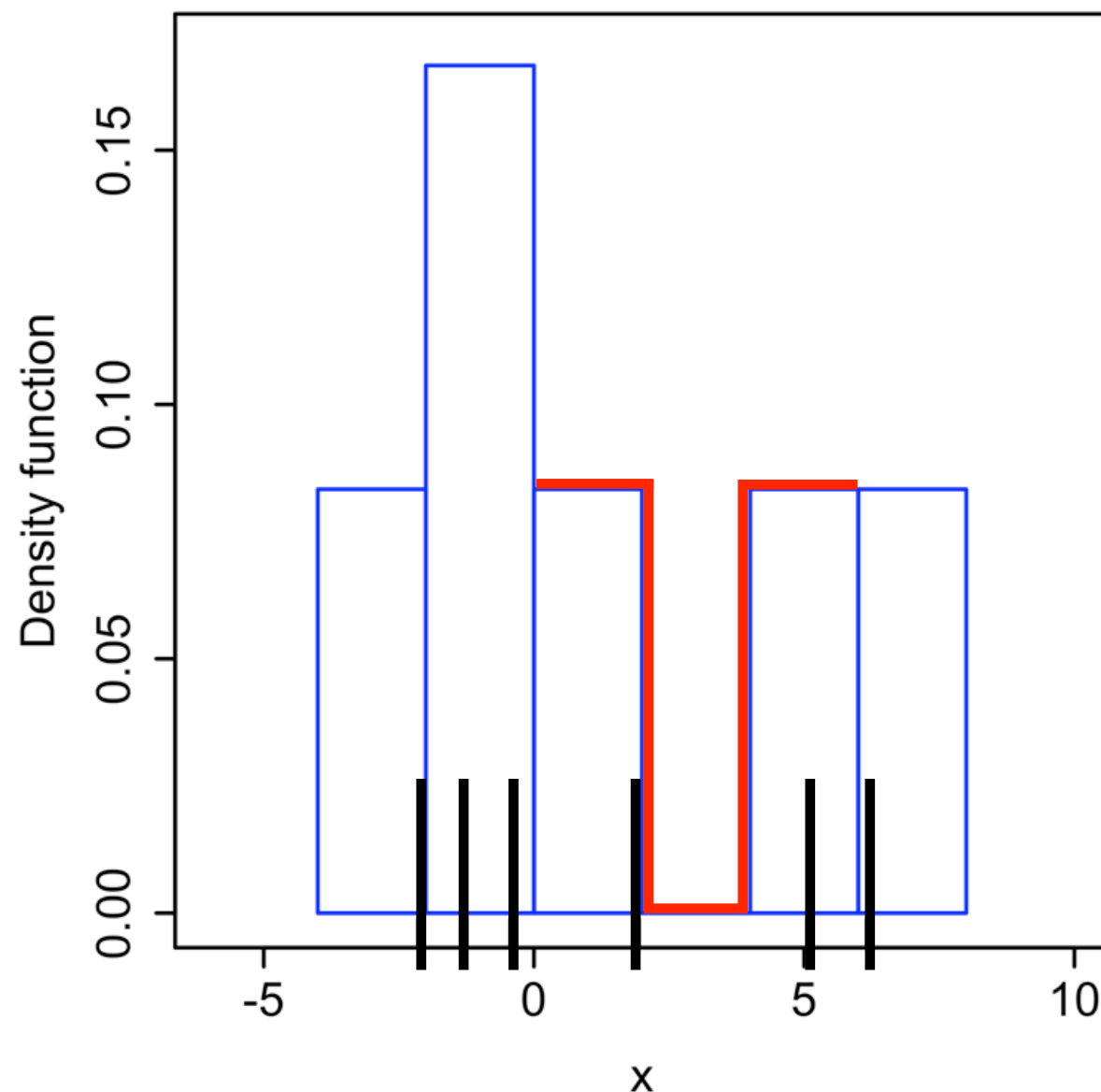
Kernel Density Estimation



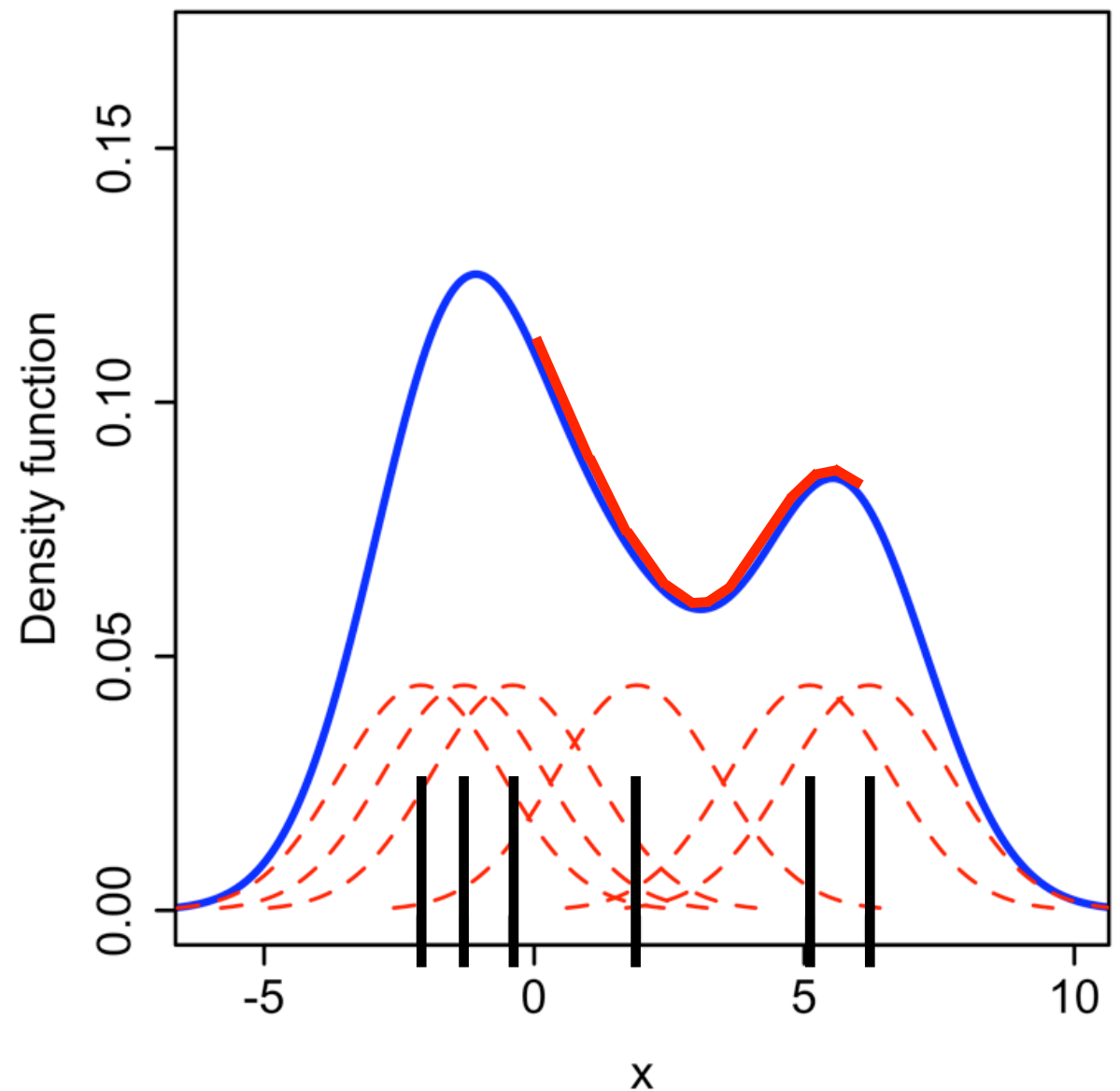
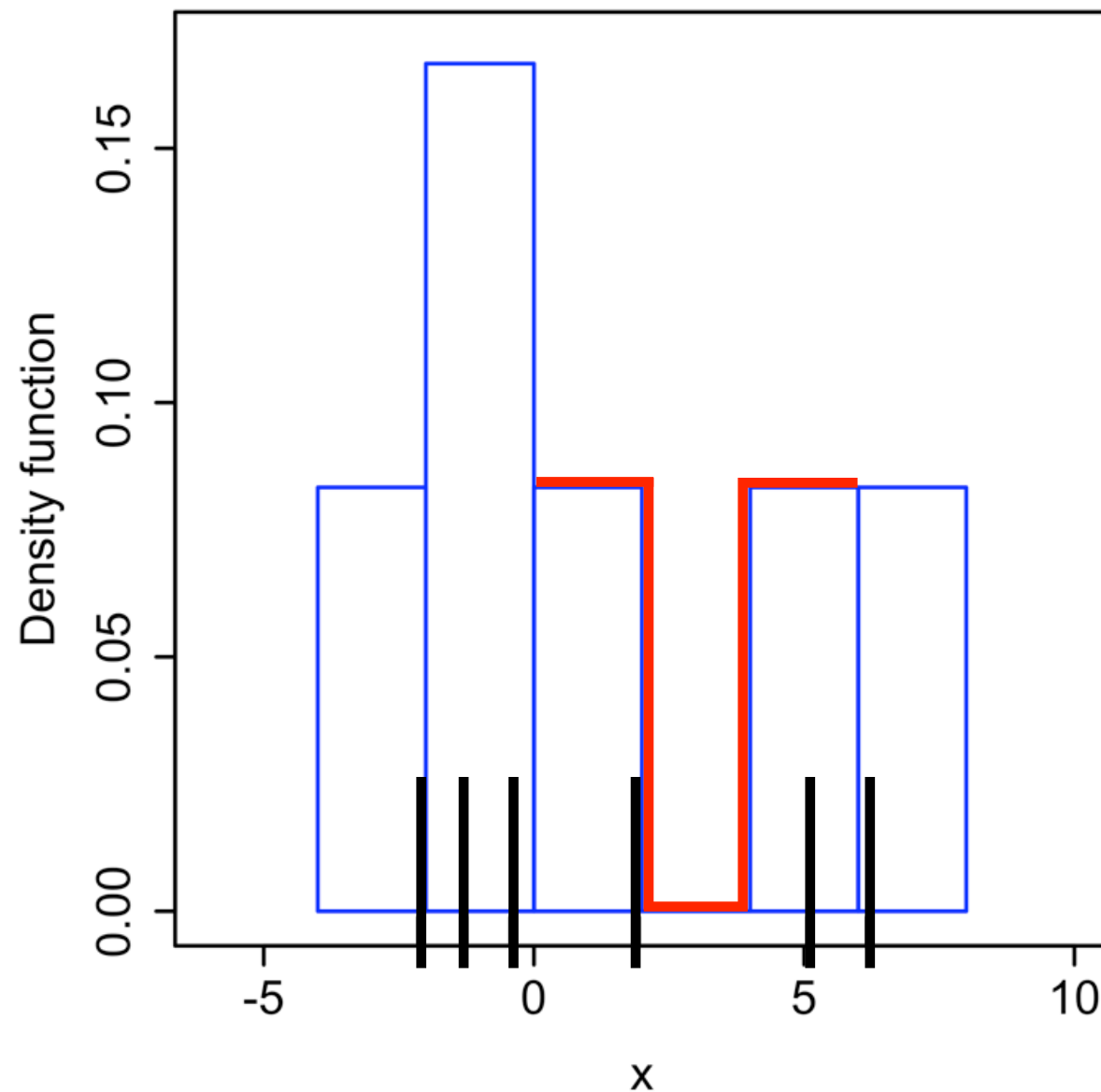
Kernel Density Estimation



Kernel Density Estimation



Kernel Density Estimation

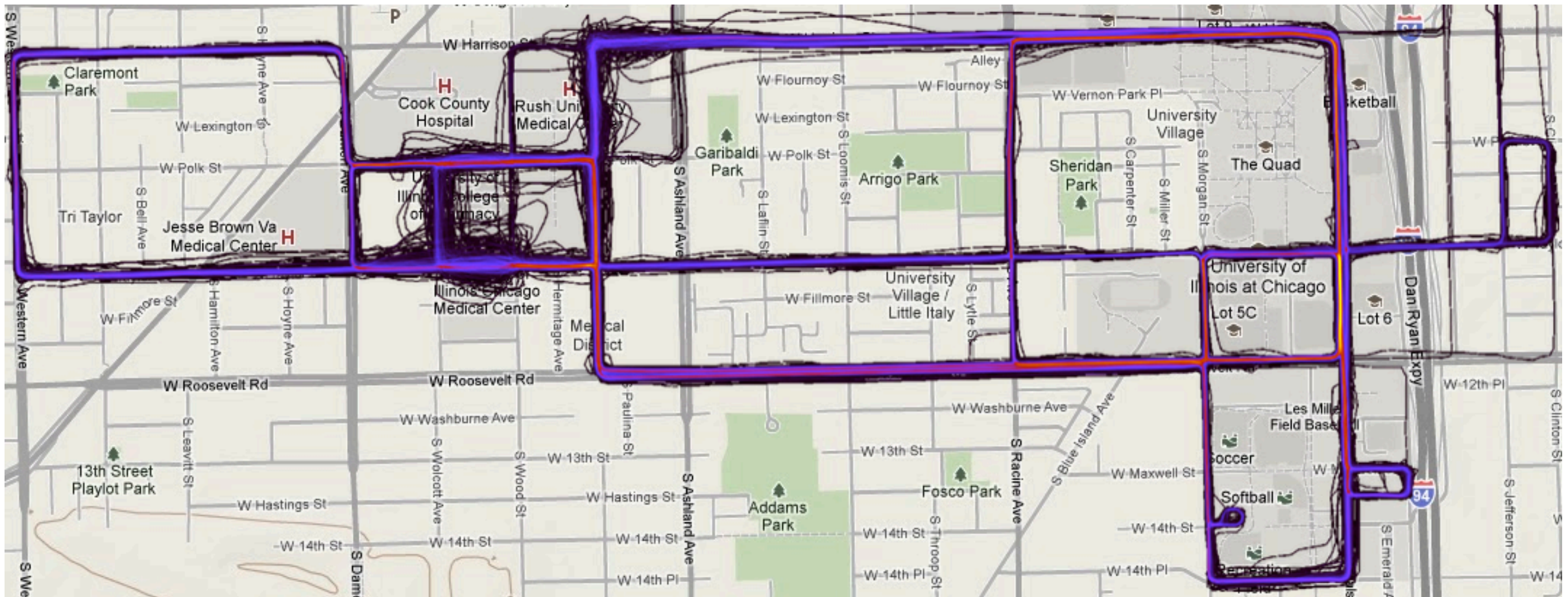


Kernel density estimation

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

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

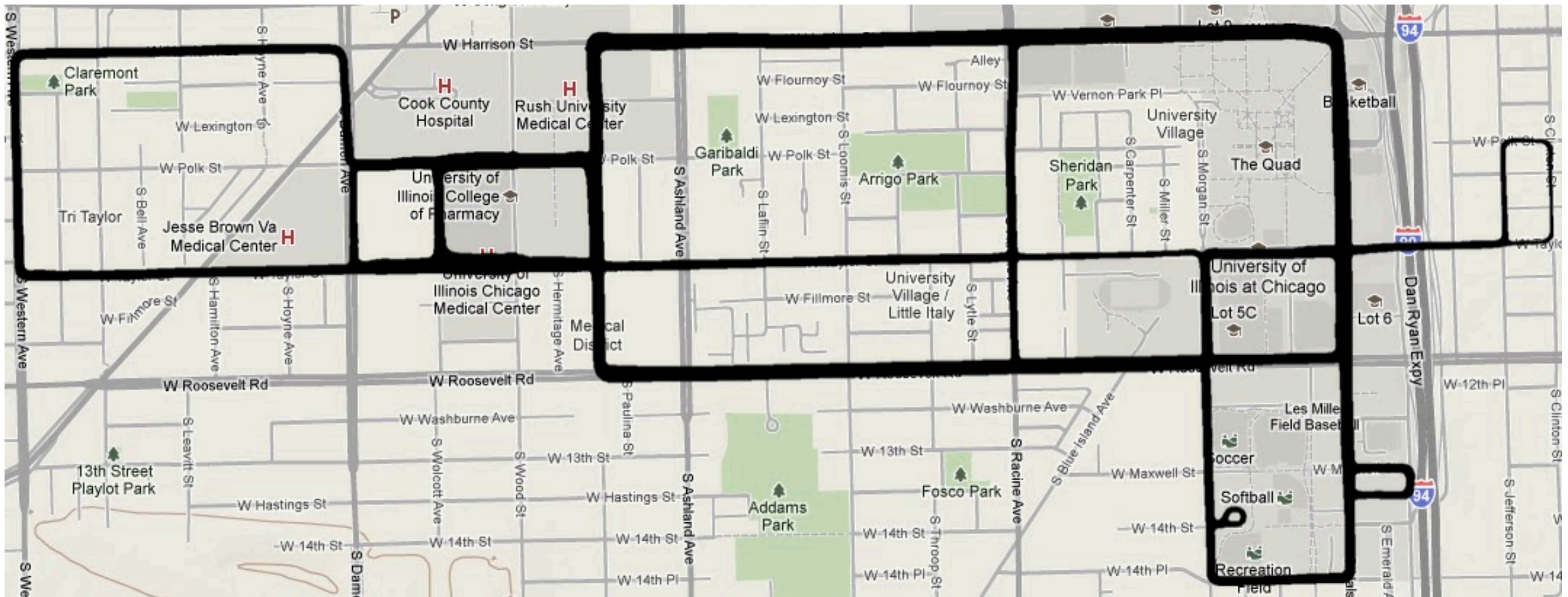
2-D histogram



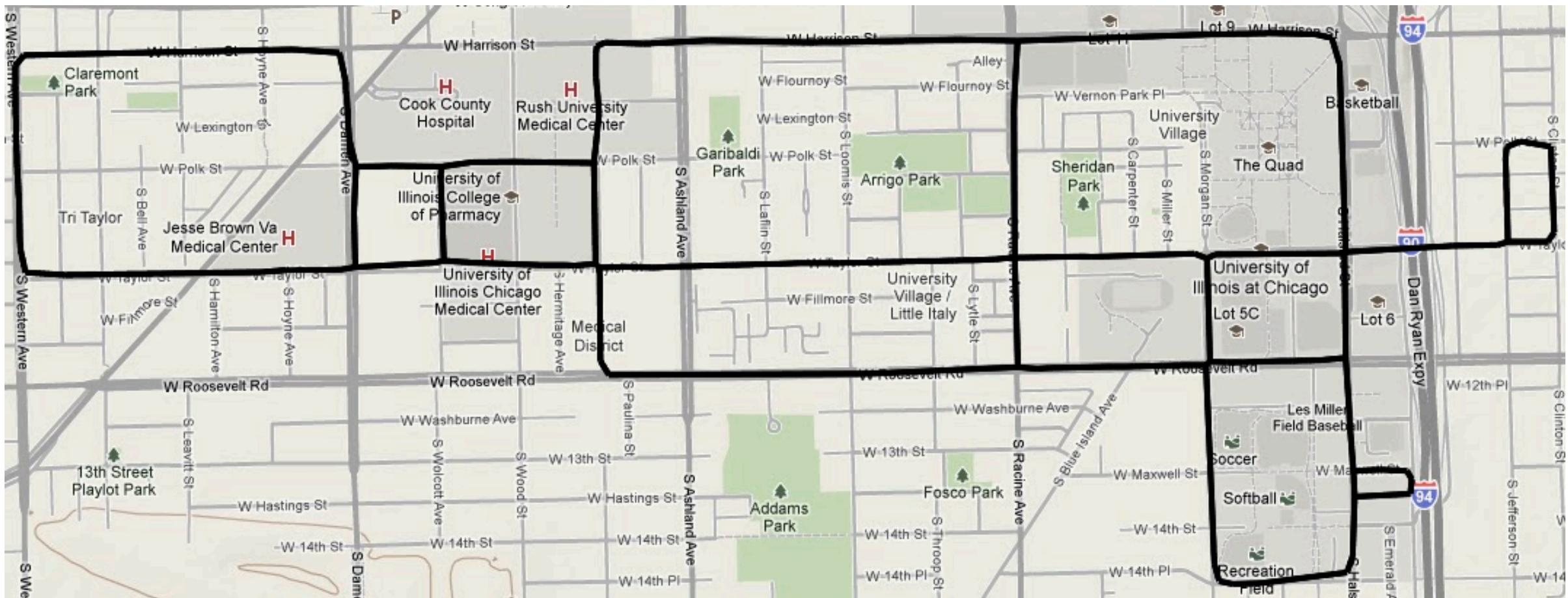
Trajectory density estimate



Thresholded image



Map extraction

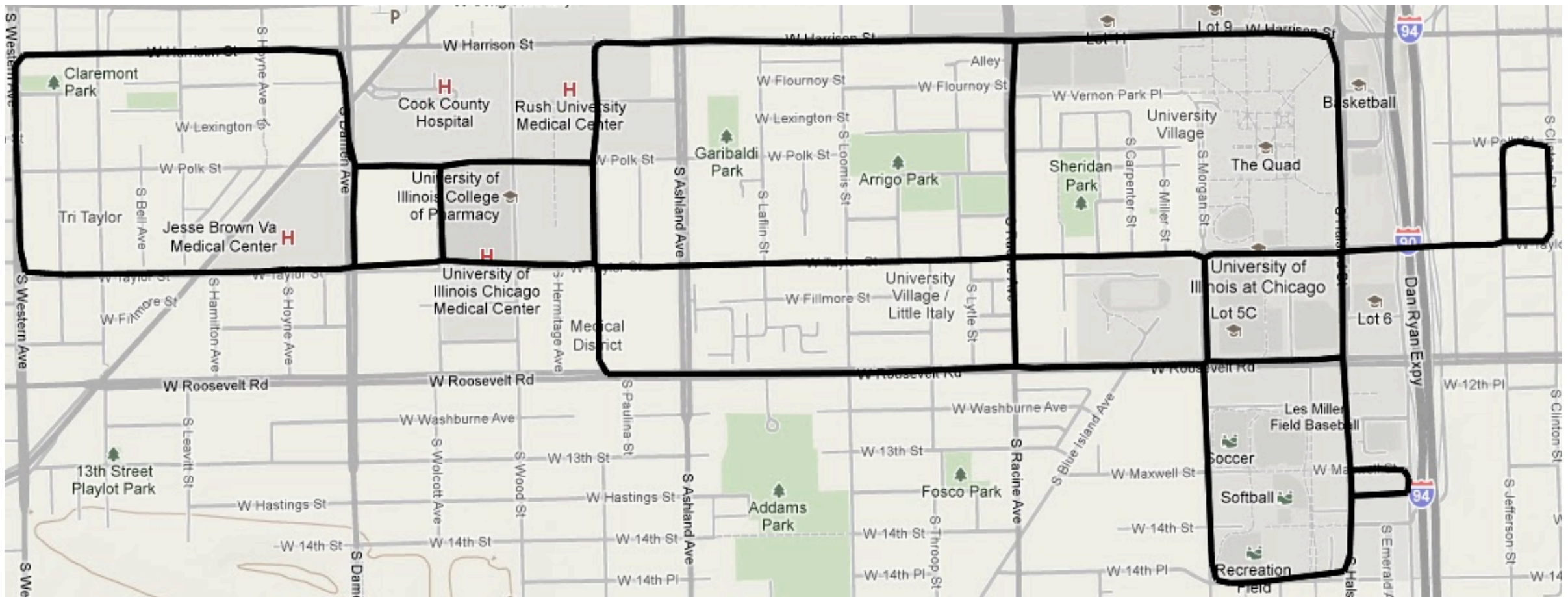


► Davies et al., 2006

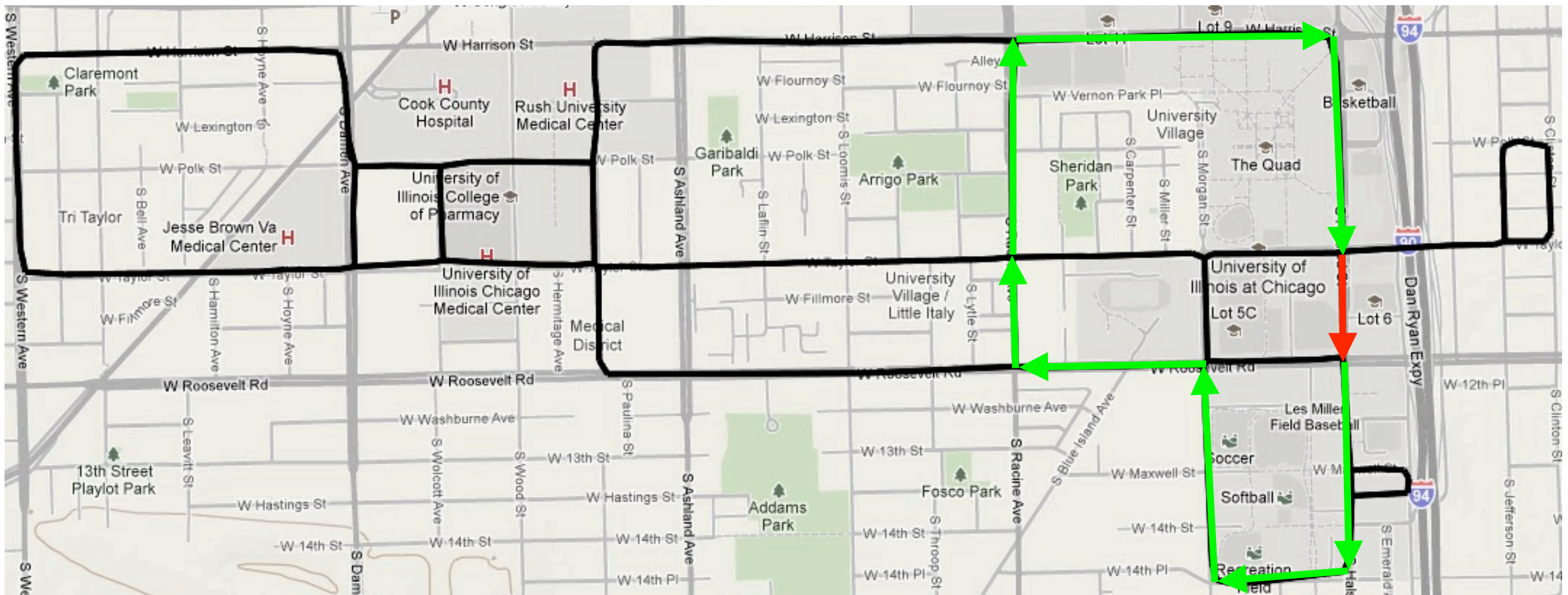
Route extraction

- ▶ 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

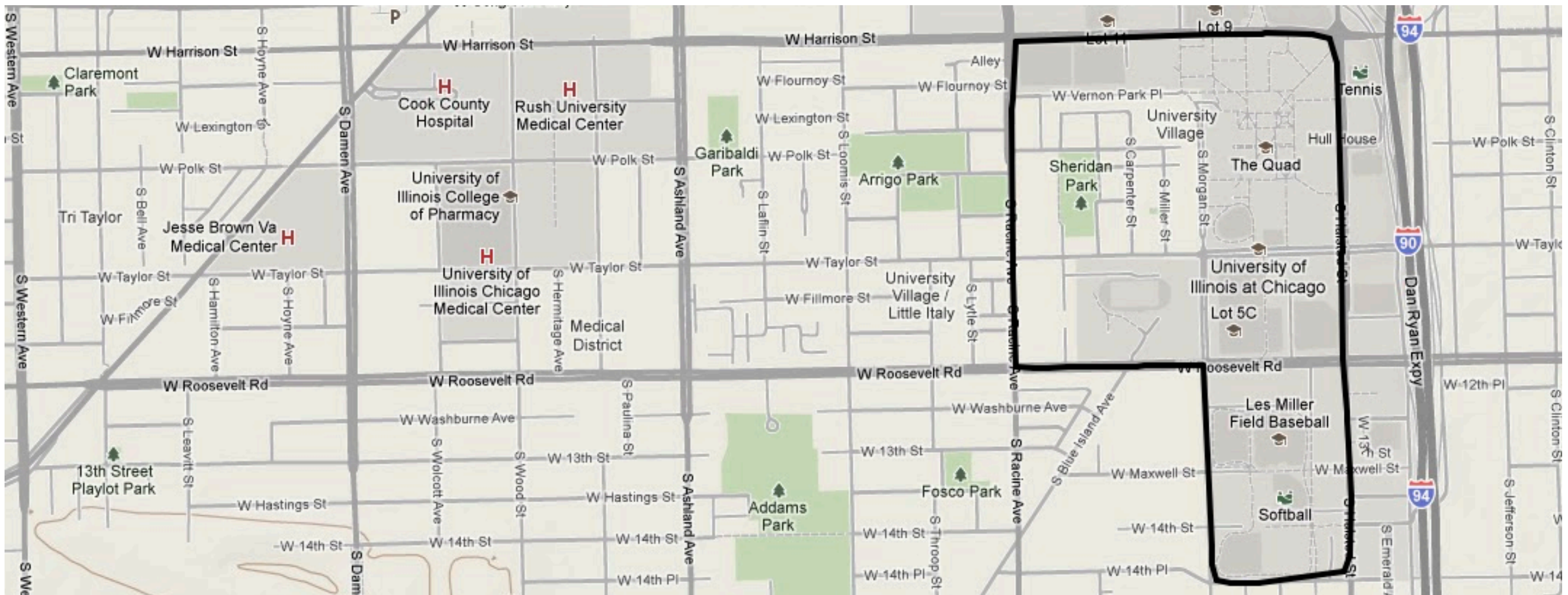
Route extraction



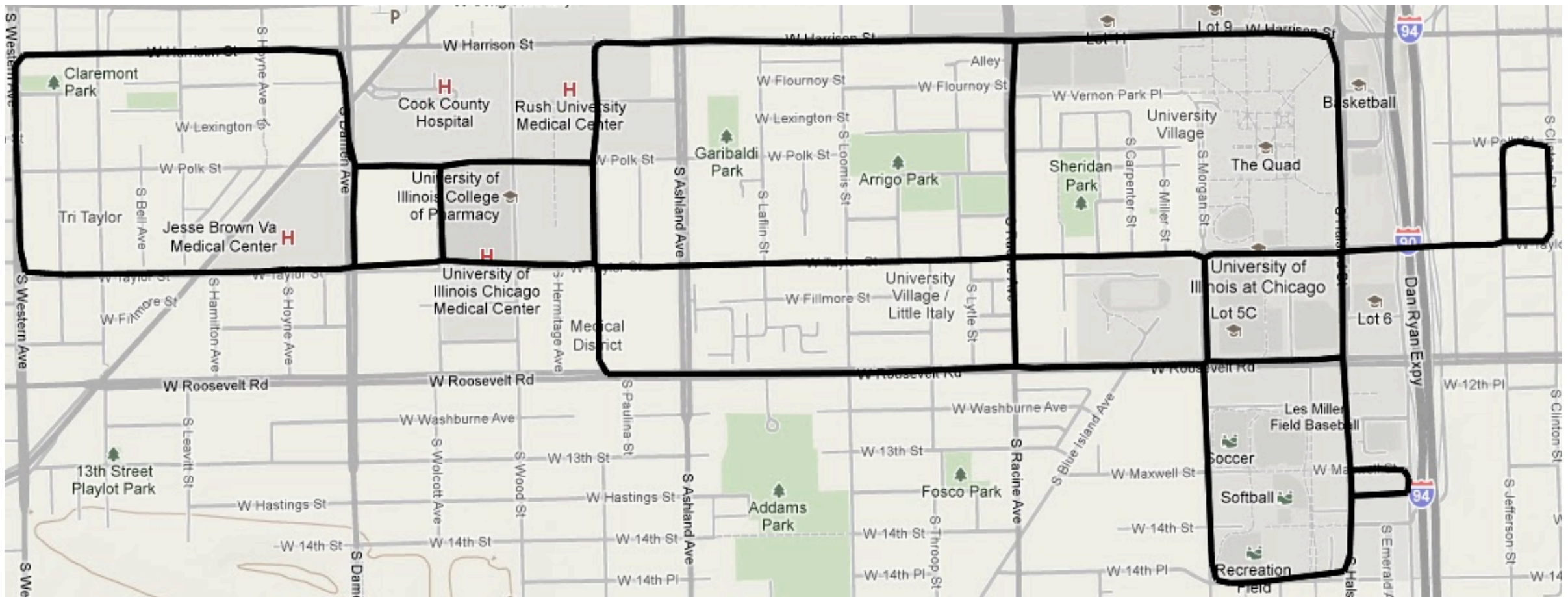
Route extraction



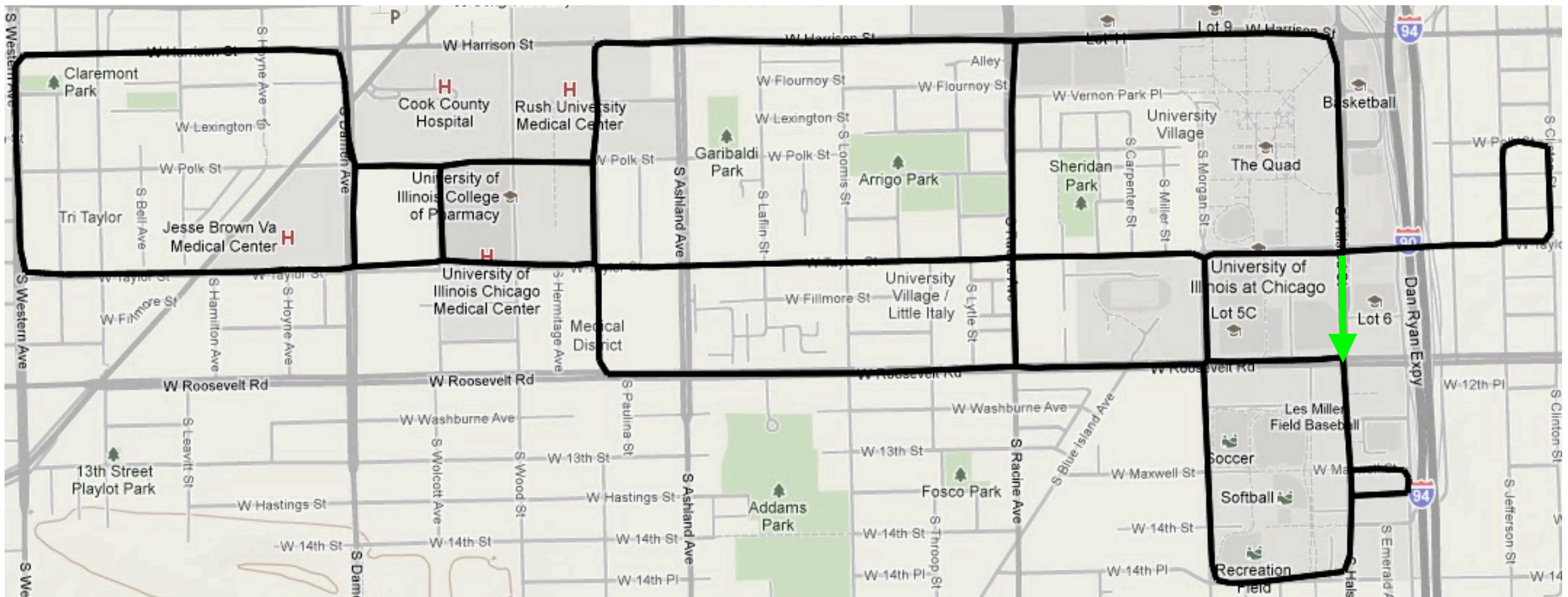
Route extraction



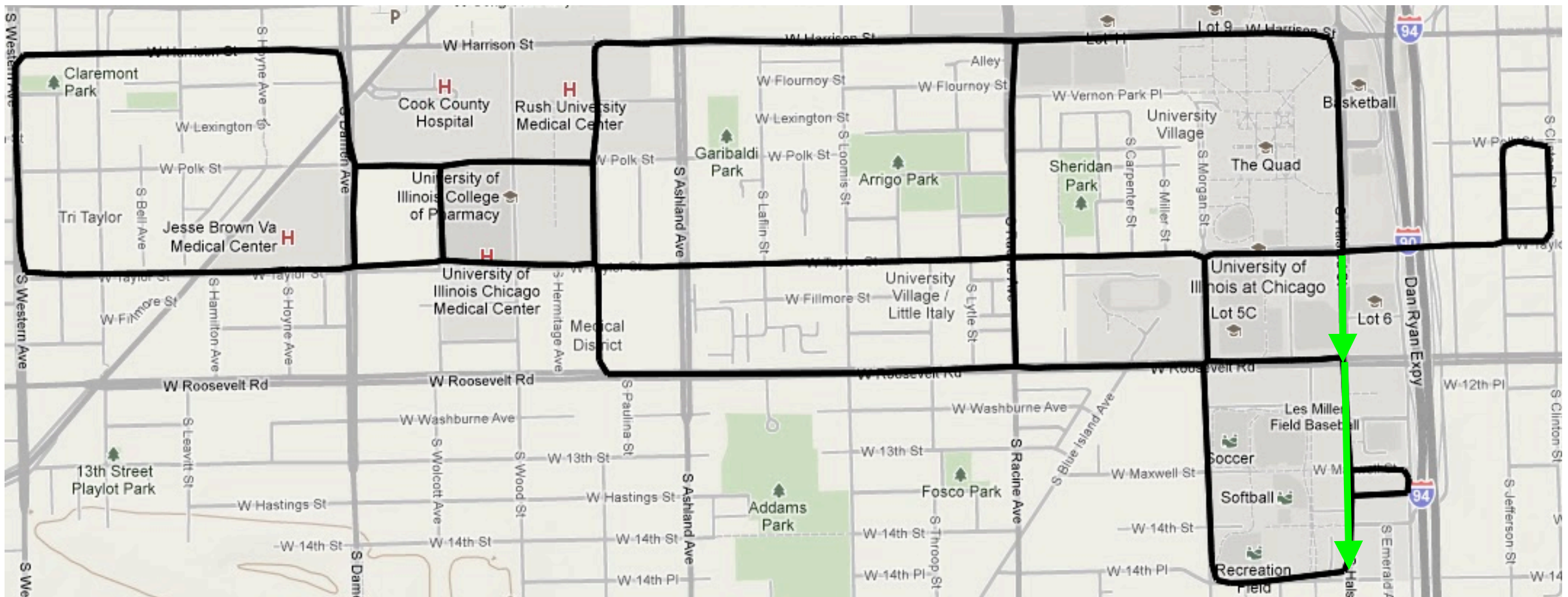
Route extraction



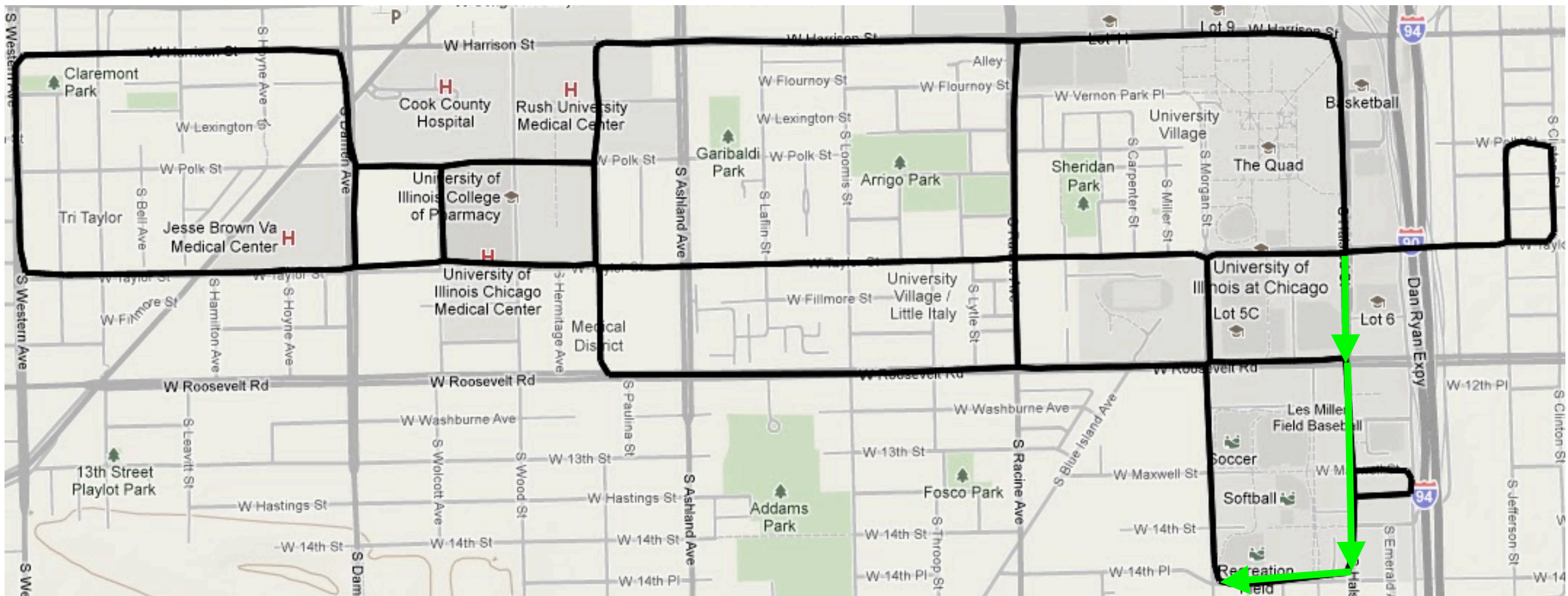
Route extraction



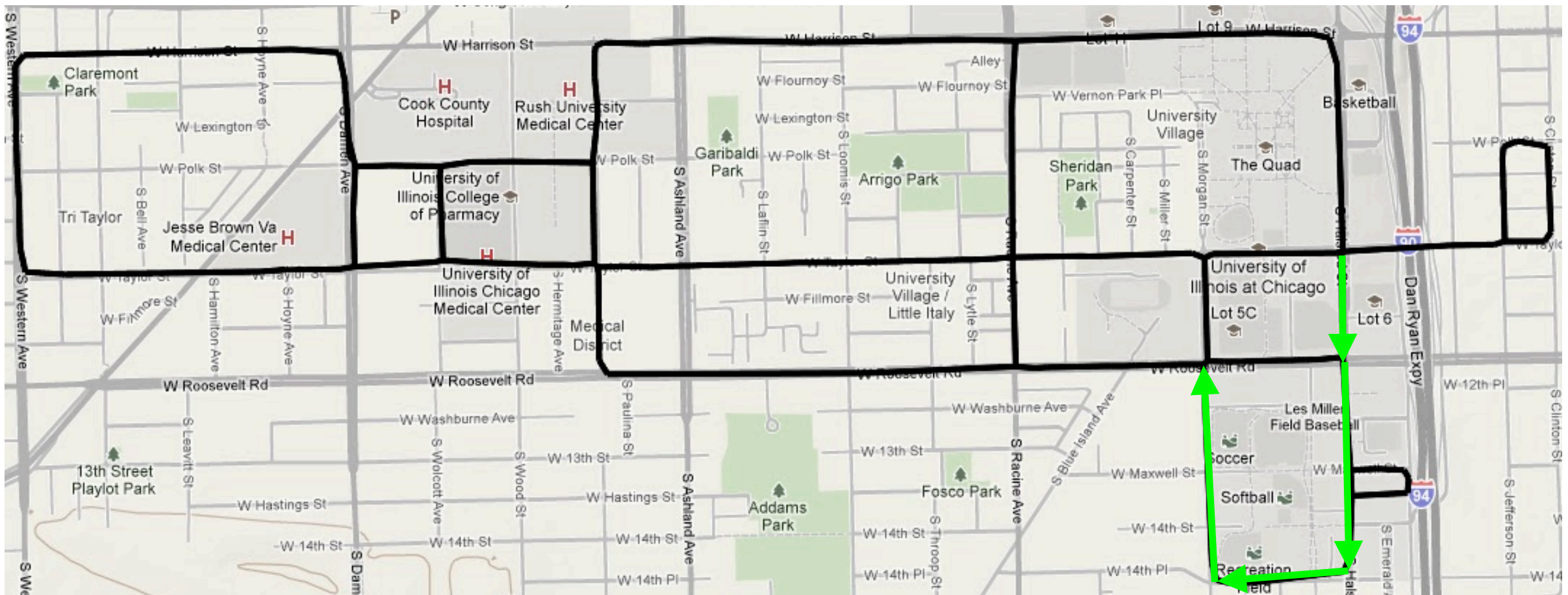
Route extraction



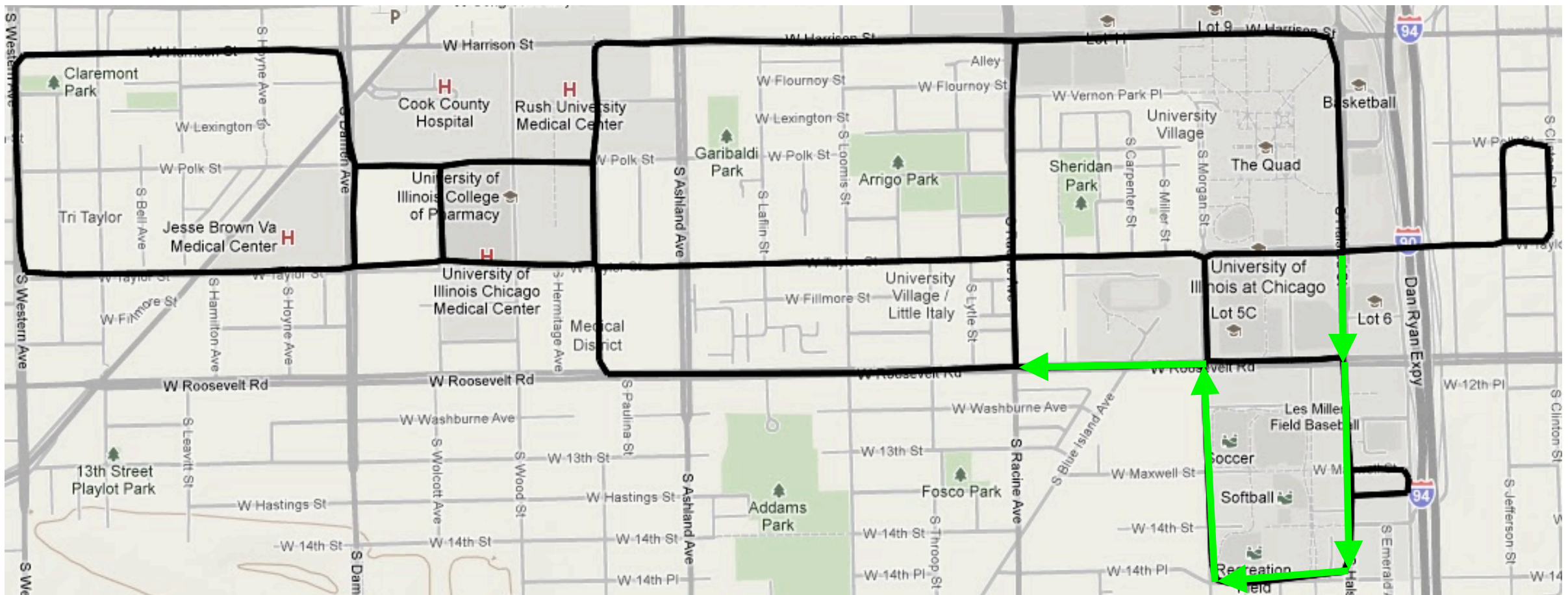
Route extraction



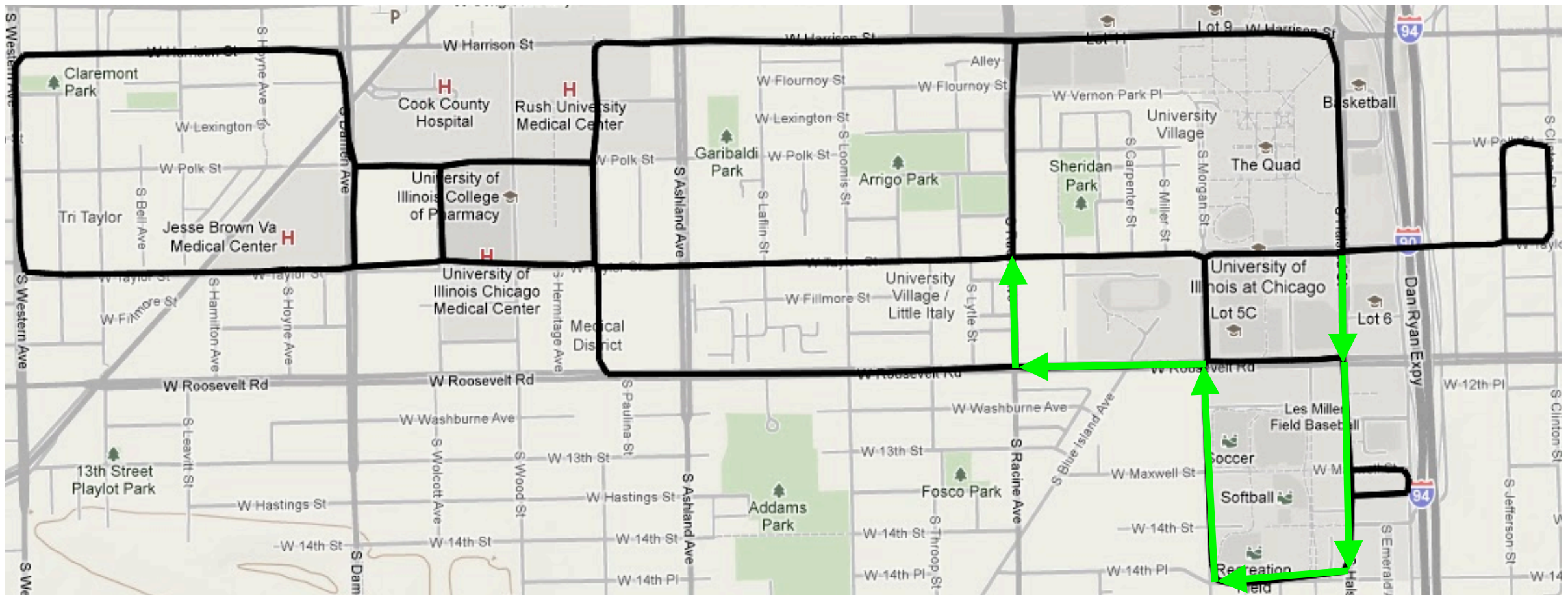
Route extraction



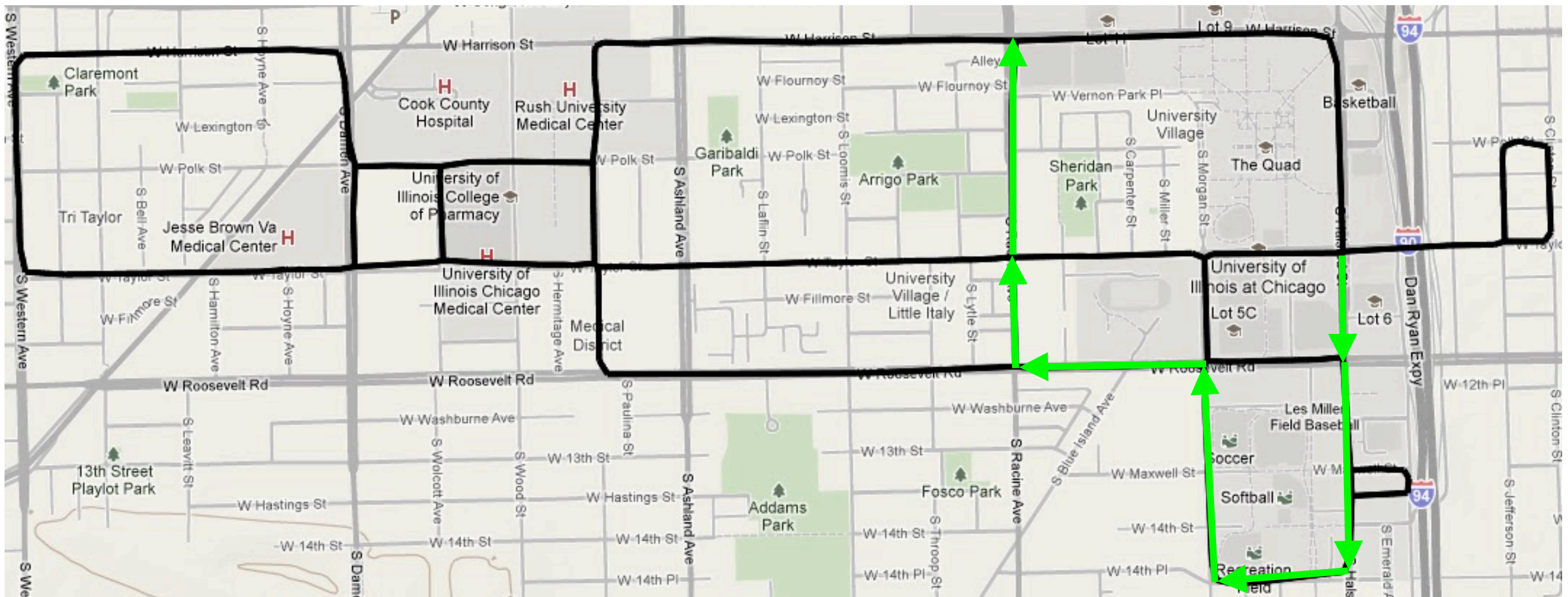
Route extraction



Route extraction

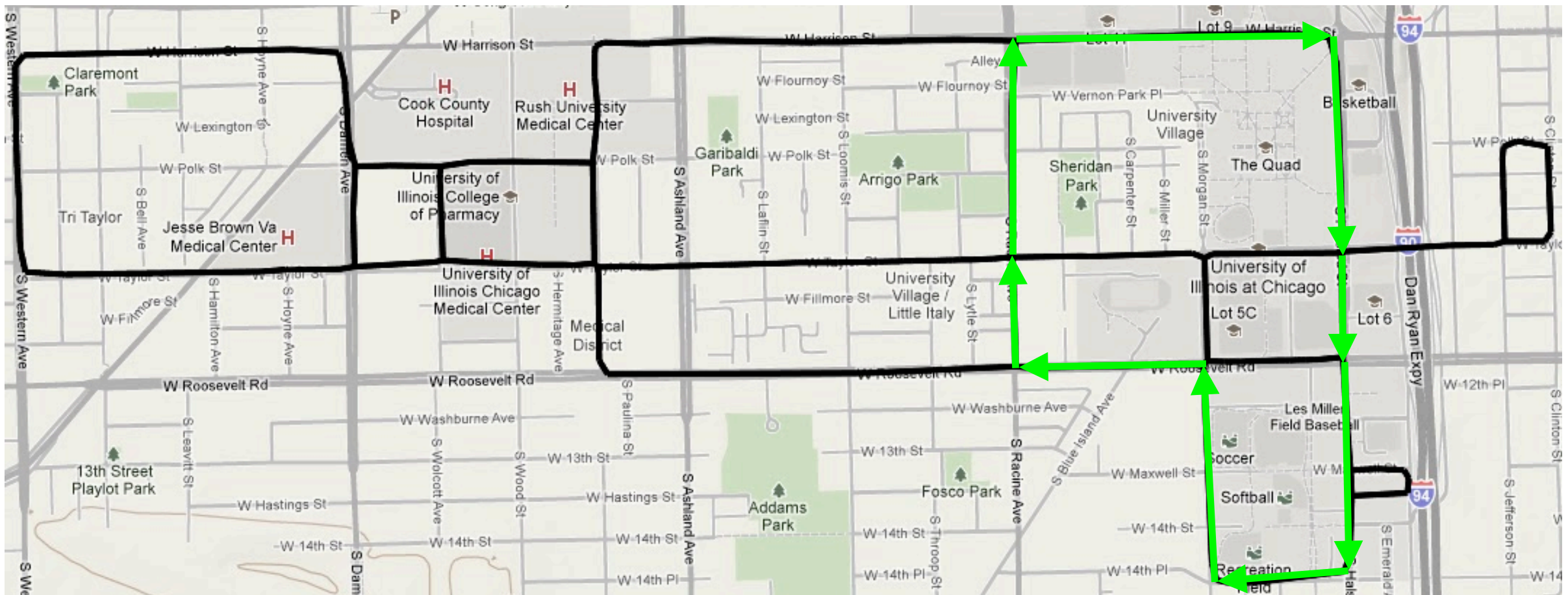


Route extraction

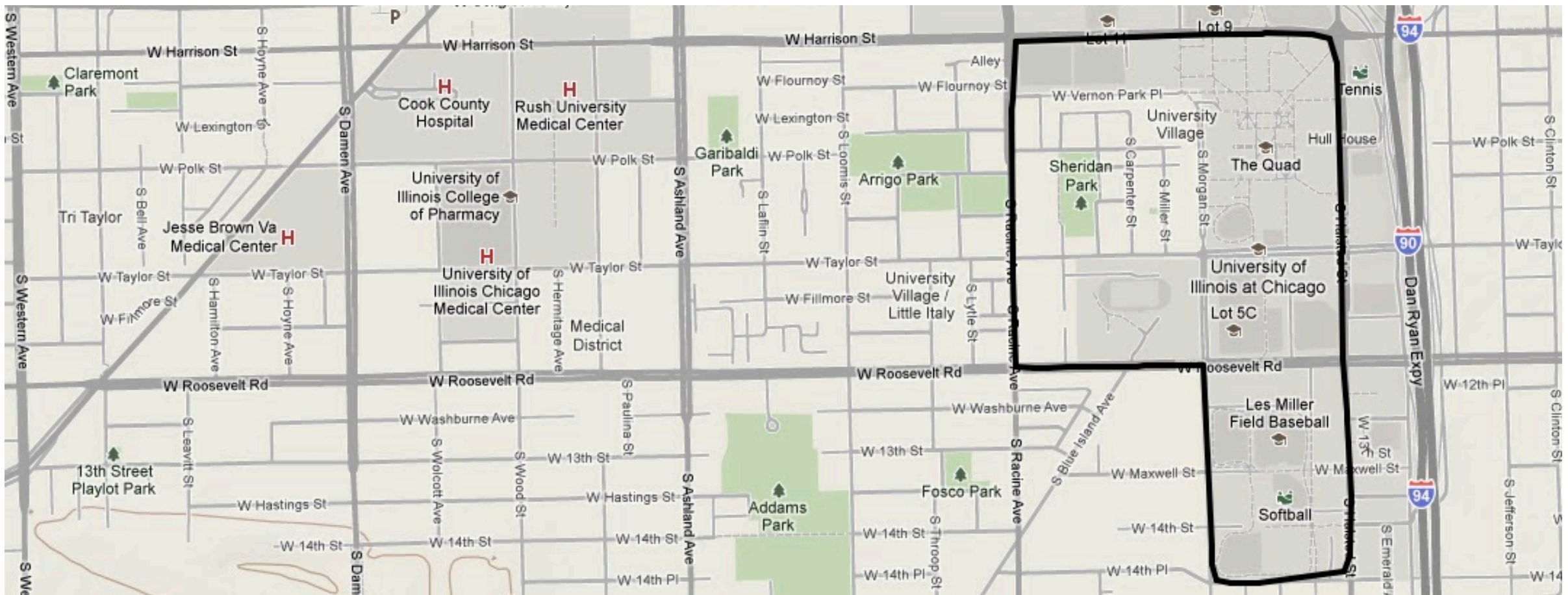


A map of the University of Chicago Medical Center area. A black outline highlights a large rectangular area covering the Medical District and surrounding streets. A green arrow indicates a route starting from the top right, moving left along W Harrison St, then down along S Ashland Ave, then left along W Roosevelt Rd, then down along S Racine Ave, and finally left along W 14th St.

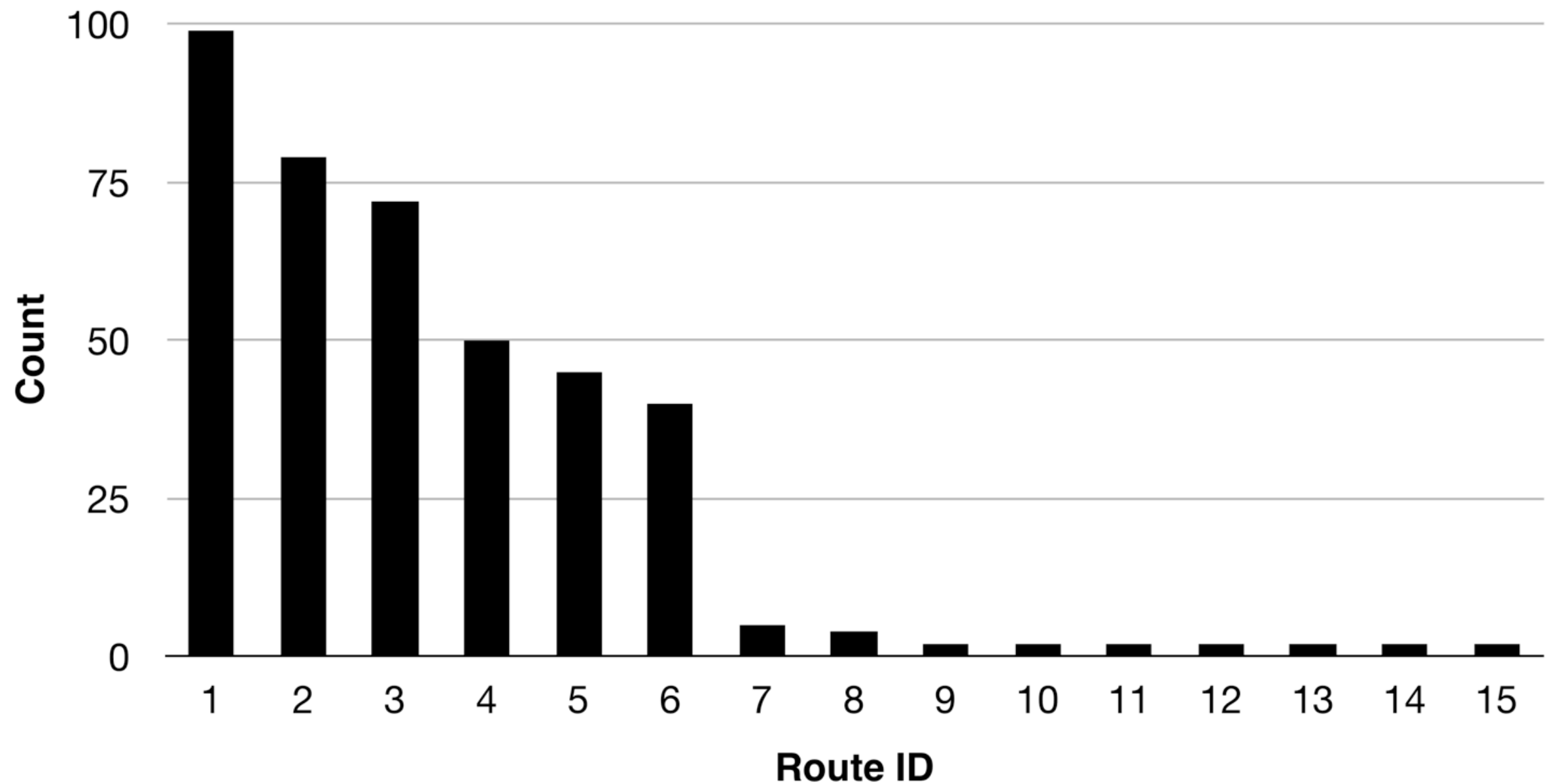
Route extraction



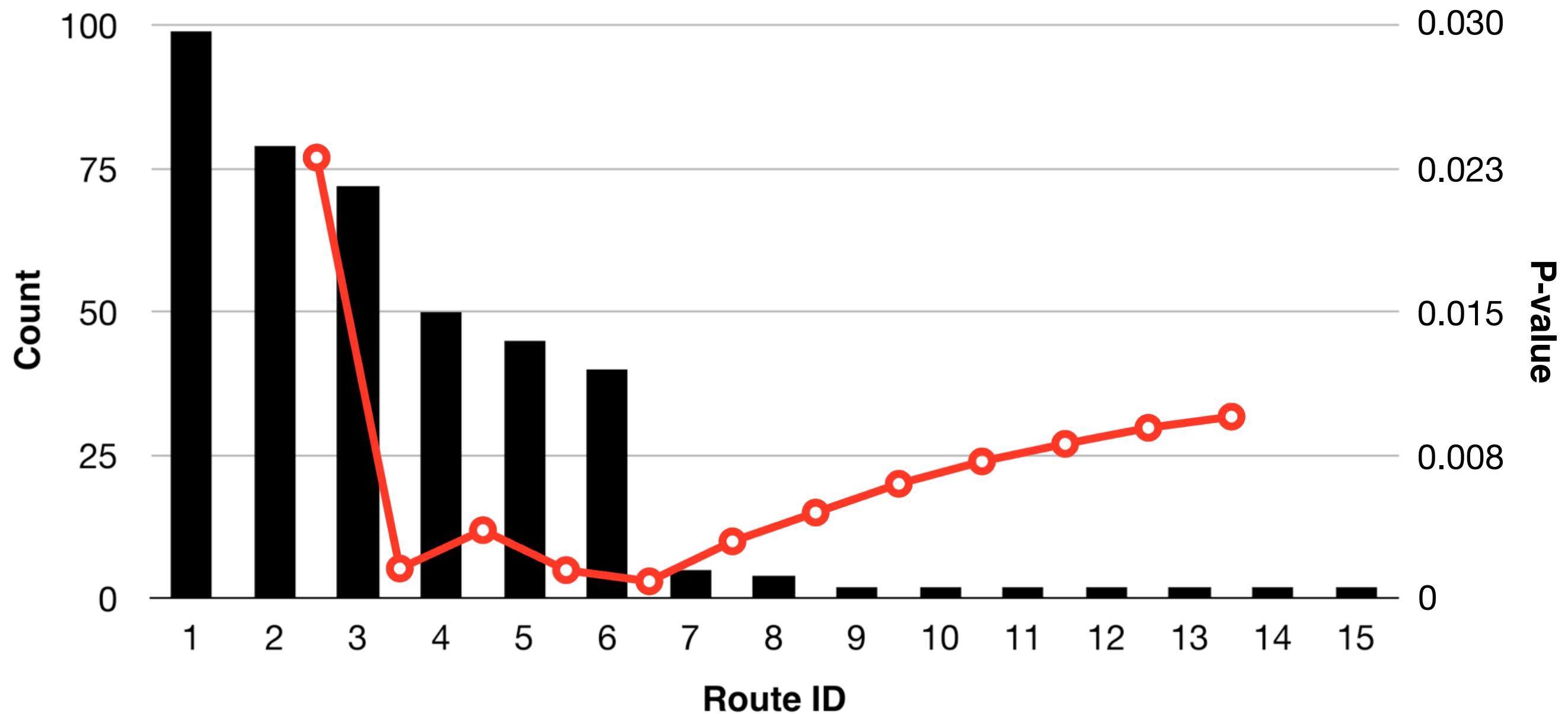
Route extraction



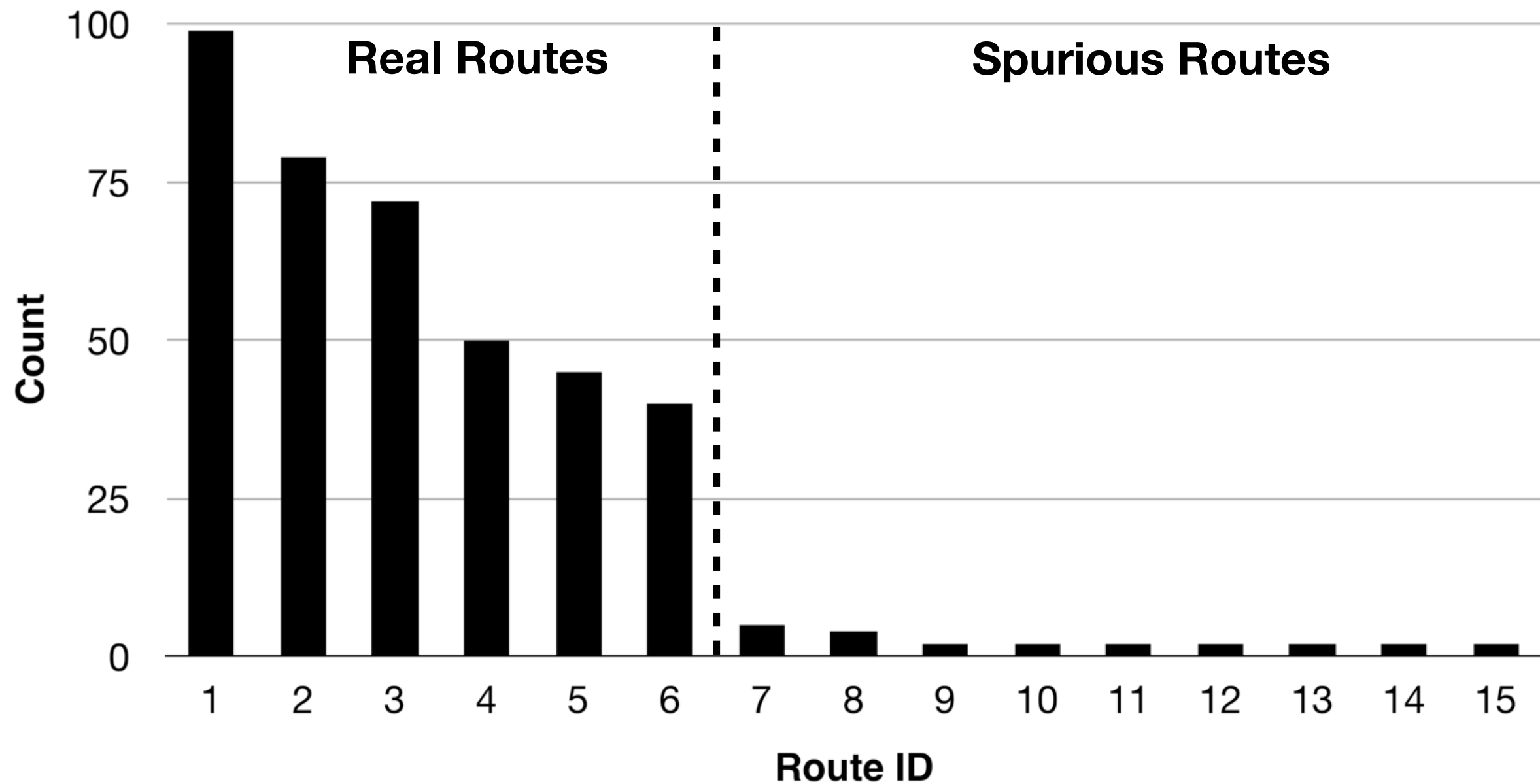
Route extraction results



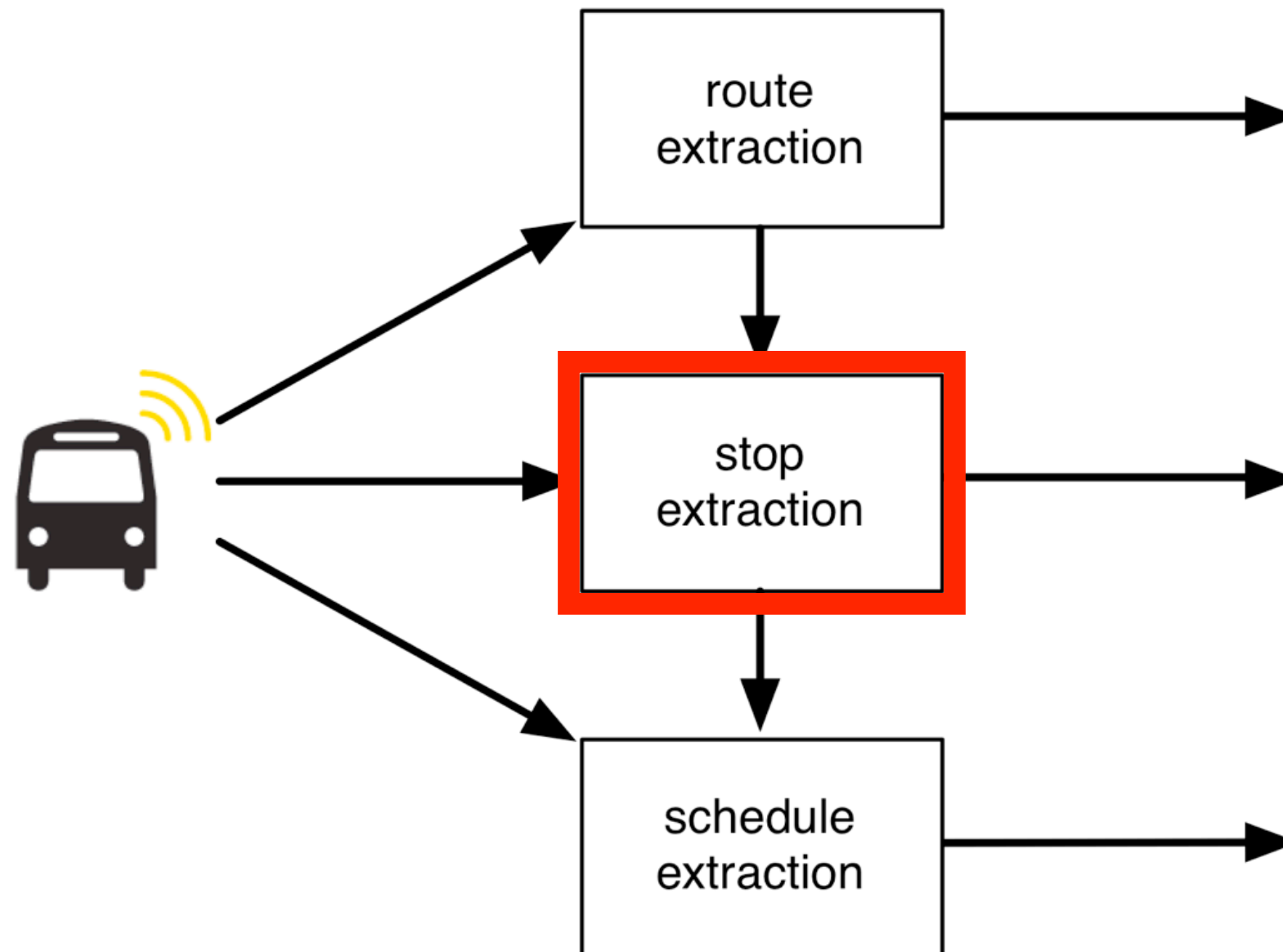
Welch's t -Test



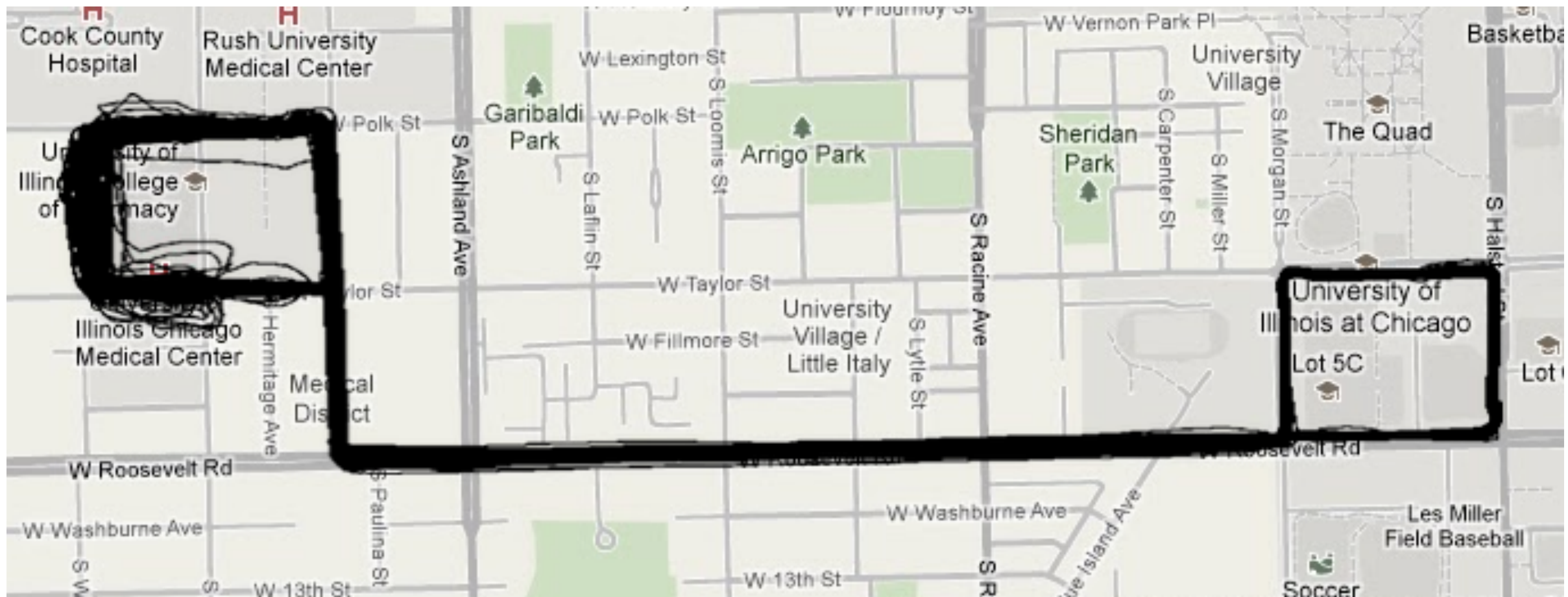
Routes separated



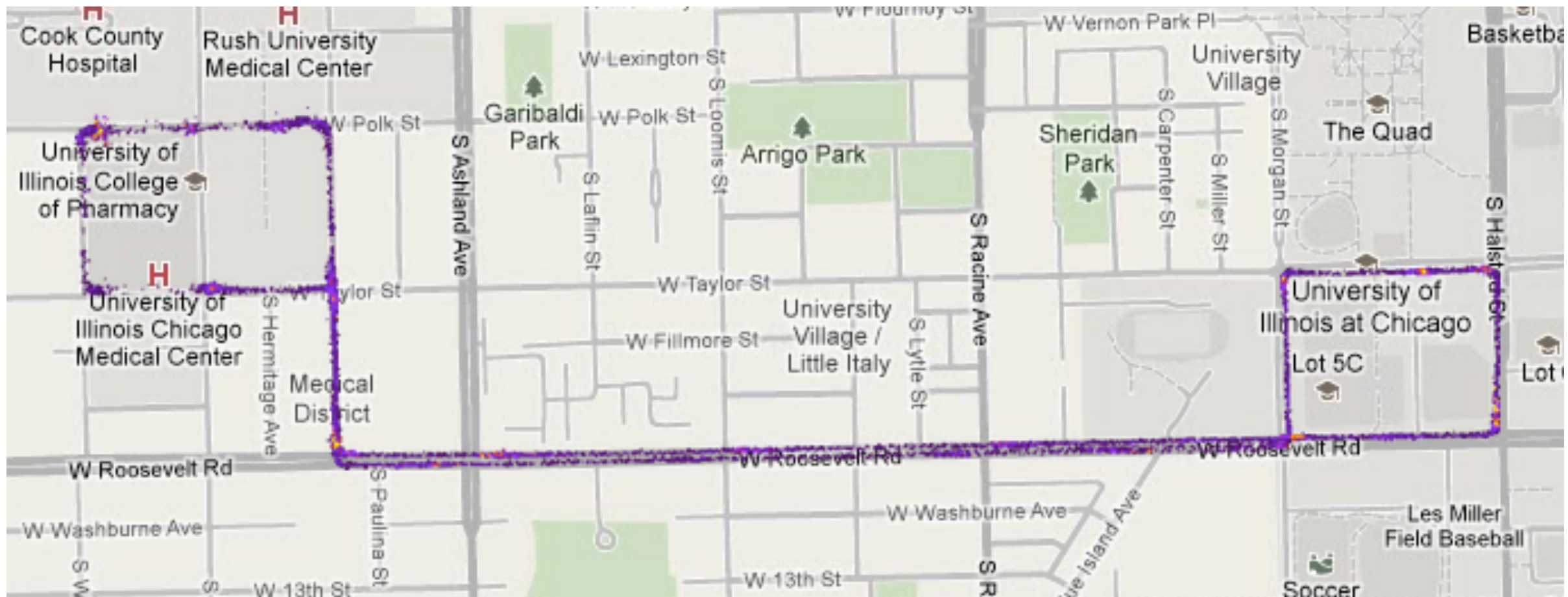
Stop extraction



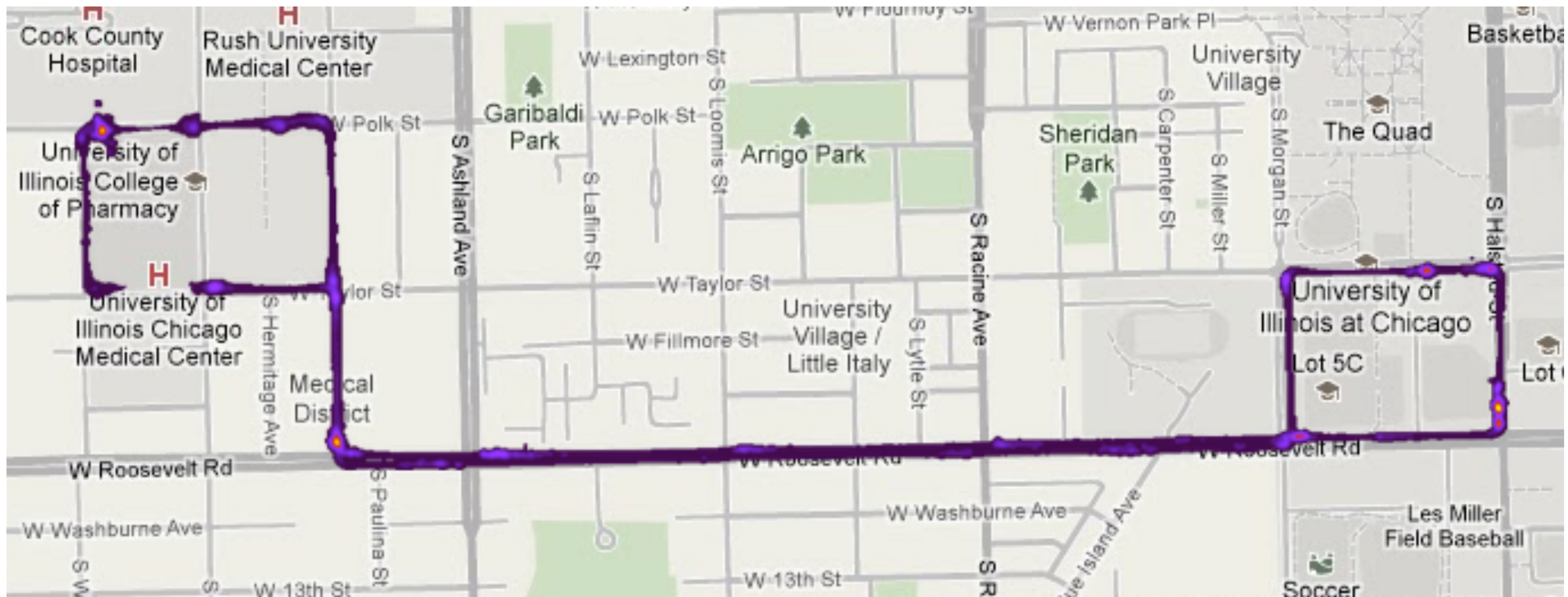
Route-labeled GPS traces



2-D histogram



Point density estimate



Thresholded binary image



Noise in binary image



Noise reduced binary image



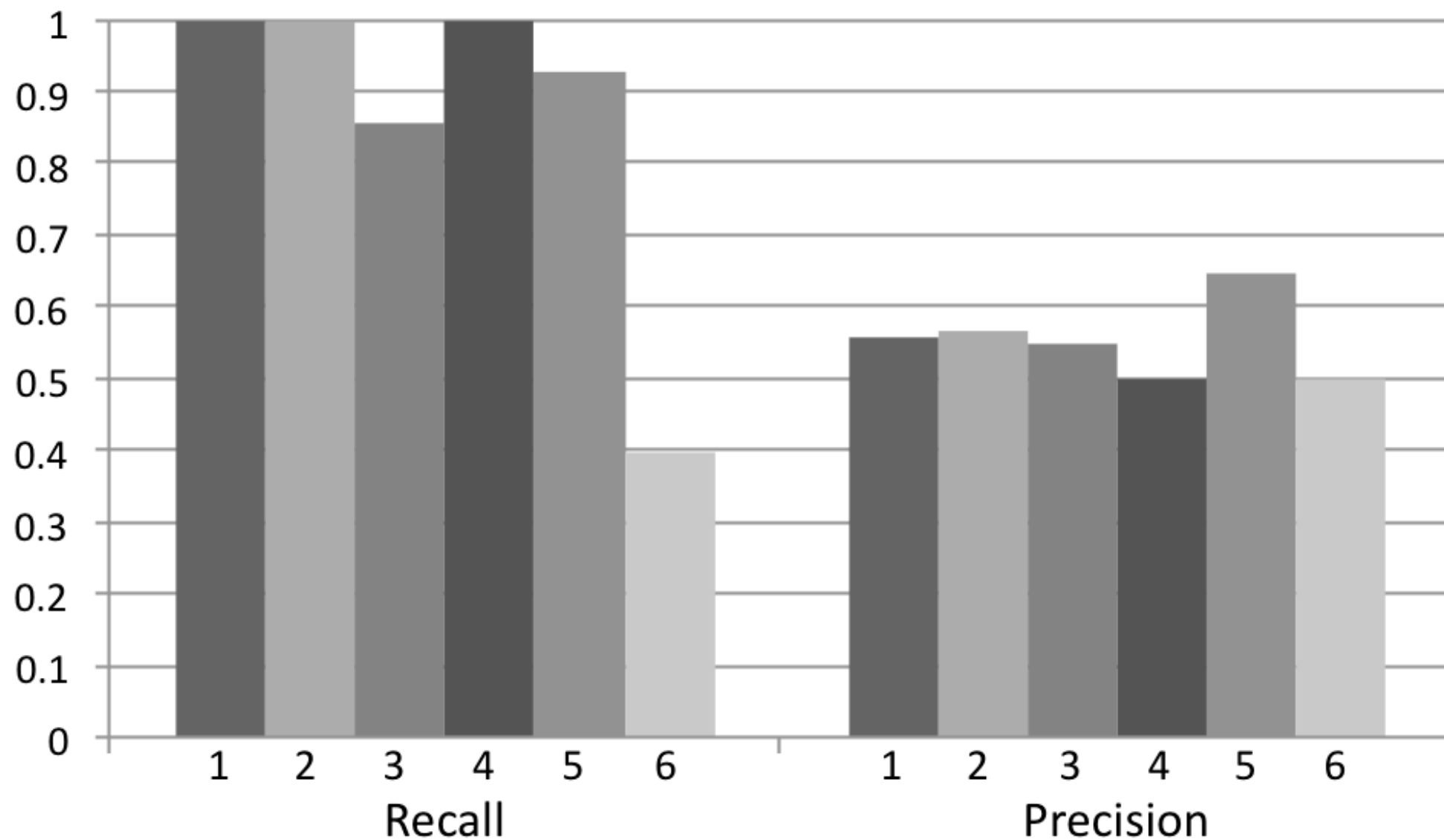
Stop extraction



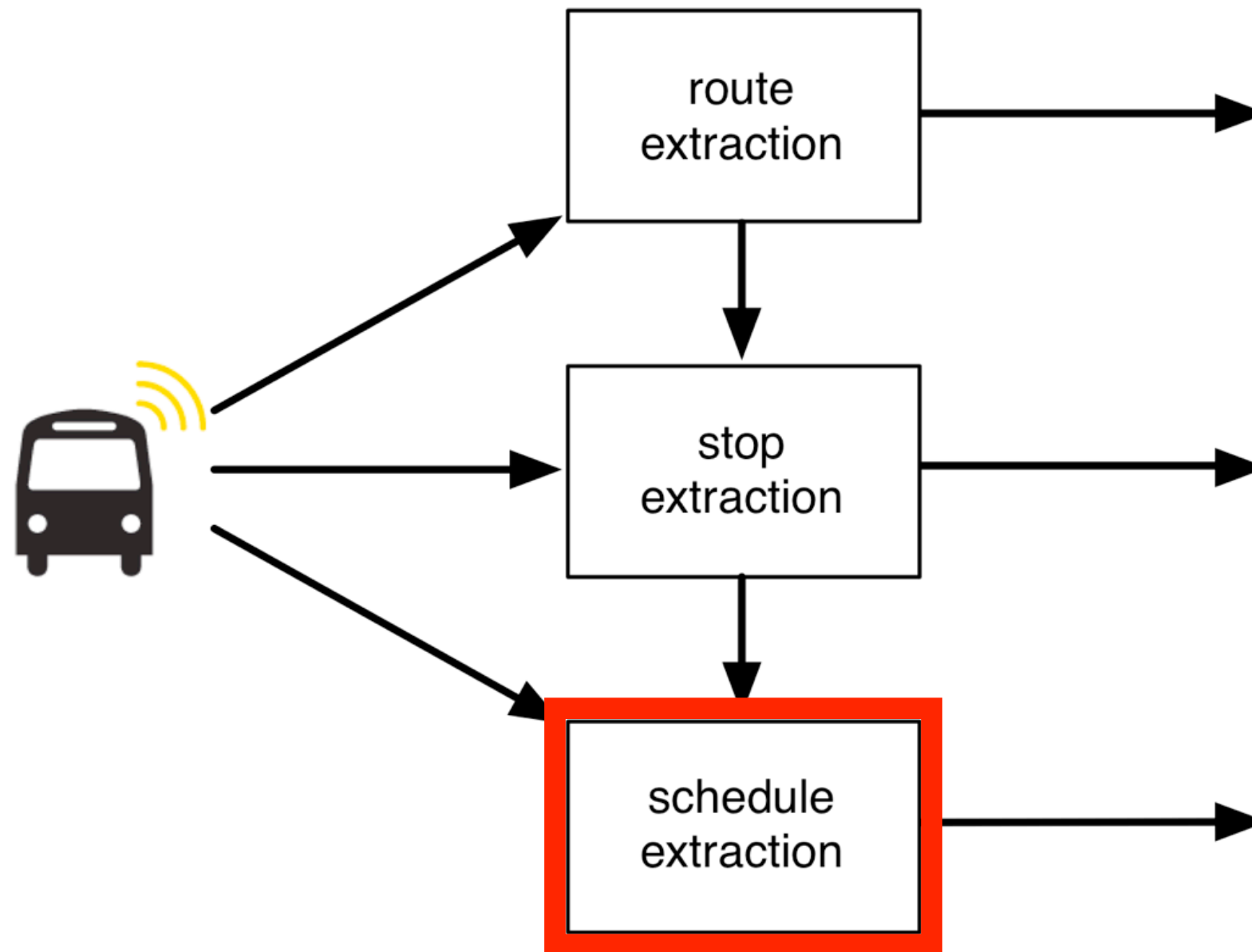
Stop extraction



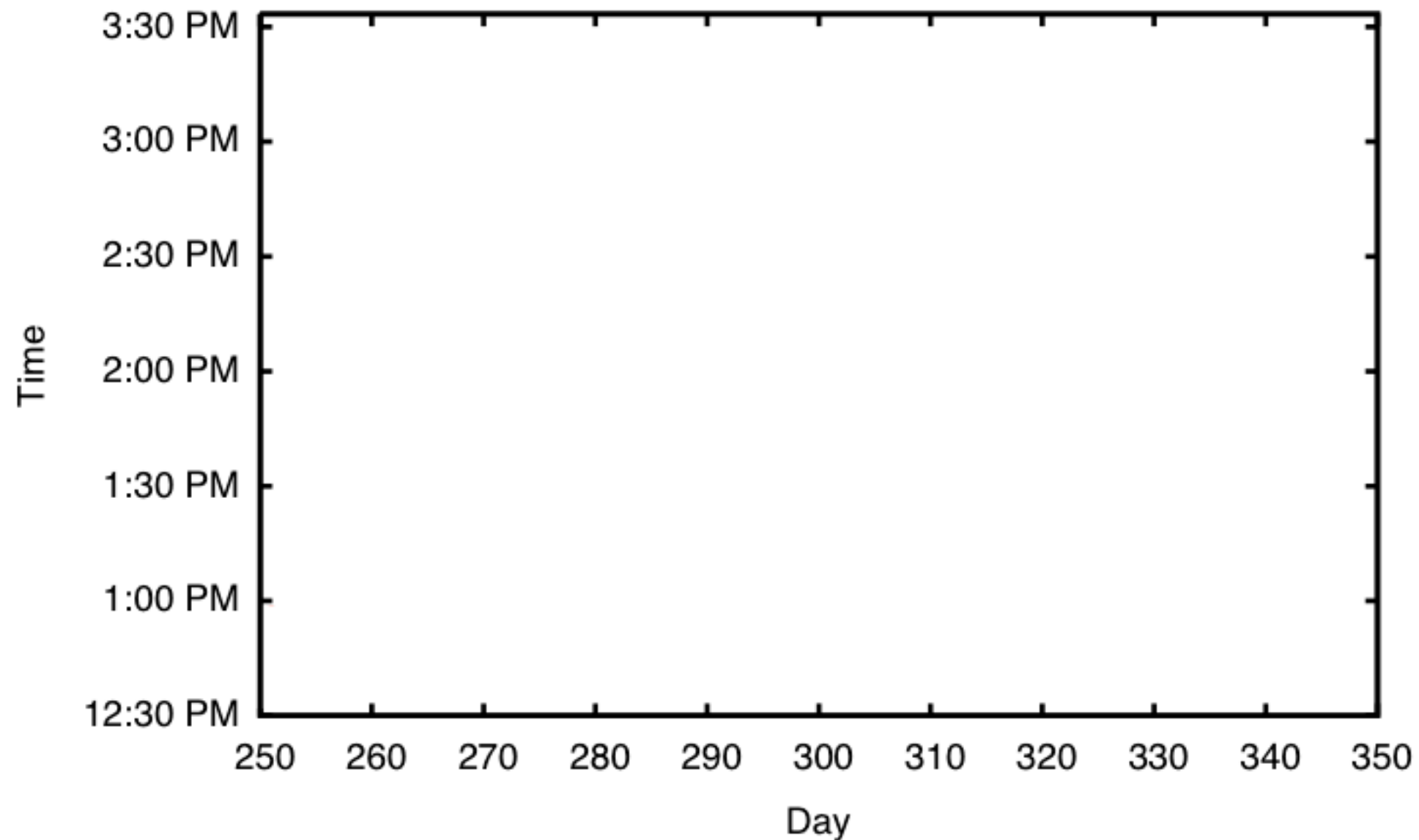
Stop extraction performance



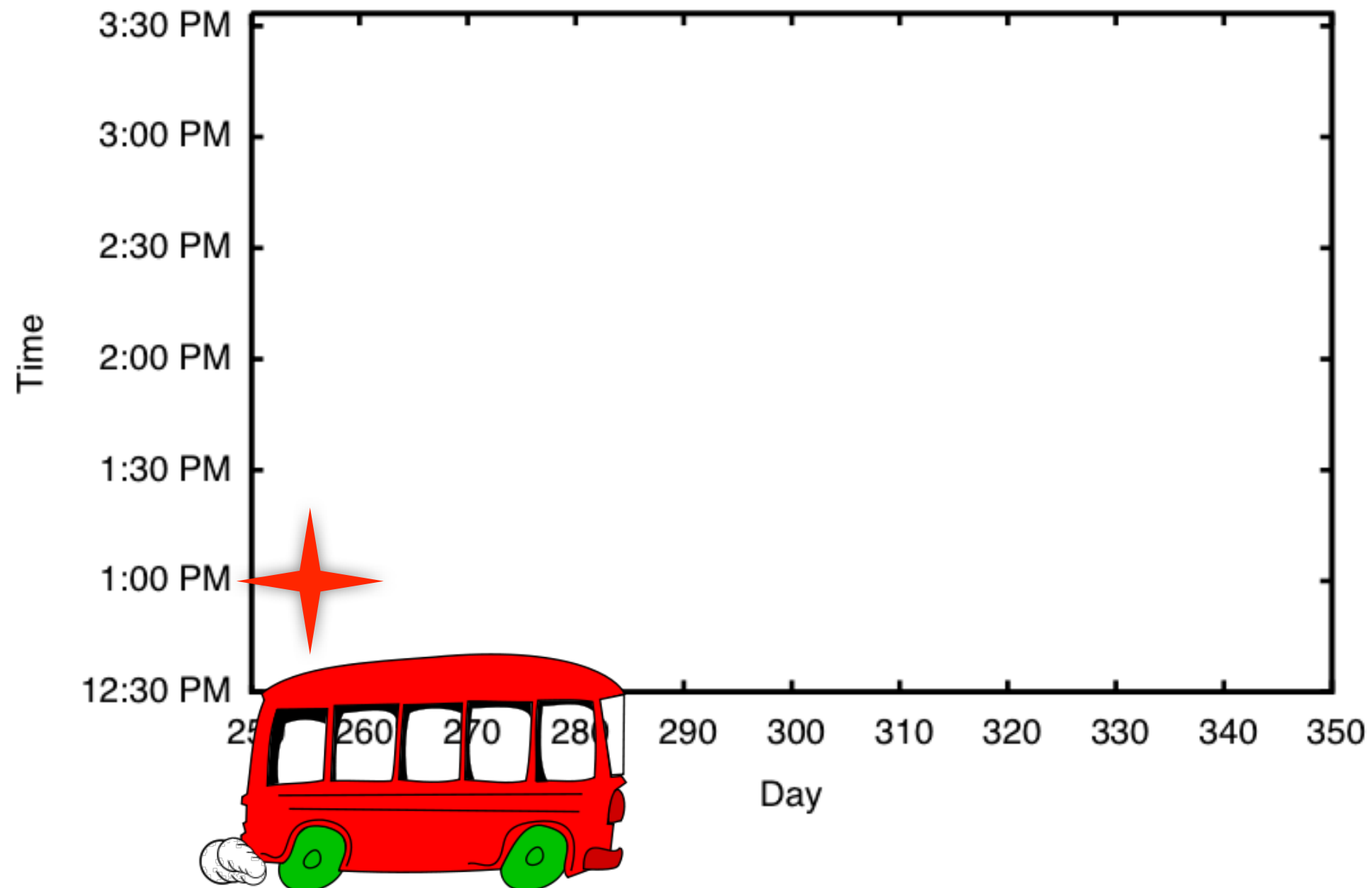
Schedule extraction



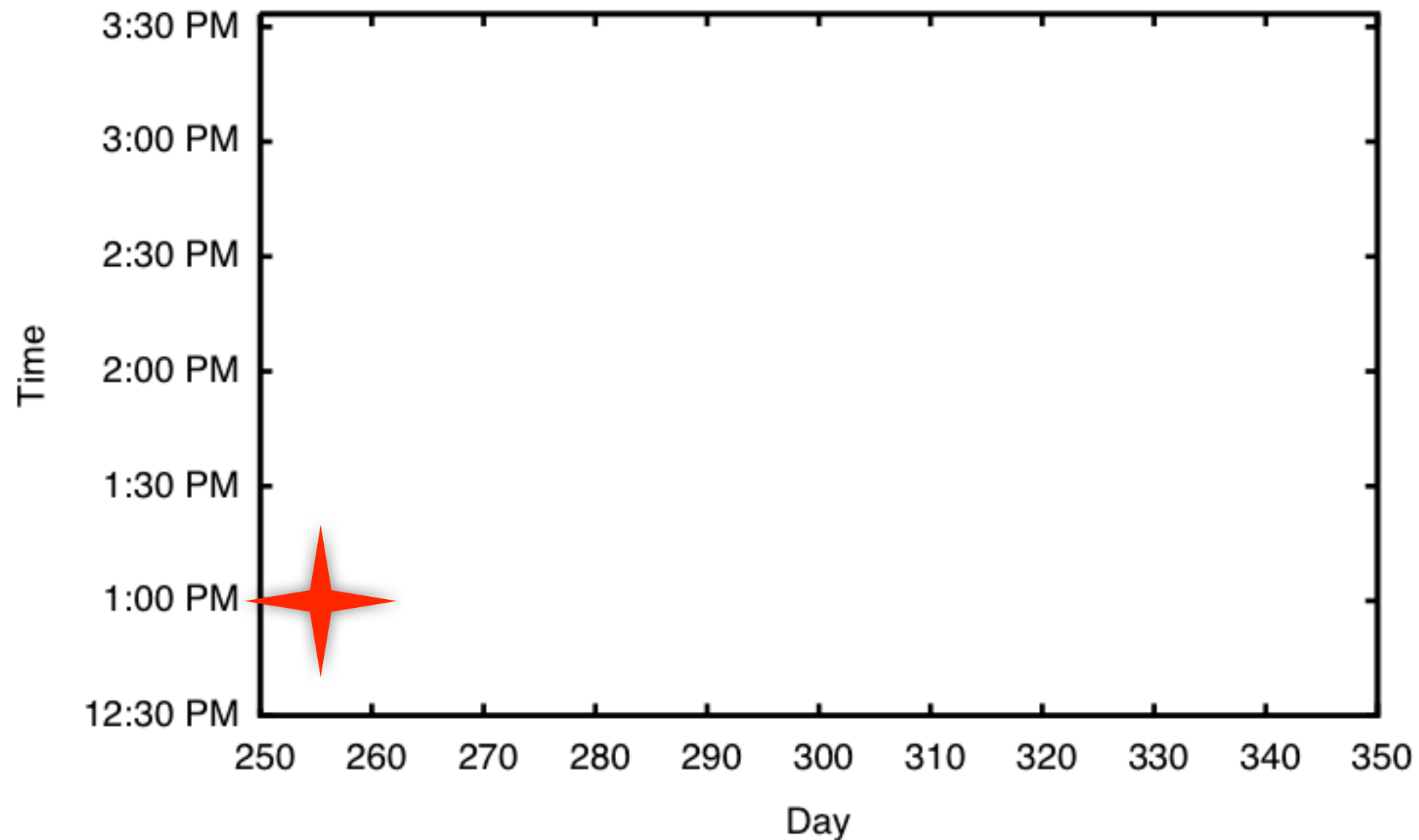
Bus stop arrival times



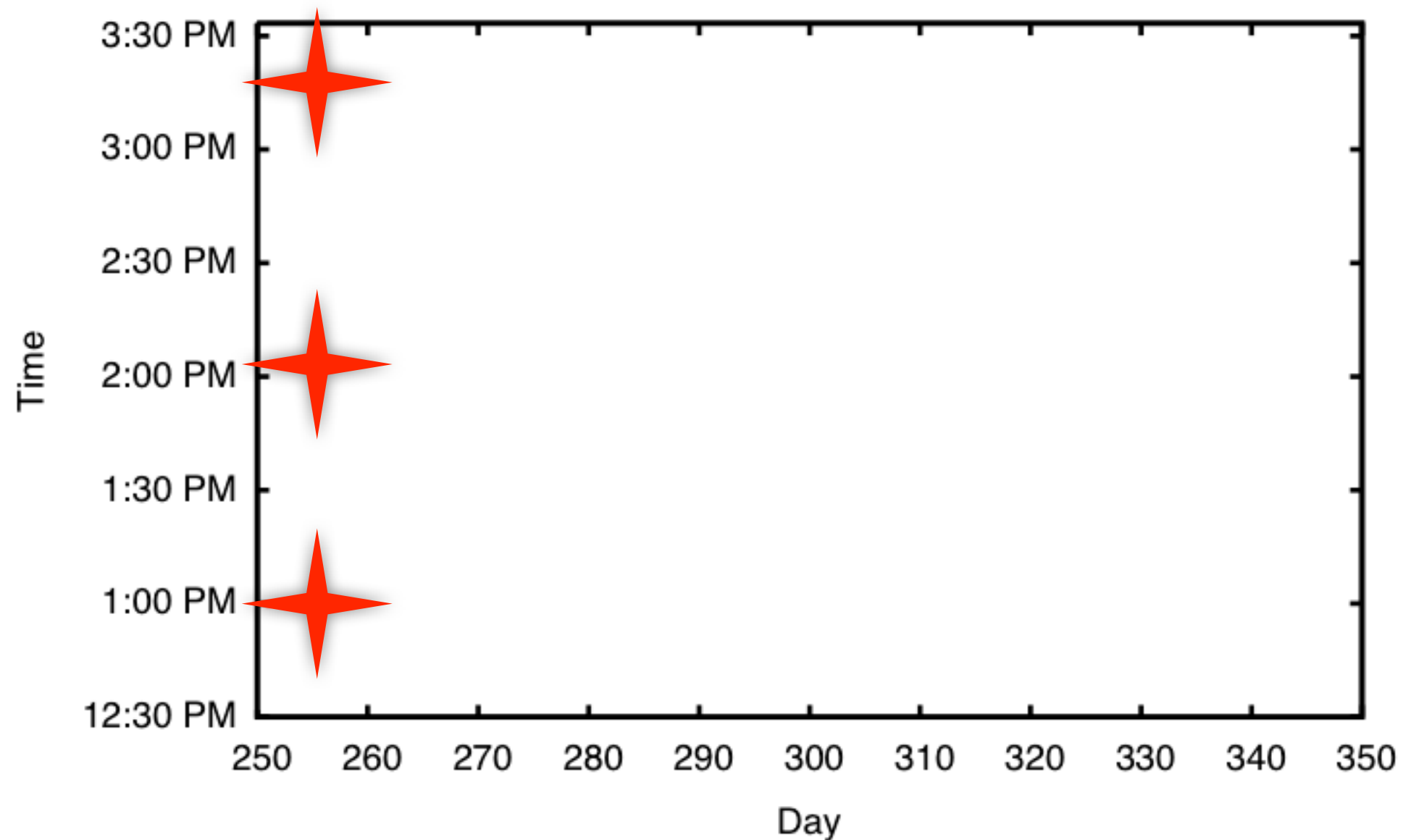
Bus stop arrival times



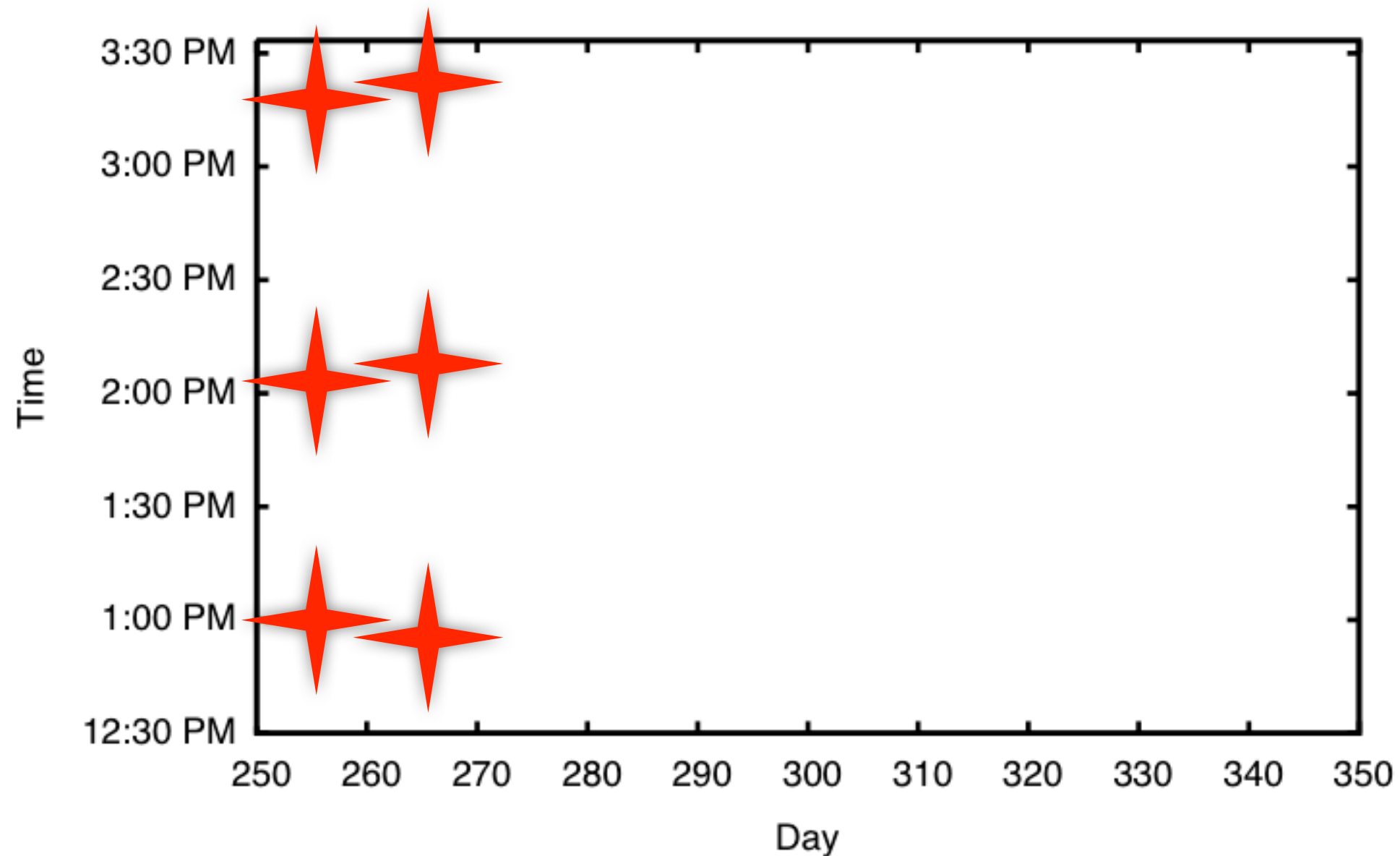
Bus stop arrival times



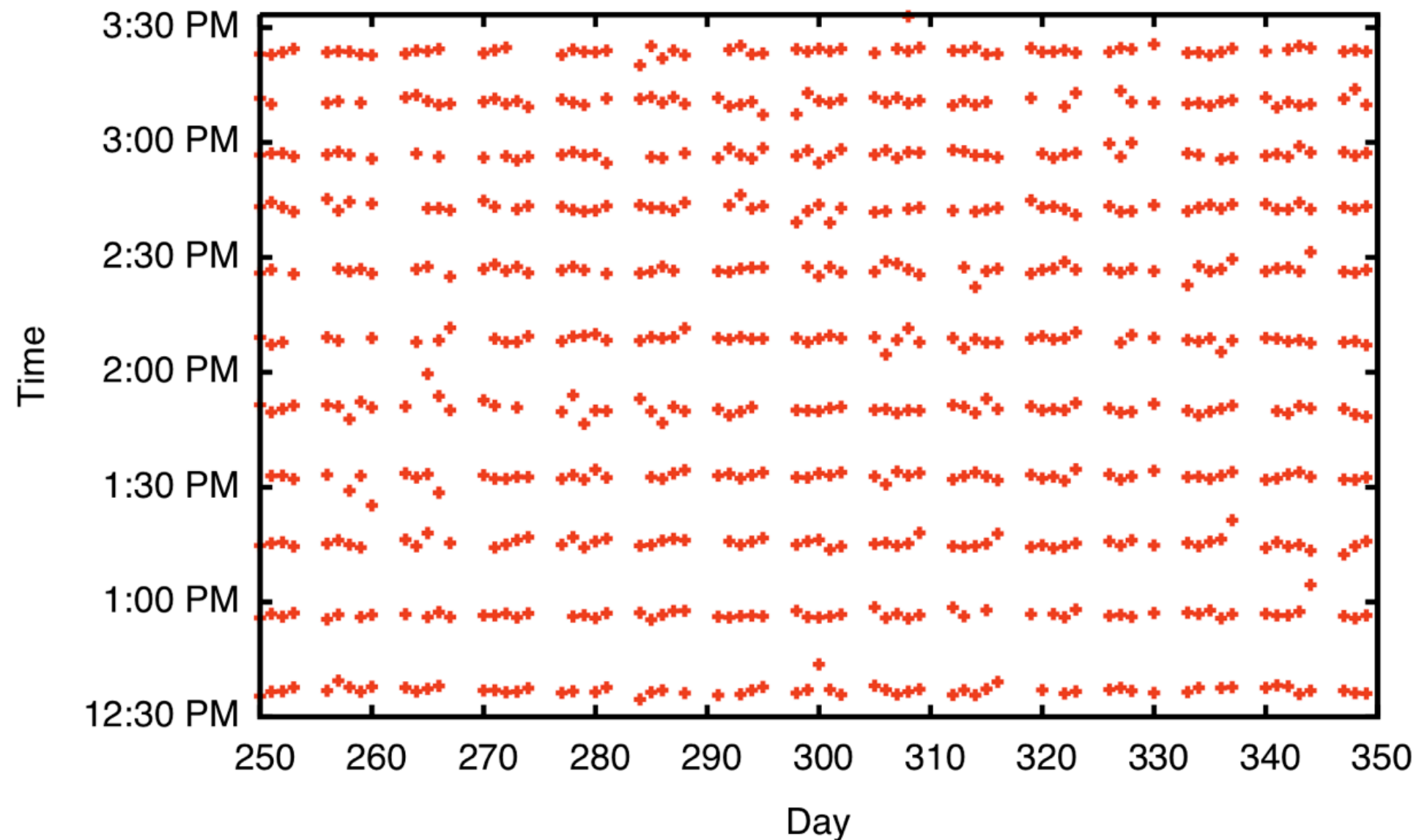
Bus stop arrival times



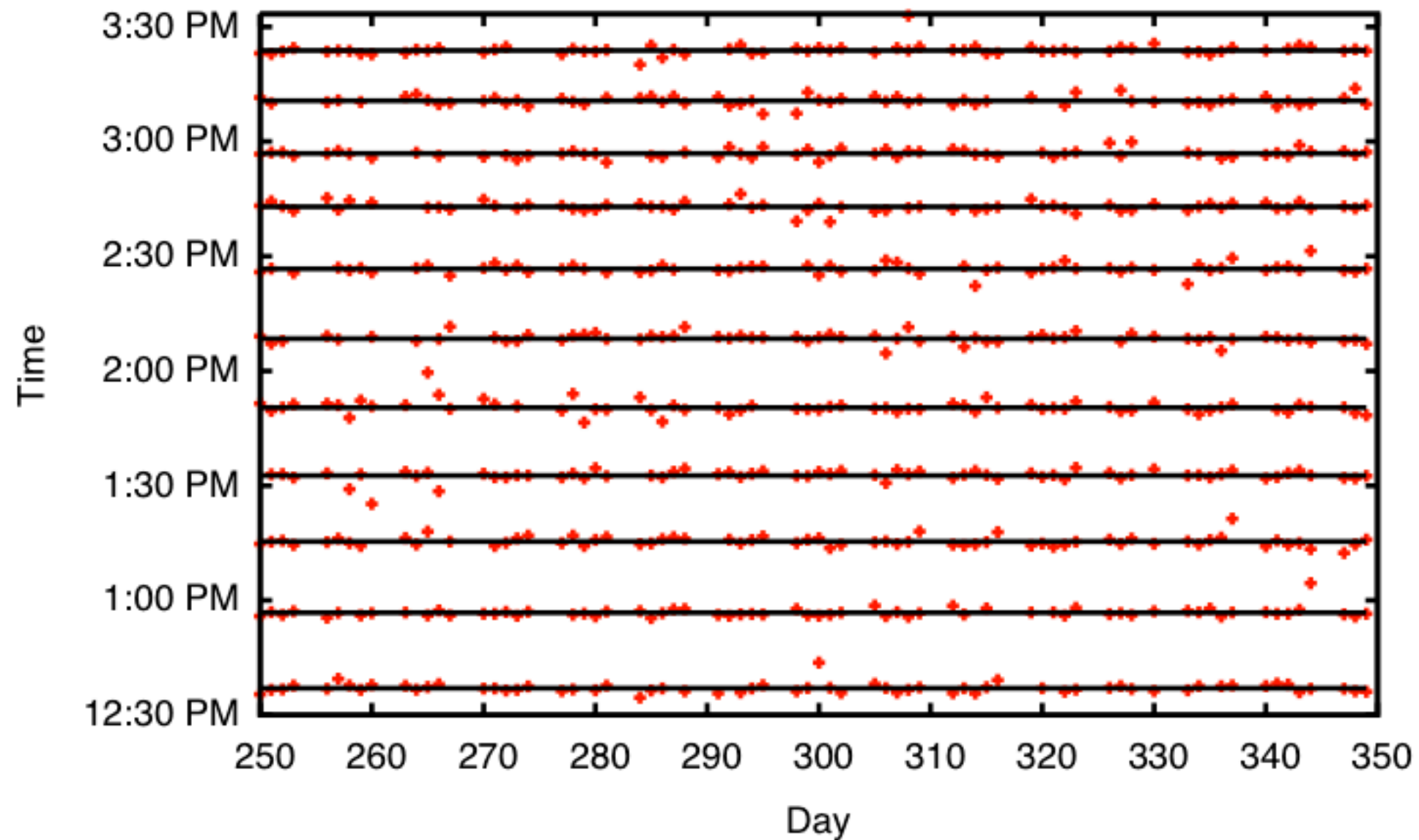
Bus stop arrival times



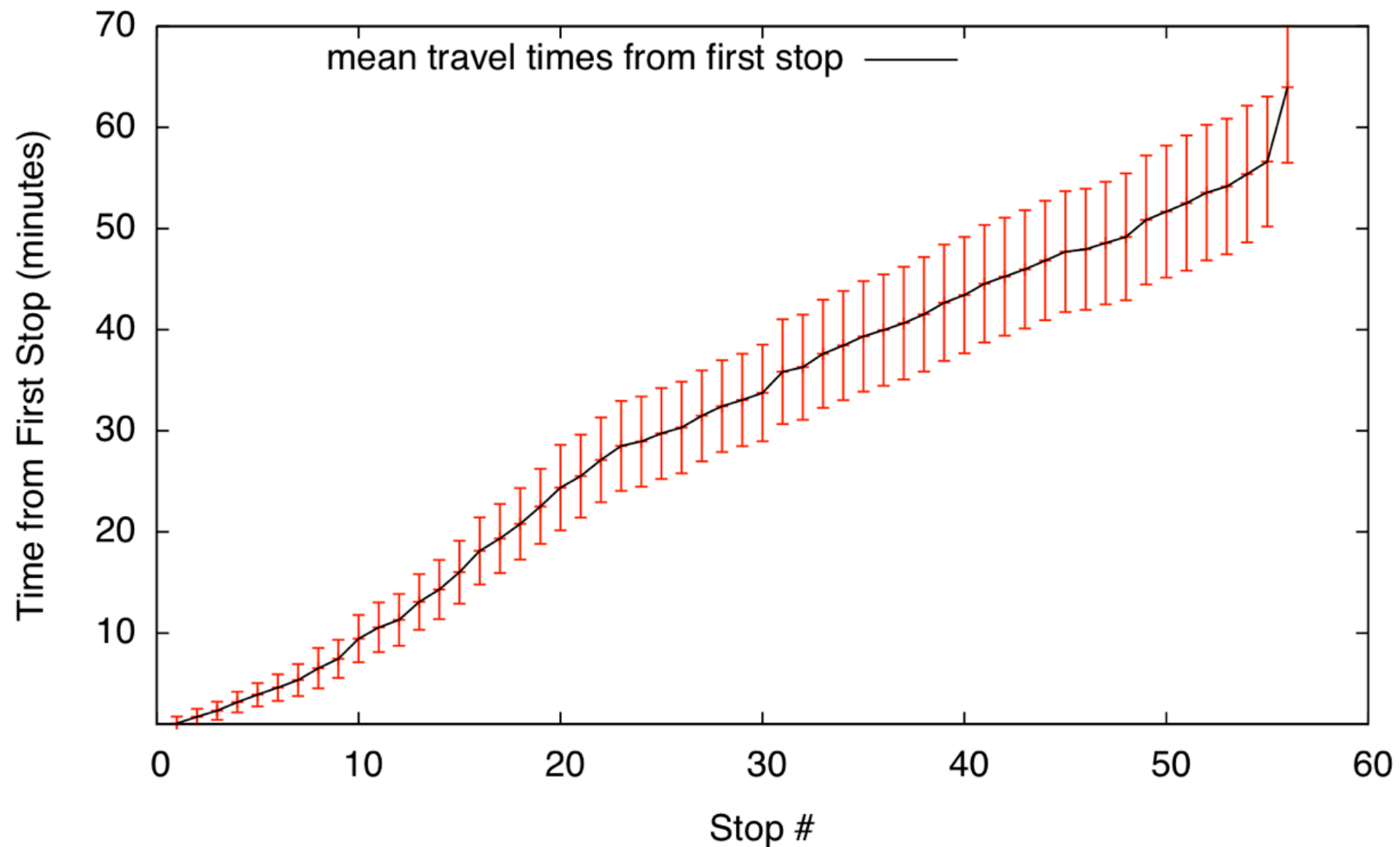
Bus stop arrival times



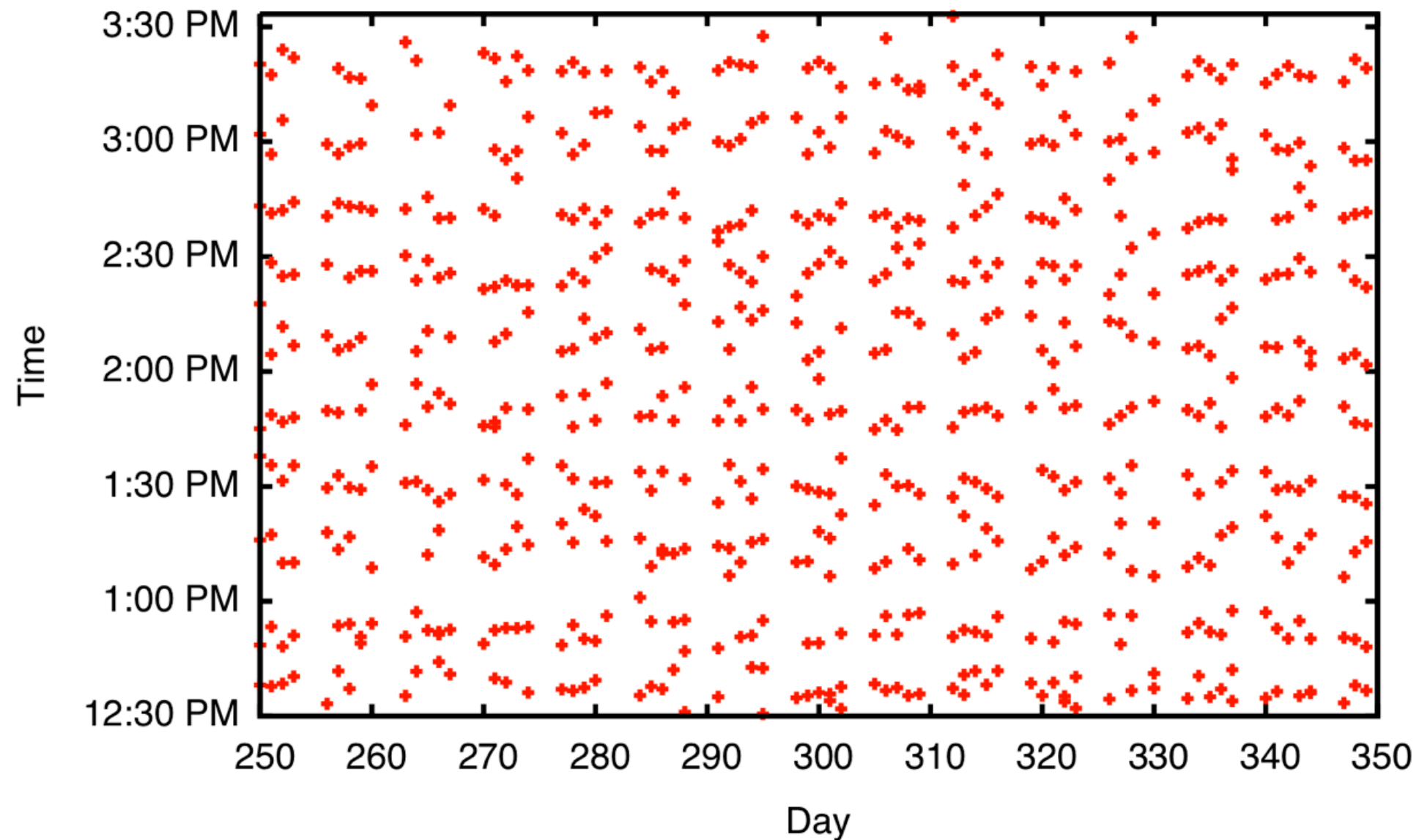
First stop schedule



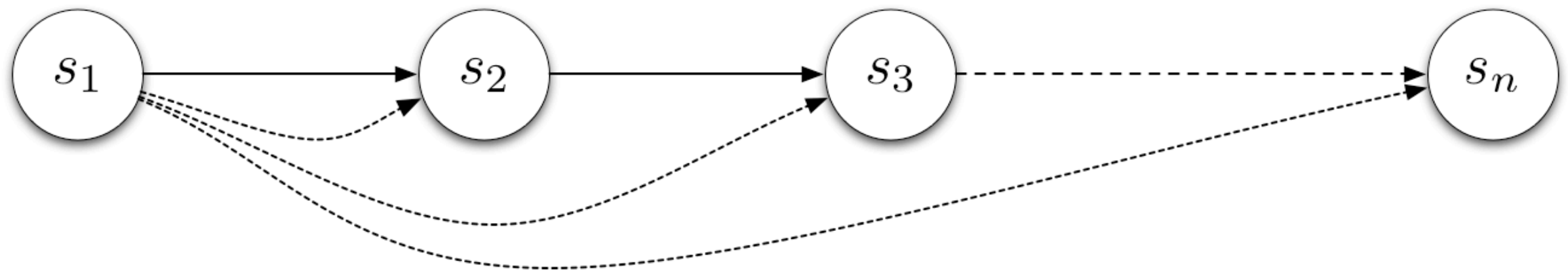
Travel time variance



Last stop arrival times

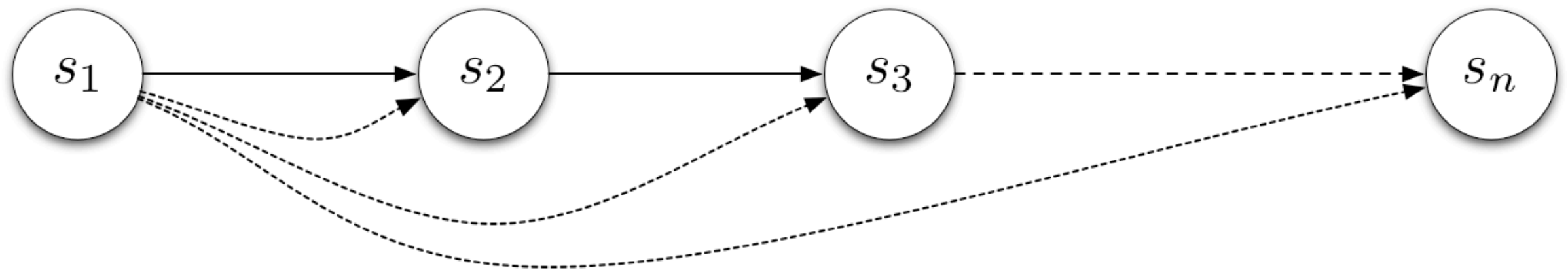


Compute mean travel times



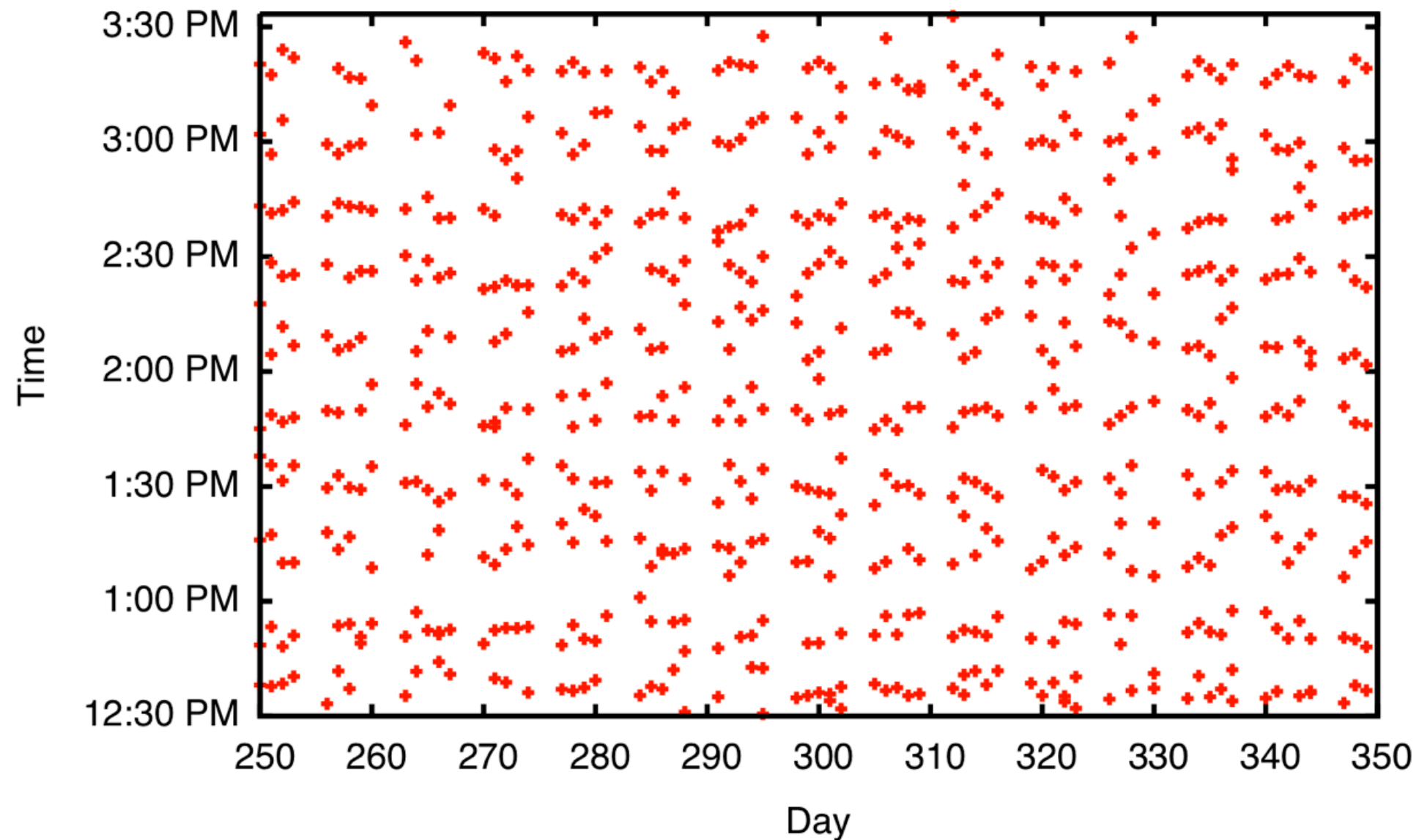
$$travel_time(1, j, t) = \frac{1}{|D|} \sum_D a_j^t - a_1^t$$

Compute downstream schedules

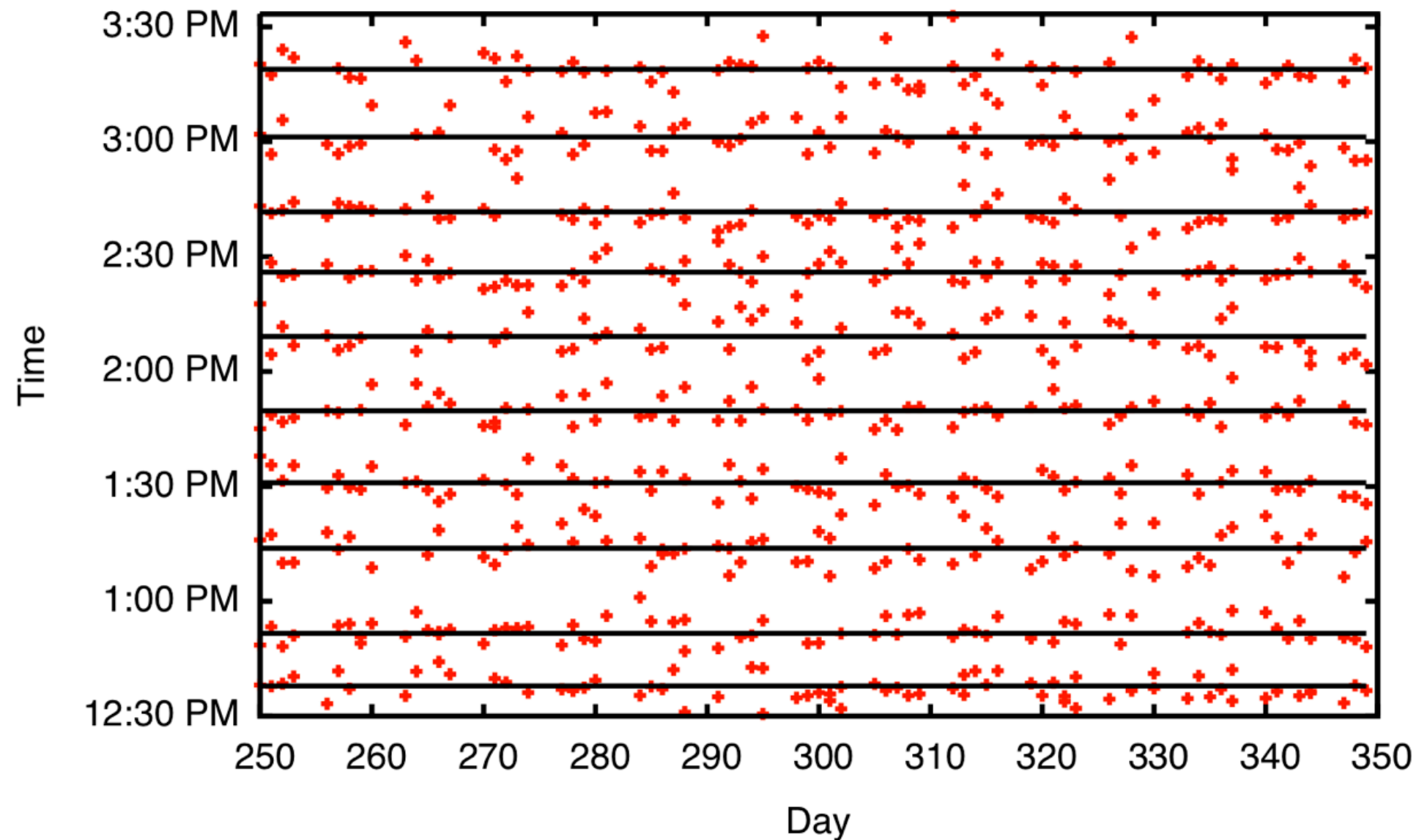


$$k_t^j = k_t^1 + travel_time(1, j, t)$$

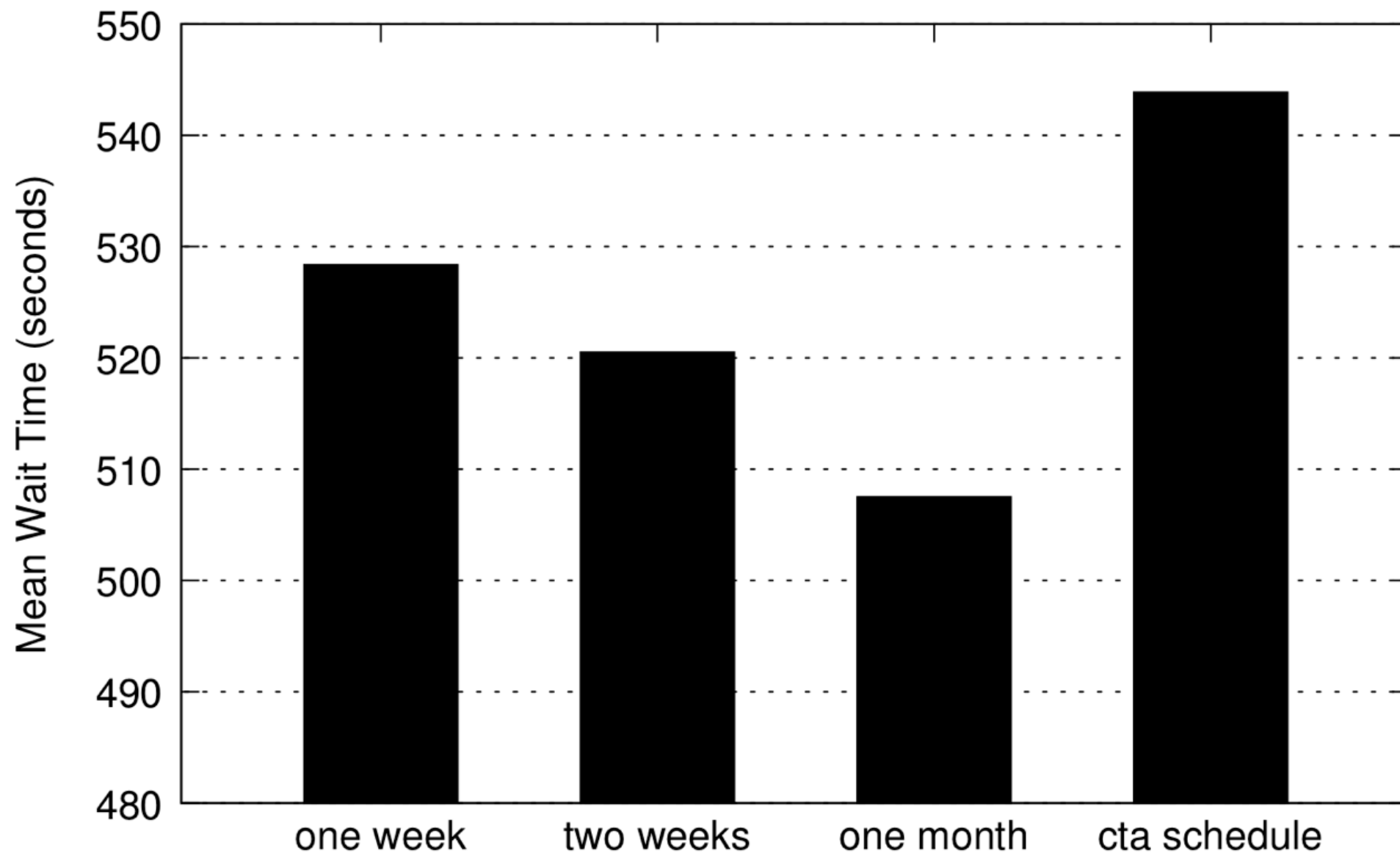
Last stop arrival times



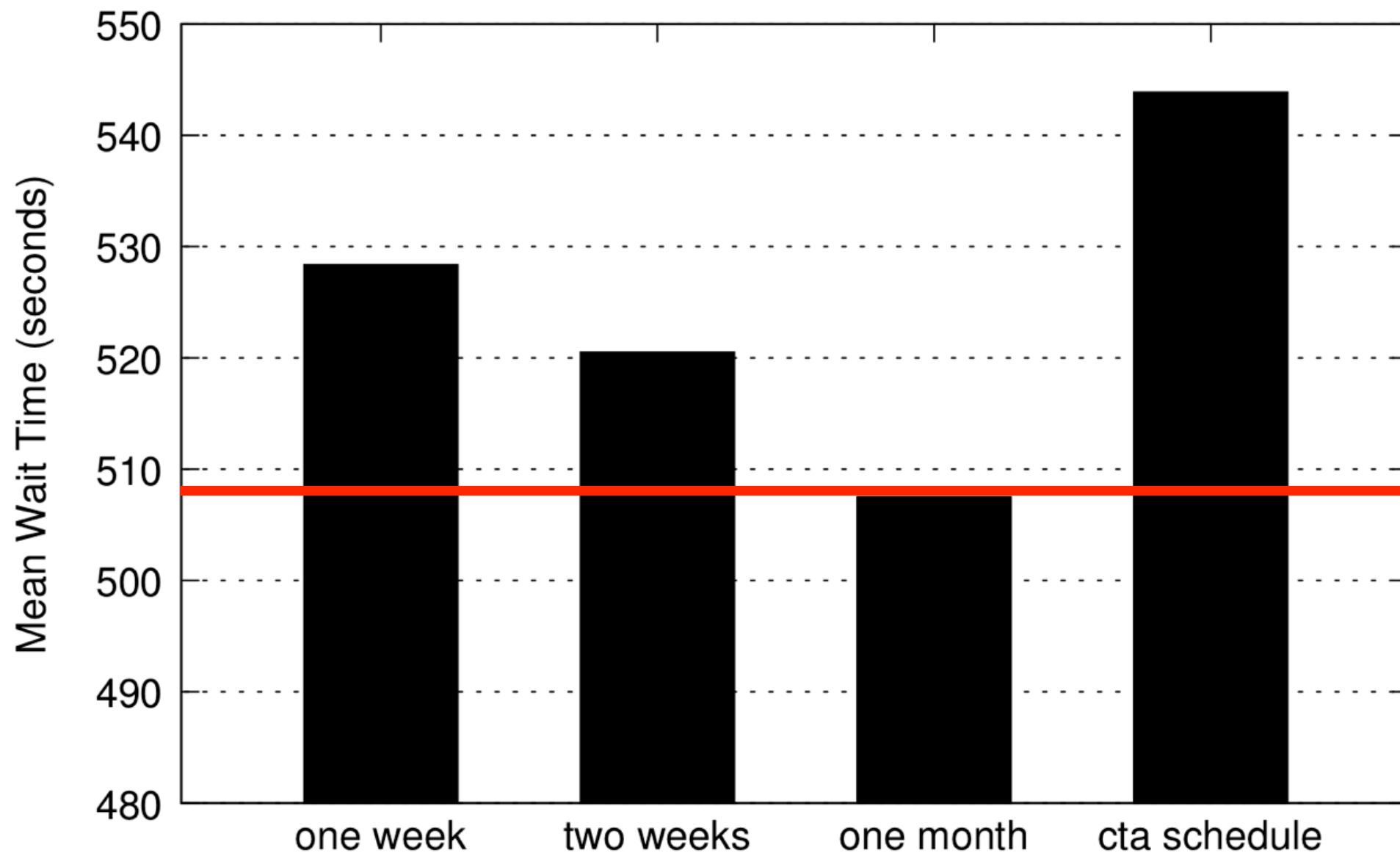
Last stop schedule



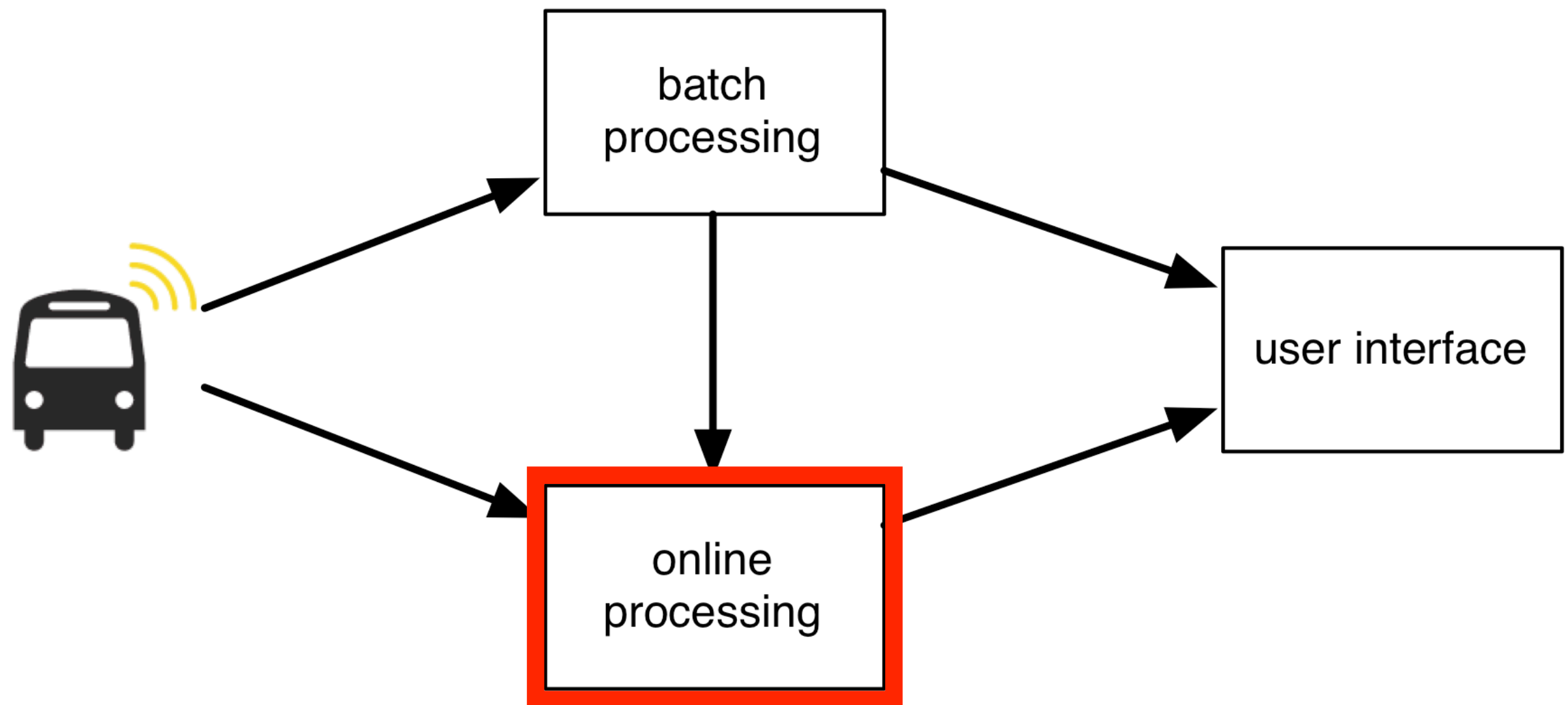
Schedule accuracy



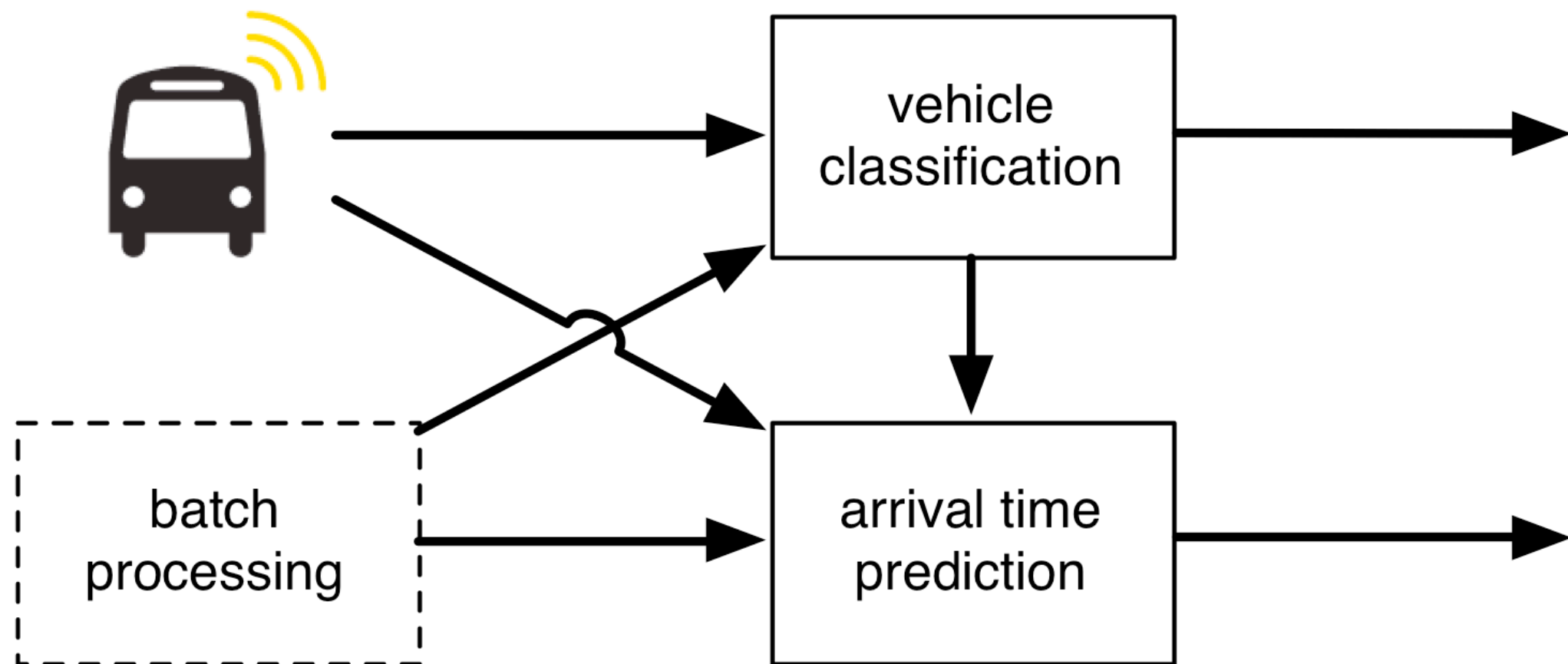
Schedule accuracy



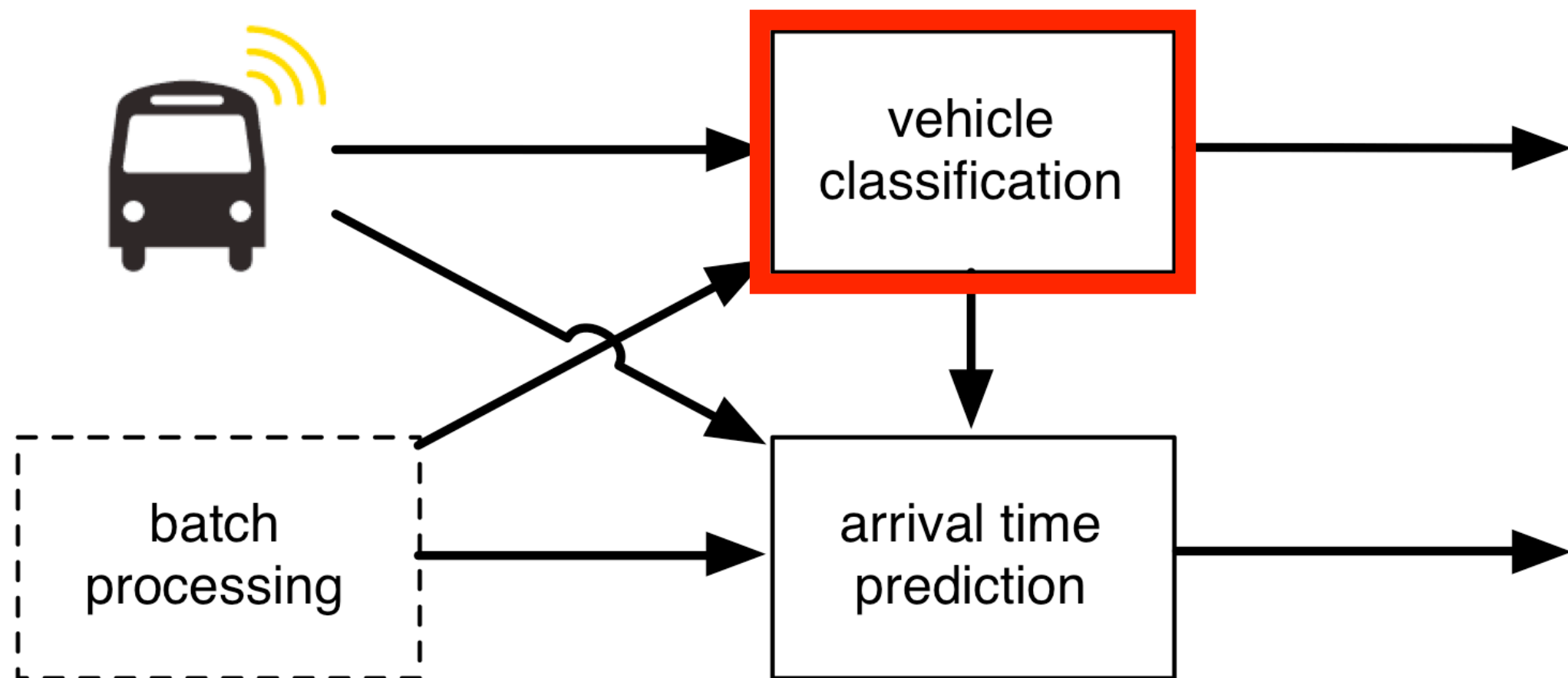
System architecture



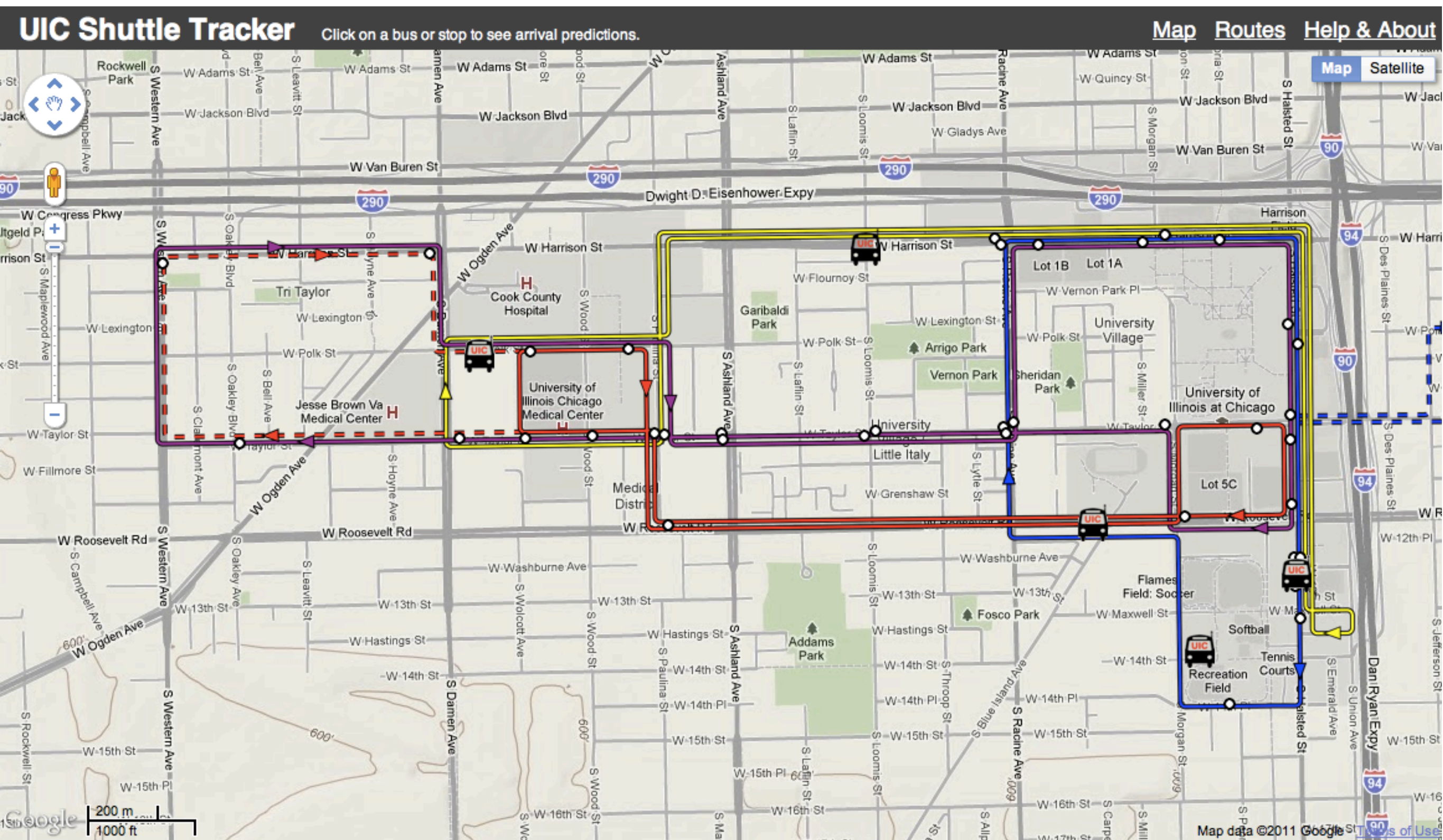
Online processing



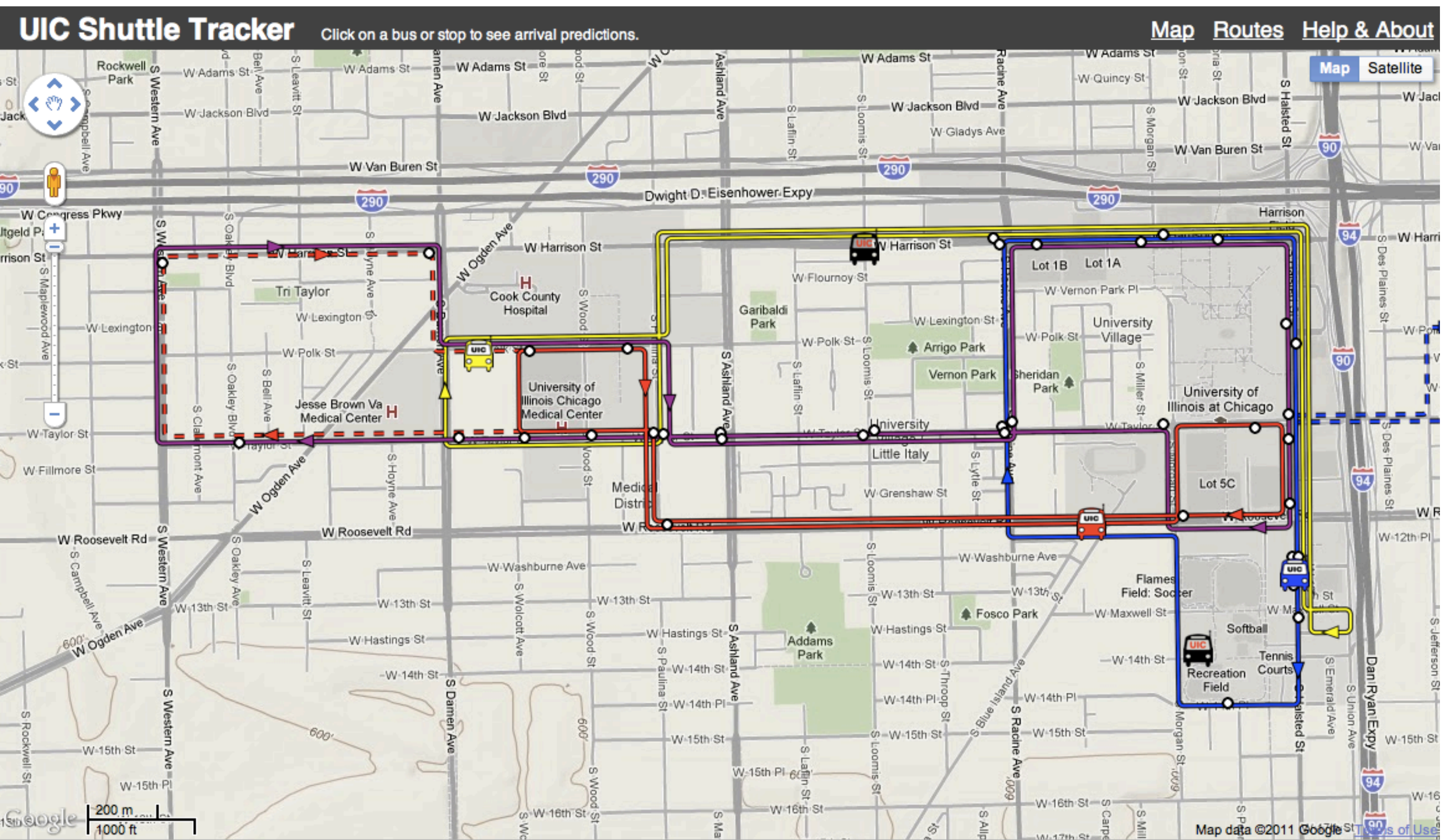
Online processing



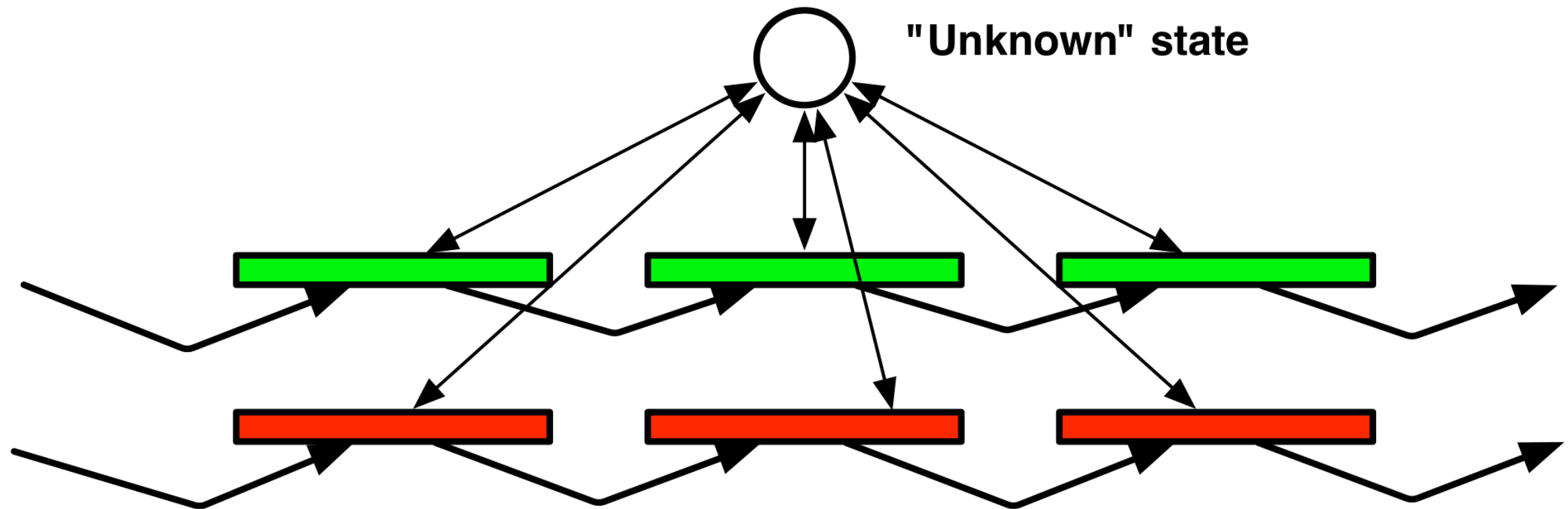
Un-classified buses



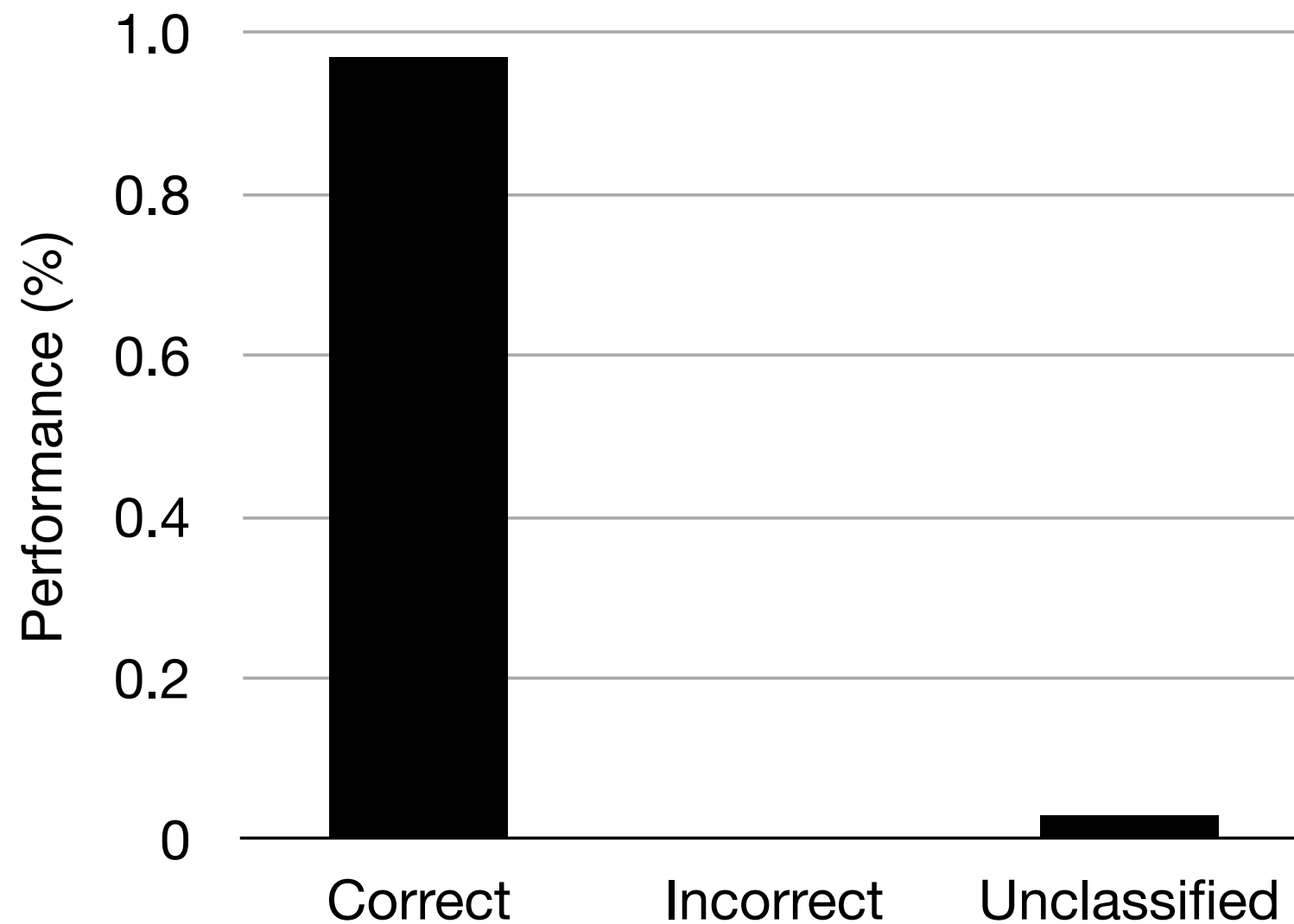
Classified buses



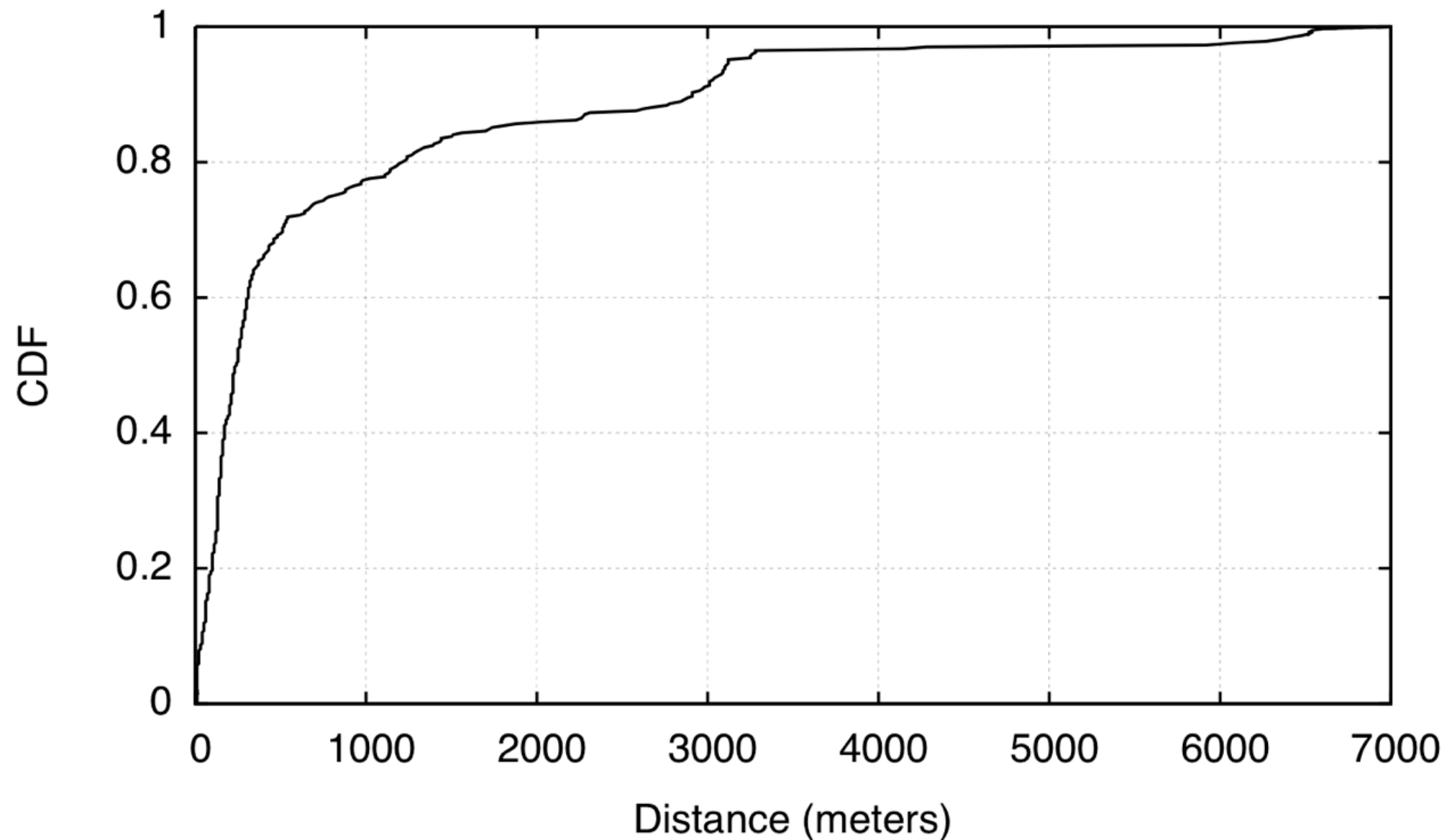
Hidden Markov model



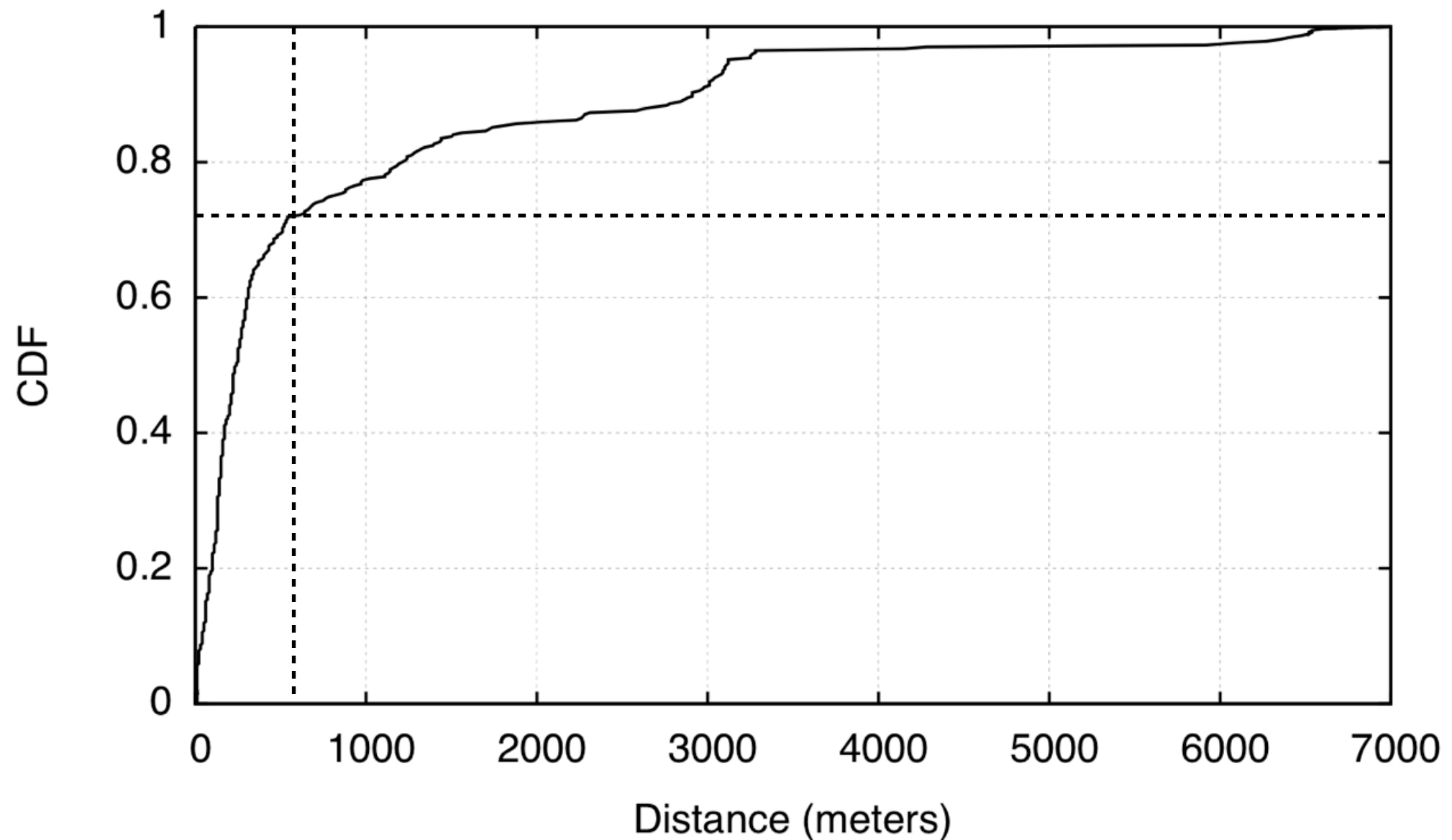
Classification accuracy



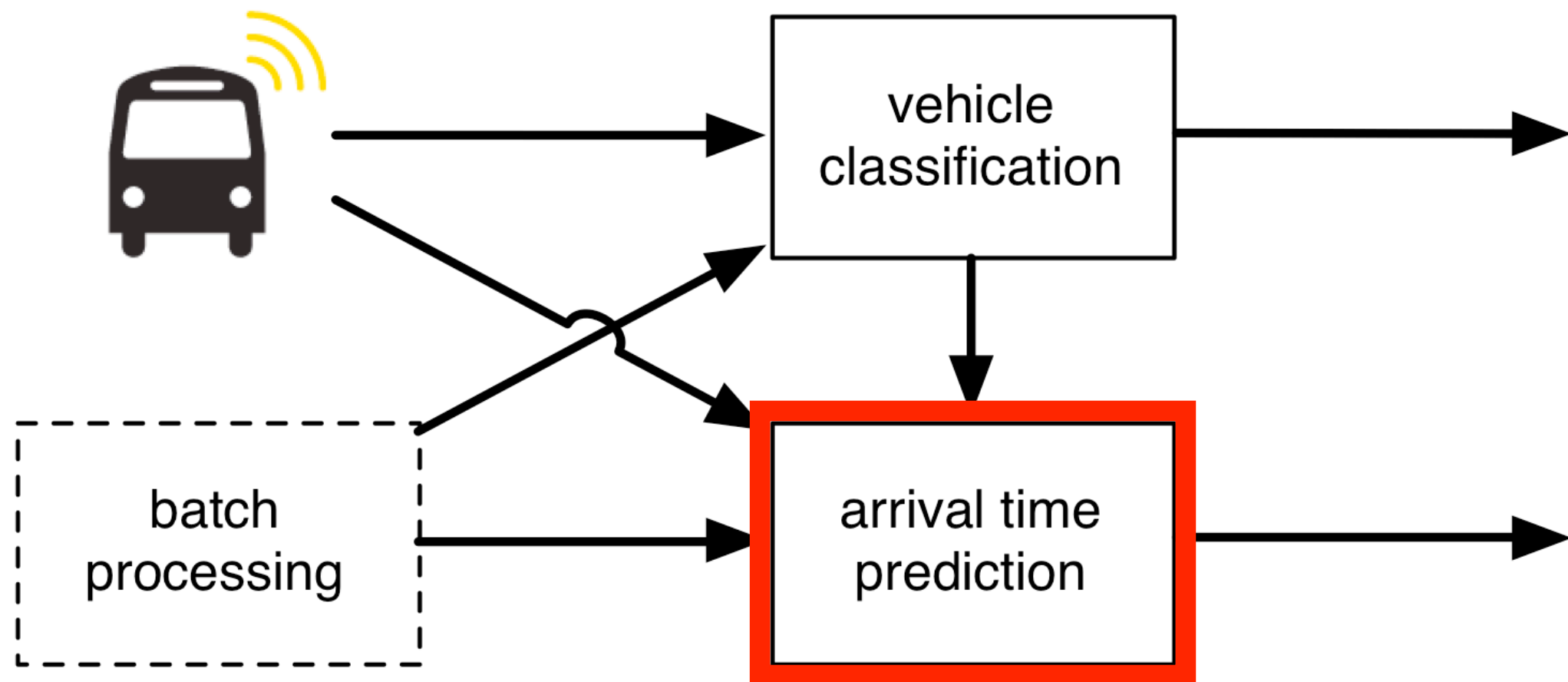
Classification delay



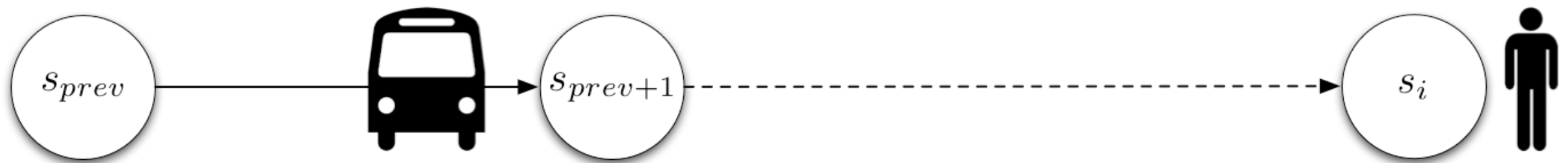
Classification delay



Arrival time prediction

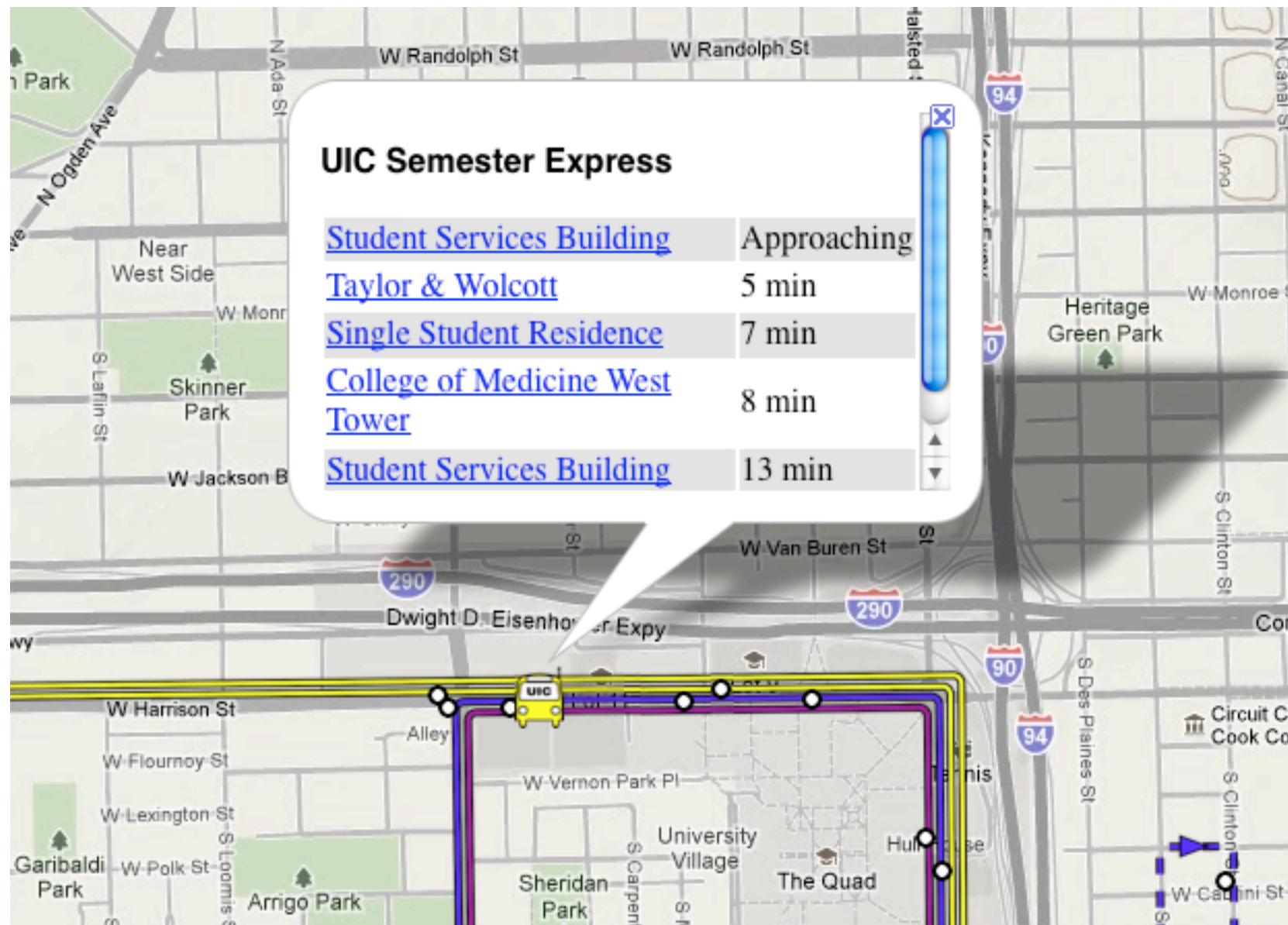


Predicting arrival times

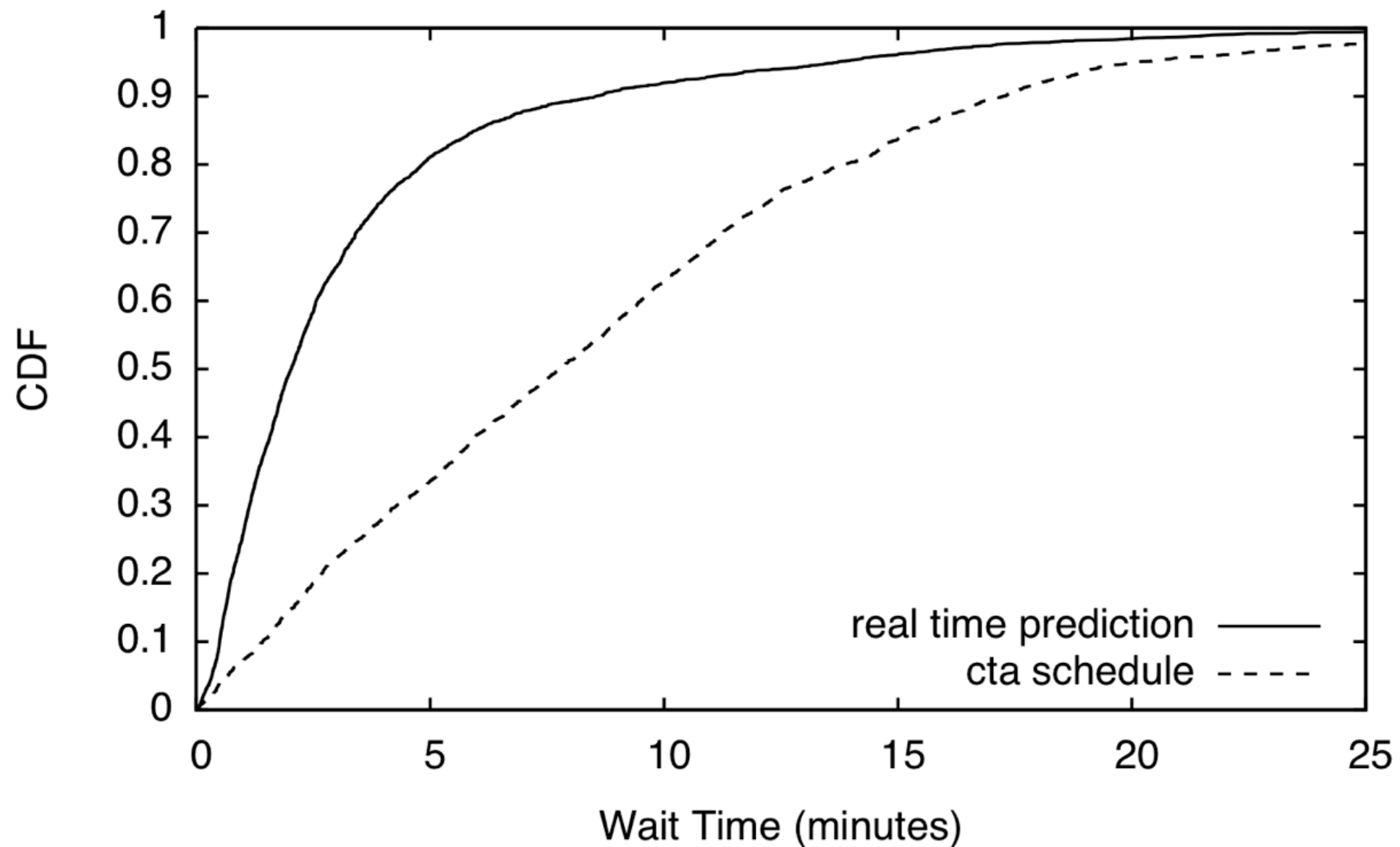


$$time_until_arrival(s_i) = \gamma travel_time(s_{prev+1}, s_i) + (1 - \gamma) travel_time(s_{prev}, s_i)$$

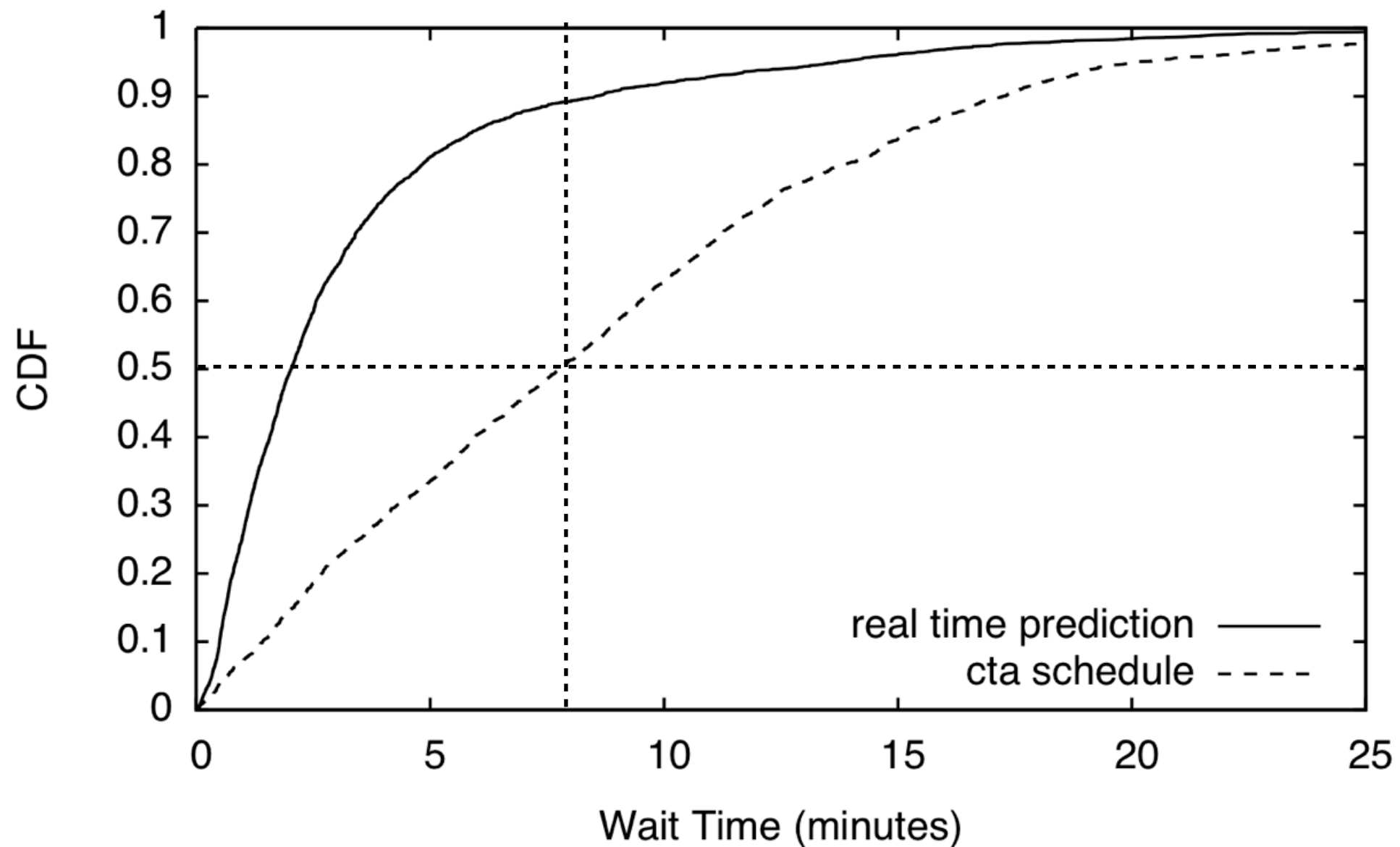
Arrival time predictions



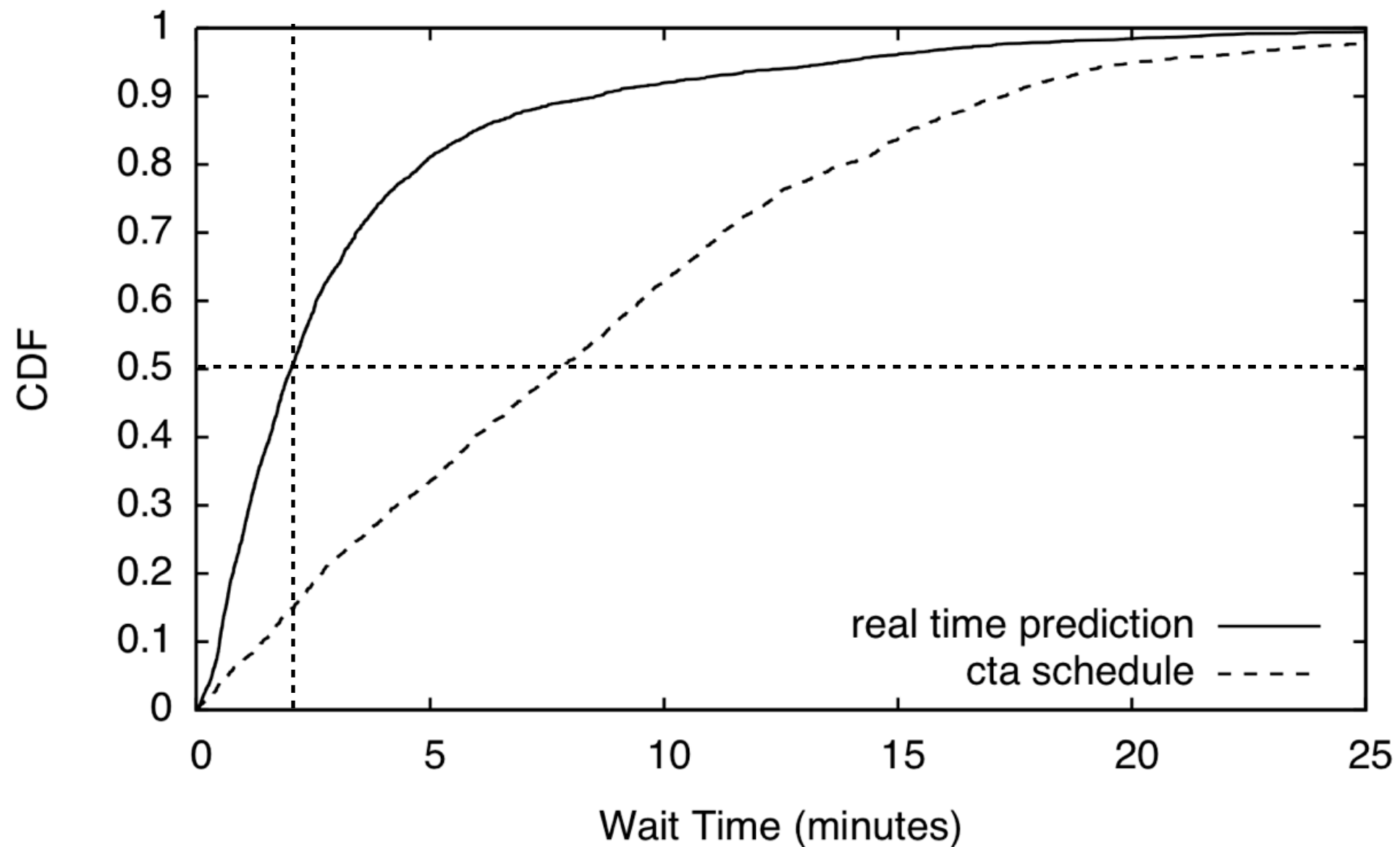
Schedule vs. real-time



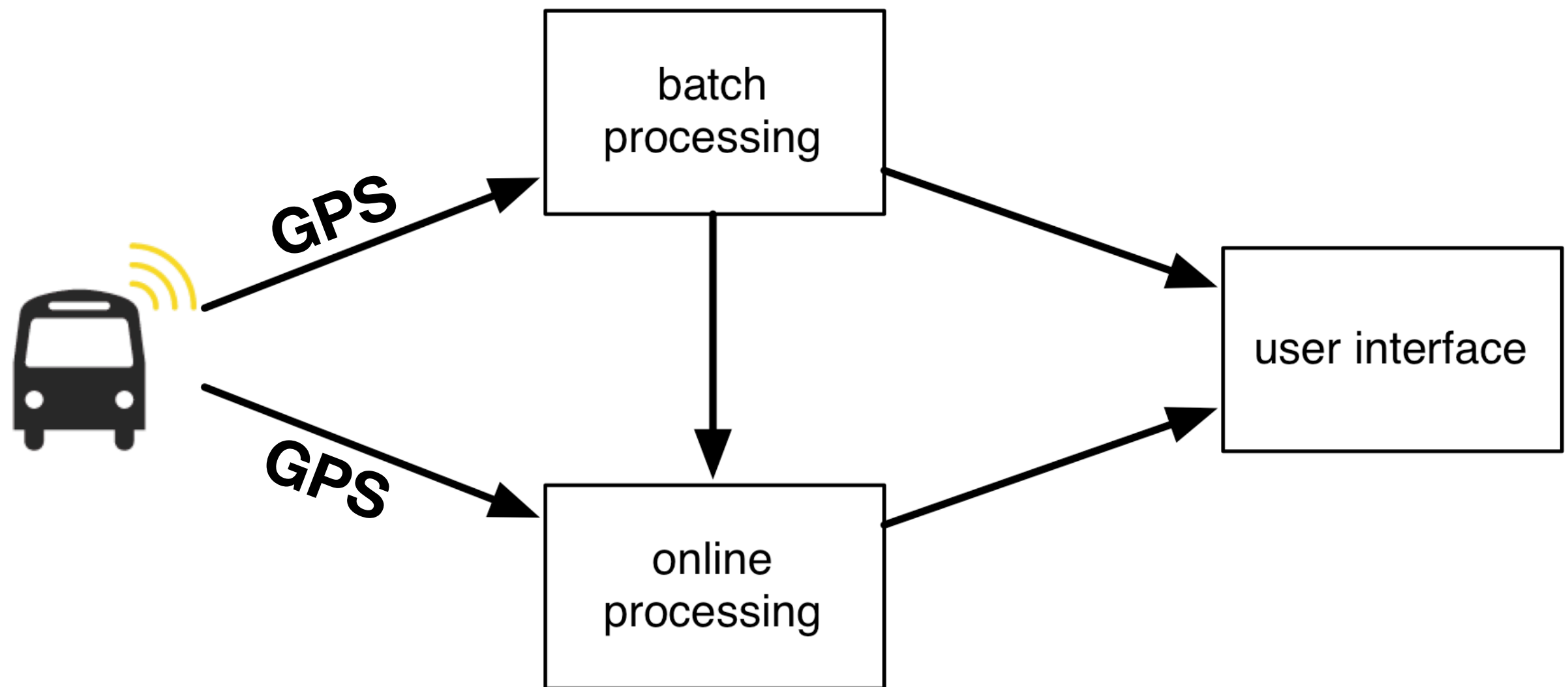
Schedule vs. real-time



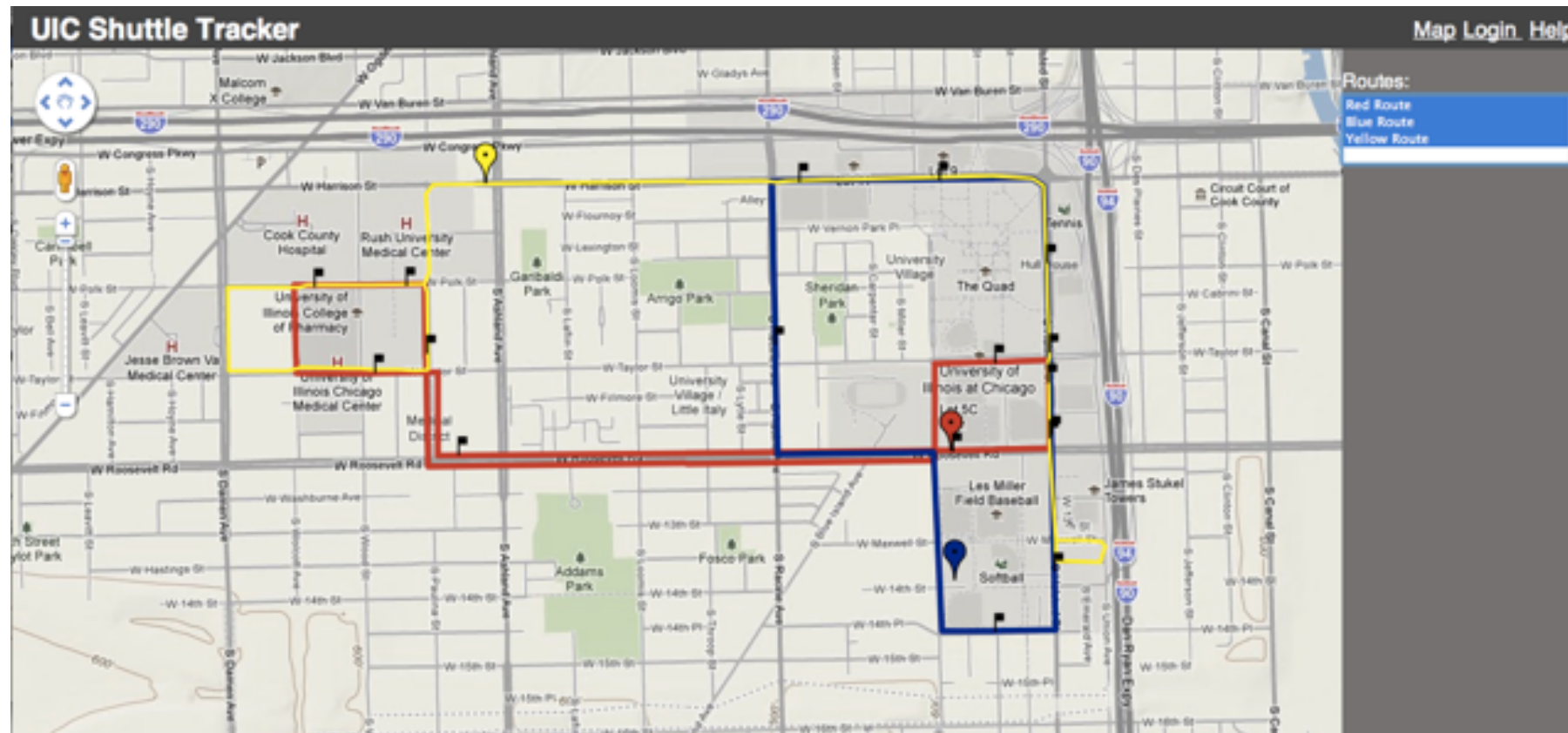
Schedule vs. real-time



System overview



Come and see our demo!



► Thursday, 3:30p-7:30p

Thanks!

Questions?