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)

**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 ([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](http://bus.uic.edu). (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](http://bus.uic.edu). To learn more, [click here](http://bus.uic.edu).

**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](http://bus.uic.edu) [Map](http://bus.uic.edu)
- **Weekend/Holiday:** 7:00 A.M. - 11:00 P.M. [30-Minute Service](http://bus.uic.edu) [Map](http://bus.uic.edu)

**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.

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Our shuttle web (before)

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- Weekend/Holiday: 7:00 A.M. - 11:00 P.M. 30-Minute Service Map

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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

- GPS

- batch processing

- online processing

- user interface
Batch processing

- Route extraction
- Stop extraction
- Schedule extraction
Batch processing

- Route extraction
- Stop extraction
- Schedule extraction
Raw GPS traces
Route map
Raw GPS traces
Kernel Density Estimation

![Kernel Density Estimation Graph]
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

- 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

- Real Routes
- Spurious Routes

Bar chart showing the distribution of routes by ID.
Stop extraction

- route extraction
- stop extraction
- schedule 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

![Bar chart showing recall and precision for different categories.]
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 graph]
Bus stop arrival times
First stop schedule
Travel time variance

![Graph showing mean travel times from first stop.](image)
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

![Bar chart showing mean wait time (seconds) for different durations: one week, two weeks, one month, and CTA schedule. The CTA schedule has the highest mean wait time.]}
Schedule accuracy
System architecture

- Batch processing
- Online processing
- User interface
Online processing
Online processing
Un-classified buses
Classified buses
Hidden Markov model

"Unknown" state
Classification accuracy

Performance (%)

- Correct
- Incorrect
- Unclassified
Classification delay

![Classification Delay Graph]

- CDF
- Distance (meters)

slide 55
Classification delay

![Classification Delay Graph]

Distance (meters)

CDF
Arrival time prediction

- Batch processing
- Vehicle classification
- Arrival time prediction
Predicting arrival times

\[
time\_until\_arrival(s_i) = \gamma \text{travel}\_time(s_{prev+1}, s_i) + (1 - \gamma) \text{travel}\_time(s_{prev}, s_i)
\]
Arrival time predictions
Schedule vs. real-time
Schedule vs. real-time

![Graph showing CDF vs. Wait Time for real-time prediction and CTA schedule]

- Real time prediction
- CTA schedule

Wait Time (minutes)
Schedule vs. real-time

![Graph showing CDF of wait time for real-time and CTA schedule predictions.](image)
System overview

- GPS
- GPS

- batch processing
- online processing

- user interface
Come and see our demo!

- Thursday, 3:30p-7:30p
Thanks!

Questions?