Development of an In-House Automated Vehicle Location System

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ABSTRACT

Students, faculty and staff at the University of Illinois at Chicago (UIC) must move around a campus that is approximately two miles from east to west and one mile from north to south, and that continues to expand. A free shuttle bus service is a primary mode of transportation.

In order to enhance the user experience, and ultimately the service, a GPS-based monitoring system is being developed. Because of limited resources, staff in the UIC Facilities Department and the Urban Transportation Center devised a way to create a low-cost system built with “off-the shelf” hardware. The system’s data is mapped on a public website so that users can 1) gain greater awareness of the bus routes and 2) determine the wait time until the next bus would arrive at their stop.

A secondary potential benefit of the system (after full implementation) is that it should allow for better operations management due to its ability to accurately locate buses. Currently, communications management with buses is achieved via two-way radios and supervisor oversight.

Implementation involved the installation of the hardware on each of the ten shuttle buses on the campus. The hardware on each bus included: a commercially available GPS locator, modem and two-way radio. An antenna was also installed on the highest building on campus (30 stories) to transmit the data. The data is transmitted at 15-second intervals over a publicly available radio frequency.

Key words: AVL—GPS—transportation planning.
INTRODUCTION

The 45,000 students, faculty and staff at the University of Illinois at Chicago (UIC) must move around a campus that is approximately two miles from east to west and one mile from north to south, and that continues to expand. The free shuttle bus service is a primary mode of transportation.

In order to enhance the user experience, and eventually the efficiency of service, a GPS-based monitoring system is under development. The data collected is mapped on a public website so that users can gain greater awareness of the bus routes and determine the wait time until the next bus will arrive at their stop. The website is under development to display the real-time location of the buses along the route. The program currently identifies the point on the route where the bus is, as well as the last point where it was detected, in order to determine its direction, which is shown as an arrow on the map. The project team is currently exploring ways to display buses on a route even if they change their scheduled run.

Future plans for the system include enhancements to the map for easier use, ADA compliance, installation of a second antenna for redundancy in data collection and ultimately map kiosks at strategic locations on campus.

SYSTEM DESCRIPTION

Hardware

In each bus a commercially available GPS locator (Garmin G-36 GPS) was installed, as well as a packet modem and a two-way radio receiver. The GPS hardware receives raw location data from the satellite, calculates the location, and sends the information out in bits. The modem on each bus receives the data in bits and converts it into tones. The two-way radio receiver on the bus transmits the tones to the radio receiver antenna, which is placed on the tallest building on campus (13 stories). The location information is then transmitted across campus via telephone wire to a receiving modem, which is connected to the dedicated server (IBM Netfinity 5000) at the Urban Transportation Center. There are sometimes gaps in the data due to a single antenna receiving data for a two-mile-wide area and therefore a second antenna is scheduled to be installed to provide for data redundancy.
The data is transmitted at 15-second intervals over a publicly available radio frequency. Figure 2 illustrates a representation of the GPS system.

Software

In order to have the bus locations appear properly on the map, the team drove the length of the bus route with a GPS receiver and marked the location of each bus stop and intersection. This GPS data series was then used to correspond to the longitude/latitude data in the map so that the bus route follows the correct path on the map.

The website was initially developed as a “jpeg” picture of the campus map on which the bus routes and the real-time location of the buses were displayed. The program identifies the point on the route where the bus is; each pixel has a direction associated with it, and its direction is shown as an arrow on the map. Because the jpeg file required so much memory to load onto each user’s
computer each time the data refreshed, on some computers the map flickered when it refreshed, a new approach to mapping was sought.

In a second iteration of programming the system, the map was rewritten in a Java program. Now only a small data file needs to be sent to update the map. Now it takes far less memory on users’ computers and there is less likelihood of problems in the way the information is displayed. Roll-overs were added to the programmed map so that at each bus stop or building marked on the map the user can obtain exact information about the address.

Additional components to the map development have included usability for those who are disabled. Therefore, a high level of contrast is required on the map for color-blind users, as well as an option for the blind to call the dispatchers’ office to obtain verbal information about bus location. Ultimately, the locations of the buses will also be provided via text so that software for the blind can read the text to the user.

Other considerations with respect to mapping were that there were multiple routes that needed to be displayed on the map: the daytime and nighttime/weekend shuttle. The team partnered with the bus dispatchers to develop a chart into which they could input each bus assignment and note the bus number and its specific route, which is communicated back to the master program. This ensures that the buses are coded to the proper route, as the routes are displayed on the map in different colors. Figure 3 shows the map of the campus and a representation of the online

The map has been in the beta testing phase since February and the response from students and faculty has been very positive. Suggestions have been made in terms of readability and user friendliness and those are being incorporated. The possibilities for this system in terms of improving productivity and quality of life for the students and faculty are very good, as the following calculations show.

![Figure 3: Online Map](image-url)
SENSITIVITY ANALYSIS

The campus shuttle runs from 7:00 AM to midnight and is free for UIC students and faculty. This study only includes the shuttle bus service and not any other kinds of commuter transportation within the campus area. Based on data given by Facilities Management Administration and field data collection, estimations of riders’ waiting time were carried out. The following section explains the methodology used for calculating the waiting time and also gives details on some of the assumptions used in the study.

Assumptions

For the purpose of some level of simplification, assumptions have been made as follows:

- All the buses start on time from their first stop (i.e. services building).
- The distance between bus stops is the same and drivers drive at the same speed.
- It takes 40 seconds for a bus to travel from one bus stop to another. It was found from field data collection that on average a passenger takes 1.1 seconds to board the bus.
- All the buses are the same new model buses and their door takes 10 seconds to open and close.
- The system transports the same number of riders per day.
- Buses do not wait at the college of medicine west for more time that the required to pick up users.
- People getting off the bus do not affect boarding patterns.

Methodology

After analyzing the data, the month of September 2002 was selected to represent the base condition. Three basic steps were necessary to analyze the data.

1. Using the number of passenger per hour per stop, find the number of passenger per minute per stop. This is done only for the main route.

2. Based on field measures, calculate boarding time for each passenger (1.1 sec), plus open/close door time (10 sec) for the buses used, and estimate a travel time between each stop (40 sec). Calculate an estimated arrival and departure time to each stop and therefore calculate the headway at each stop.

3. From 2 and 3, knowing the number of arrivals per minute to each stop and knowing the headways at any given stop, calculate waiting time at any given stop for any given route. Therefore, total waiting time for the system is known.

Based on the above methodology, it was found that the total waiting time for the system for the month of September 2002 was 459 hours. The following figure shows the sensitivity analysis of
the potential? waiting time reduction given the percentage of riders using the website for bus location.

FIGURE 4: Sensitivity Analysis from the GPS system

CONCLUSIONS

For many commercial bus systems, the cost of GPS systems ranges from $5,000 to $30,000 per bus. This system designed in-house is dramatically less, at only $380 per bus. Despite the lower cost, the system is effective and it provides significant benefit to the users. The system will improve the mobility and accessibility of UIC faculty, staff and students.

Additionally, since the dispatcher and the supervisor have access to all the real-time data as well, they will know the exact location of the buses and their staff. It will make easier for the dispatchers to re-route buses, or expand the system in the future. It will also be easier to handle the deployment of spare buses either for high demand or an on-route bus breakdown. Most of all, this system provides an easier way to control delays, therefore on-time performance and consumer satisfaction should be improved.
ACKNOWLEDGMENTS

A project as complex as the design and implementation of an AVL involves many people at so many different levels. In the particular case of our project, we have had the involvement of faculty, students and staff from different college units and departments of the University of Illinois at Chicago.

Specifically, we would like to acknowledge the hard work and time spent of two individuals. Jim Limber, an engineer from the Physical Plant Administration unit at the University of Illinois at Chicago, is the mastermind behind the idea and George Yanos, a network specialist in charge of the hardware and software of the Urban Transportation Center at the University of Illinois at Chicago, is the web designer and programmer.

REFERENCES