

# **Using Custom Transportation Data Collection Software with Handheld Computers for Education, Research, and Practice**

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## **Abstract**

In an effort to facilitate data collection for research, give students first-hand experience collecting data for course projects, and generate interest in the transportation field through outreach, the Portland State University Intelligent Transportation Systems (ITS) Laboratory has developed custom data collection software for handheld computers using the Palm OS platform. The software is designed to export the collected data to desktop computers in common file formats suitable for analysis in spreadsheet and geographic information systems (GIS) applications. Data collection problems addressed include recording position over time, recording the geographic location of features, and performing cumulative vehicle or pedestrian counts.

## **Introduction**

As transportation researchers, we routinely deal with sizable and dynamic transportation data in our efforts to understand, model, quantify, and validate transportation systems. Where appropriate, these data can be incorporated into our transportation courses as lecture material, assignments, or laboratory work to promote active student learning. Educational research and our experience has shown that engaging students in active learning can significantly improve student outcomes.<sup>1</sup> The use of existing data to illustrate and emphasize theory, however, precludes student exposure to the data collection process. We feel students benefit from collecting and analyzing their own data. Most students learn as they struggle with comparing real-world observations with expected results or textbook examples. Further, they learn important lessons about data quality, accuracy, time, and expense necessary for data collection. While desirable, the collection of effective data for educational purposes tends to be time-consuming, requiring many people, many hours of their time, and is highly manual. Equipment to automate data collection is typically costly and not available for classroom purposes. These restrictions usually mean if any data collection is incorporated in transportation coursework, it is of short duration and relatively simple (e.g., intersection vehicle or pedestrian counts or parking surveys).

We have attempted to incorporate the data collection “process” into the classroom and laboratory by creating tools using equipment readily available at low cost (often referred to as “commodity hardware”) and custom open-source software. We have developed software for Palm OS handheld computers which, when coupled with global positioning system (GPS) devices, allow a great deal of transportation-related data to be collected rather easily. Data collection assignments

can be designed to encourage exploratory learning as students seek to reconcile collected data with classroom lessons. In addition, the relatively low cost of our approach allows a number of devices to be used. This encourages a greater amount of data to be collected by a number of students and assembled over multiple years. Furthermore, we have found this tool to be robust enough to be used in research and professional practice (as discussed later). This synergy is an added feature of our tool – allowing students the opportunity to participate in research or practice.

There are three broad classes of data collection scenarios that we desired to address, each of which has a large number of applications in transportation research and engineering.

- Recording one's location in one or two (or even three) dimensions over time. Applications include recording transit vehicle trajectories or analyzing changes in traffic flow using a probe vehicle. Past data collection efforts have typically involved an odometer transducer or a GPS receiver attached to a notebook computer that runs commercially available position logging software. The bulk and cost of this solution does not allow it to scale well and the software provided with most GPS receivers tends to be somewhat inflexible.
- Association of features with geographic locations. By recording electronically where in space different characteristics were observed these data could later be accessed with a geographic information system (GIS) either alone or in comparison with other archived data for interpretation and analysis. This is of particular interest in places like Portland, Oregon, where large amounts of transportation and planning related data are already available in GIS formats for use by engineers and planners.
- Recording the occurrence of individual events over time at a specific point. Some of the more common applications in this case include tabulating turns at intersections or determining the mix of vehicle types present on a facility. This general class of problems involves recording the time of each event, some descriptive category information for the event, and the cumulative number of events up to the present time. Using more than one device and observer, this can be done over the length of a facility, for example at an intersection approach or freeway segment.

In this paper, we briefly describe the hardware, software, and cost of the tool we developed to automate these three data collection procedures. For illustrative purposes, since we have made the software available free to other users, a “user manual” type description of the software is presented. We then describe four applications to demonstrate robustness of the tool: 1) a data collection and analysis used in an undergraduate course; 2) field data inventory in a graduate-level projects in urban and regional planning; 3) travel time studies for graduate level research; and 4) use of the tool by practicing professionals. In conclusion, we offer some insights about how this tool has improved our research environment as well as our outreach efforts to high school students in the Portland metropolitan area.

### **Custom Data Collection Tool**

All three of our data collection scenarios discussed previously are location-specific, time-based, may involve collecting data in moving vehicles, and tend to be located quite far from the lab or classroom. Time and location information can easily be gathered using GPS receivers. We first considered notebook computers, however previous experience indicated that, while portable, they were too large, expensive, and complex for our purposes. GPS receivers for use with laptops are available for approximately \$100-\$200. Software bundled with these units is primarily targeted at the consumer market for auto navigation systems. Common software titles such as

*Rand McNally Street Finder Deluxe* or *Navman's SmartST Professional* are not well suited for data collection beyond recording travel routes and logging latitude and longitude at predefined intervals. Total cost for the notebook approach would be \$1000-\$1800 per setup, perhaps less for used items.

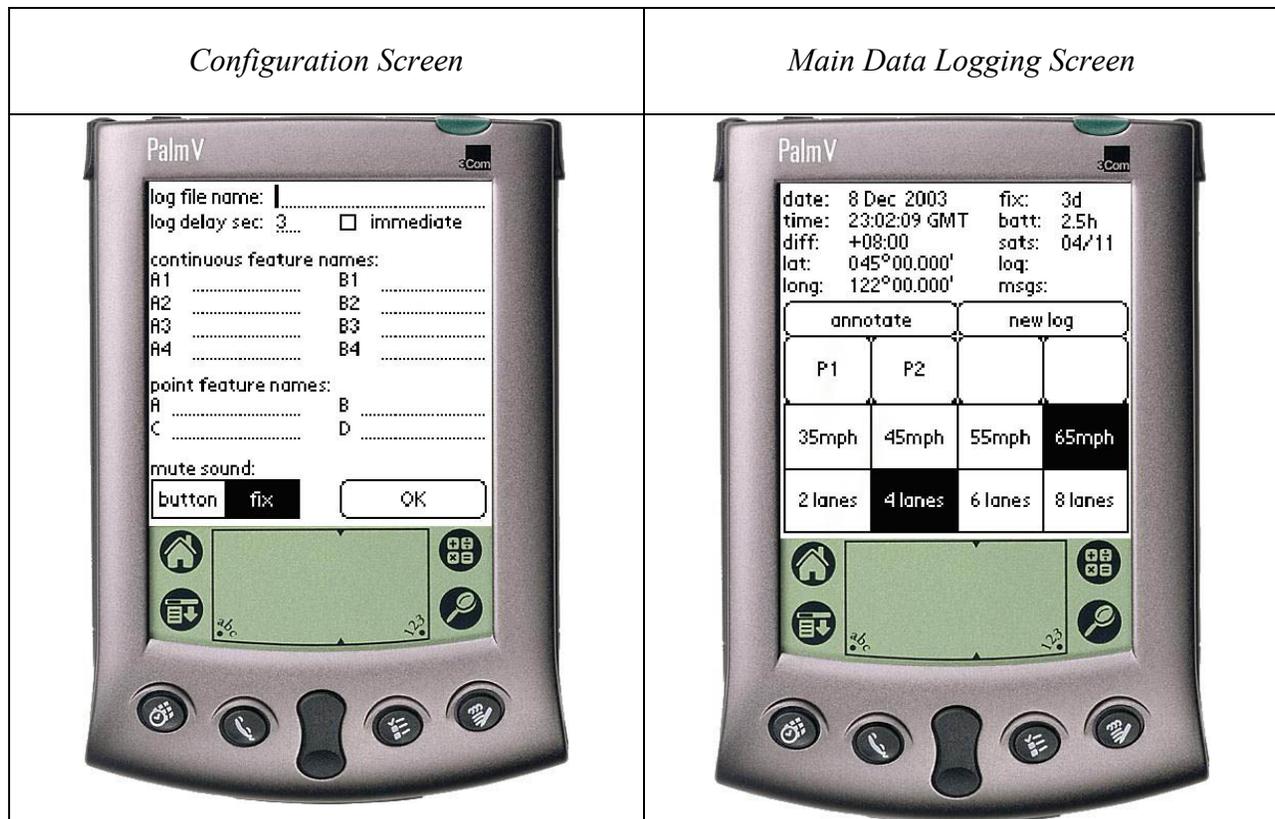
We next considered handheld computers as our hardware platform. Based on software needs and availability, we considered Palm OS platforms. Palm OS-based handheld computers were readily available at prices that allow for the purchase of several devices. Basic used or new Palm hardware were available from Internet auction sites between \$50-\$100. GPS receivers for use with handheld computers are available at a cost between \$180-\$300 (less expensive receivers can also be found for older handhelds). Software bundled with these units is also primarily targeted at the consumer market for auto navigation systems. We purchased and used Palm V handhelds and Magellan GPS Companion GPS receivers for our purposes. Total cost for the handheld approach was \$100-\$300 per setup.

We then developed two software applications, ITS-Count and ITS-GPS, which provide solutions to our three main data collection scenarios. Open-source software for Palm OS, which provided some core GPS functionality, was already available. The open-source development model was chosen for its compatibility with our desire to share our collection tools with the research community. We continue to invite those interested in the software to contact us—we provide the software for free download at [www.its.pdx.edu](http://www.its.pdx.edu). This software has been used with the Palm V and IBM WorkPad c3 devices and the Magellan GPS Companion GPS receiver. It is likely that the software will work with other devices, but other configurations have not yet been extensively tested. In addition, an accompanying data retrieval Windows application is used to retrieve the recorded data from the handheld computer, compute additional information, and save it on a desktop machine in various file formats (DBF, CSV, ESRI shapefile) which may then be loaded by a spreadsheet or GIS program for display and analysis. The following sections describe the two software applications and the type of data they are designed to collect.

#### Location and Time-based Data: ITS-GPS

Our first software program, ITS-GPS, handles the first two data collection scenarios – recording location over time and associating features with geographic coordinates. Both of these problems depend on recording position information, so both can be solved with a GPS receiver as the main data source. We are aware of locational inaccuracies associated with GPS data but have not yet found them to be a constraint of the use of ITS-GPS. ITS-GPS was built on the base of an open source GPS application called TZGPS that was originally developed by Tom Zerucha (see <http://tzgps.sourceforge.net>). ITS-GPS can be used to collect travel time information, vehicle trajectories, intersection delay measurements, locations of point features, and other inventory type data.

When the data logging software is started on the handheld computer, the user is presented with the configuration screen shown in Figure 1. At this point, the user specifies information related to the current data collection session, starting by giving the data log file a name. While recording data, the software will make an entry in this log at regular intervals specified in the field called “log delay.” By default this interval is set at three seconds. If the user wants only to record position versus time, the feature name fields may be left blank. If he or she wishes to record additional information, the appropriate feature name fields must be filled in.



**Figure 1** ITS-GPS Screen Captures

There are two types of features which are handled by ITS-GPS, which we refer to as continuous and point features. Point features are the simpler of the two, and are used to record discrete events or physical objects occurring at one specific point in space. While logging data, a button will be available for each point feature specified. When a button is tapped with the stylus, the corresponding feature will be noted in the next log entry. For more accurate location of point features, the user may check the box labeled “immediate” which will force a log entry at the moment the feature is noted rather than waiting for the log delay to elapse. The program can record up to four different kinds of point features in a single data logging session. These four point features are referred to as A, B, C, and D on the configuration screen in Figure 1.

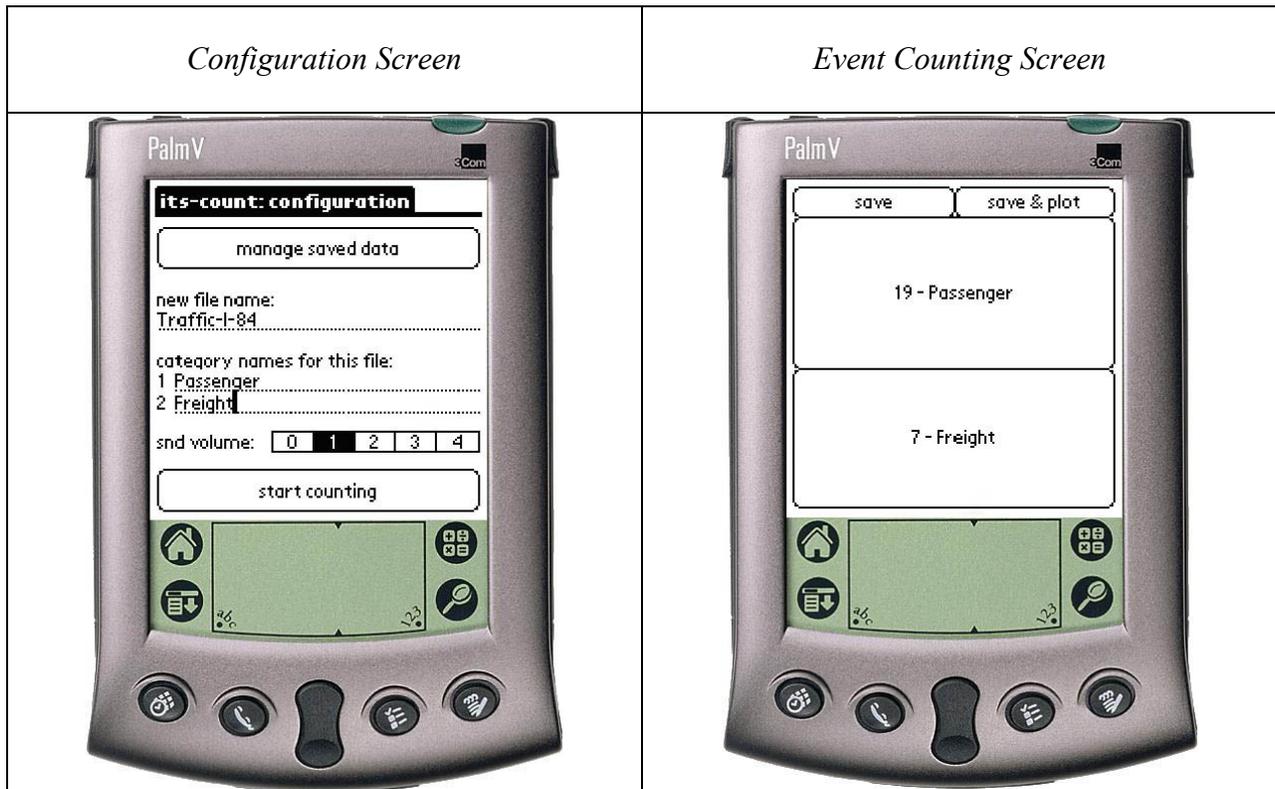
Continuous features, on the other hand, are used to record features that persist over a distance or time (i.e. features which have length) but may change in some detail over that length. The software can record two types of continuous features in a single data logging session. Each continuous feature type is implemented as a multiple-choice selection between four different options. The types are referred to as A and B, and the choices within each type are numbered 1-4 on the configuration screen in Figure 1. During data collection, a continuous feature is not noted at individual log entries. Instead, every log entry includes a record of whichever of the four multiple choice options is currently selected for each of the two continuous feature types. Perhaps the best way to illustrate the difference between the two types of features is by example. If the user were interested in recording information about a highway facility, he or she might want to record the number of lanes and the speed limit all along the facility. By toggling the appropriate feature, continuous data collection can be made.

After setup is complete, the program will be logging time and position information from the GPS receiver at the time interval specified by the user as shown in Figure 1. The user can note a point feature or change the currently selected continuous feature by tapping the buttons provided on the bottom half of the form with the stylus. An annotation button is provided which allows the user to associate arbitrary text information with the current position in the log file. The upper half of the display provides the user with status information while he or she is logging data.

Counting and Classification Data: ITS-Count

Our second data collection software, ITS-Count, deals with counting different classes of events at a single point over time. The types of count data that can be collected with ITS-Count have many different uses in transportation engineering and research. These include measuring saturation flow at intersections, performing turning counts, and finding gap times for pedestrian crossings.

Before data collection begins, the user is presented with a configuration form (see screen capture in Figure 2) where he or she may set options related to the current data collection session. The “manage saved data” button at the top of the configuration form is used to plot, view, and delete previously saved data sets. A descriptive filename is entered for the data about to be collected, and the event categories are described on the following two lines. In Figure 2, the arrivals of passenger vehicles and freight vehicles are being counted separately, so the categories have been named accordingly. The user need not provide names for both categories if he or she will be recording only one type of event.



**Figure 2** ITS-Count Screen Captures

Once the software is configured, the software switches to the event counting screen as shown in Figure 2. The user may at this point either tap the buttons on the screen with the stylus or use the hardware buttons below the screen to record the occurrence of events. We found the on-screen buttons to be less than optimum as input devices when the user is not looking at the Palm display, so the four hardware buttons at the bottom of the handheld computer (which would normally call up built-in applications such as the calendar or notepad) have been reassigned to provide another method of input. Each time a button is pressed, a new line is added to the data set to record the event. This line includes a time stamp, the event category, and the cumulative count for that category. As each event is recorded, the display is updated to indicate the new cumulative count.

### Data Processing

Once the user returns to the office or lab, they can use an accompanying Windows application to retrieve the log files from the handheld computer, calculate distance traveled and speed between each pair of consecutive log entries, and save the log in comma separated value (CSV), dBase (DBF), or ESRI shapefile formats on the desktop PC. CSV files are essentially a text format and can be loaded into many different applications including spreadsheet software. Figure 3 shows an example of ITS-GPS exported data viewed in Excel. DBF files are intended for database software but can also be loaded into spreadsheets and geographic information systems (GIS) software. The ESRI shapefile option allows the saved data to be imported directly into ArcGIS as a polyline representing the path taken during data recording. All recorded feature information will be associated with the appropriate line segment along the path.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	date	time	elapsed	latitude	longitude	continuous A	continuous B	none	nor	non	none	dist mi	vel mi/h	dist km	vel km/h	notes
2	2003.11.01	21:49:33	3	45.41576	-122.631	Sidewalk	no data	0	0	0	0	0.001384	1.660396	0.002227	2.672219	none
3	2003.11.01	21:49:36	3	45.41571	-122.631	Sidewalk	no data	0	0	0	0	0.003492	4.189972	0.005619	6.743286	none
4	2003.11.01	21:49:39	3	45.41566	-122.631	Sidewalk	no data	0	0	0	0	0.003753	4.503069	0.006039	7.24718	none
5	2003.11.01	21:49:42	3	45.41561	-122.631	Sidewalk	no data	0	0	0	0	0.003753	4.503069	0.006039	7.24718	none
6	2003.11.01	21:49:45	3	45.41557	-122.631	Sidewalk	no data	0	0	0	0	0.00338	4.055995	0.00544	6.527664	none
7	2003.11.01	21:49:48	3	45.41552	-122.631	Sidewalk	no data	0	0	0	0	0.003752	4.502511	0.006039	7.246282	none
8	2003.11.01	21:49:51	3	45.41548	-122.631	Sidewalk	no data	0	0	0	0	0.00338	4.055995	0.00544	6.527664	none
9	2003.11.01	21:49:54	3	45.41543	-122.631	Sidewalk	no data	0	0	0	0	0.003966	4.758978	0.006383	7.659037	none
10	2003.11.01	21:49:57	3	45.41538	-122.631	Sidewalk	no data	0	0	0	0	0.003753	4.503069	0.006039	7.24718	none
11	2003.11.01	21:50:00	3	45.41533	-122.631	Sidewalk	no data	0	0	0	0	0.003753	4.503069	0.006039	7.24718	none
12	2003.11.01	21:50:03	3	45.41529	-122.631	Sidewalk	no data	0	0	0	0	0.003127	3.752446	0.005033	6.039137	none
13	2003.11.01	21:50:06	3	45.41524	-122.631	Sidewalk	no data	0	0	0	0	0.003967	4.760033	0.006384	7.660735	none
14	2003.11.01	21:50:09	3	45.41519	-122.631	Sidewalk	no data	0	0	0	0	0.003753	4.503069	0.006039	7.24718	none
15	2003.11.01	21:50:12	3	45.41515	-122.631	Sidewalk	no data	0	0	0	0	0.003127	3.752446	0.005033	6.039137	none
16	2003.11.01	21:50:15	3	45.41511	-122.631	Sidewalk	no data	0	0	0	0	0.00338	4.055995	0.00544	6.527664	none
17	2003.11.01	21:50:18	3	45.41506	-122.631	Sidewalk	no data	0	0	0	0	0.003753	4.503069	0.006039	7.24718	none
18	2003.11.01	21:50:21	3	45.41502	-122.631	Sidewalk	no data	0	0	0	0	0.003127	3.752446	0.005033	6.039137	none
19	2003.11.01	21:50:24	3	45.41498	-122.631	Sidewalk	no data	0	0	0	0	0.003127	3.752446	0.005033	6.039137	none
20	2003.11.01	21:50:27	3	45.41496	-122.631	Nosidewalk	no data	0	0	0	0	0.001466	1.758797	0.002359	2.830585	none
21	2003.11.01	21:50:30	3	45.41495	-122.631	Nosidewalk	no data	0	0	0	0	0.000843	1.01214	0.001357	1.628925	none
22	2003.11.01	21:50:33	3	45.41491	-122.631	Nosidewalk	no data	0	0	0	0	0.002932	3.518308	0.004719	5.662319	none
23	2003.11.01	21:50:36	3	45.41487	-122.631	Nosidewalk	no data	0	0	0	0	0.002933	3.519022	0.00472	5.663467	none
24	2003.11.01	21:50:39	3	45.41483	-122.631	Nosidewalk	no data	0	0	0	0	0.002931	3.517595	0.004718	5.66117	none
25	2003.11.01	21:50:42	3	45.4148	-122.631	Nosidewalk	no data	0	0	0	0	0.00213	2.556019	0.003428	4.113623	none

Figure 3 Example Data From ITS-GPS, Viewed In Excel

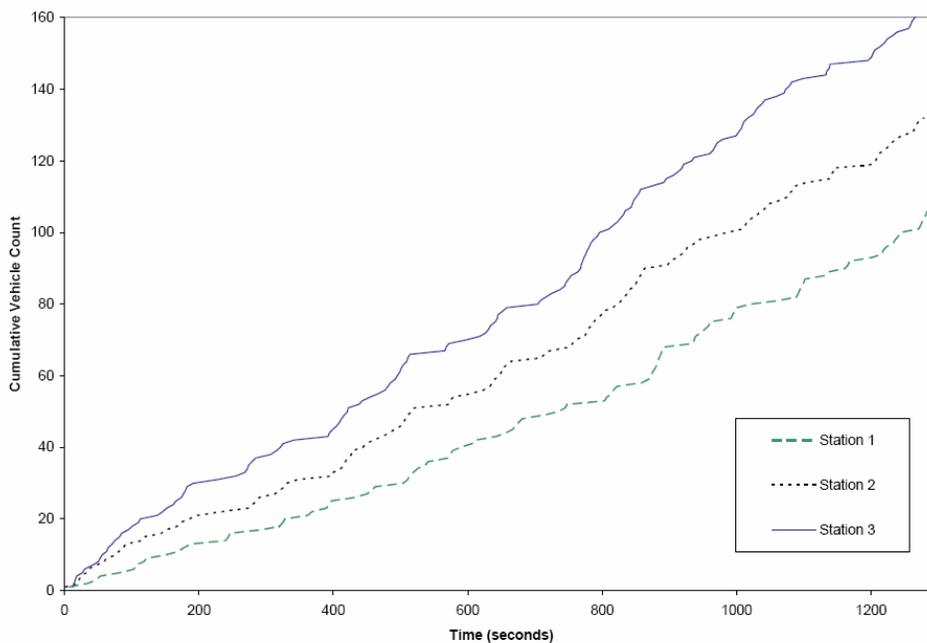
## Example Applications

We will discuss here only a few possible applications – users are encouraged to find new uses for the software and provide feedback. These examples demonstrate the flexibility of the tool to be used in education, research, or practice.

### Application 1: Cumulative Passenger Vehicle Counts for Undergraduate Assignment

One of the primary purposes of ITS-Count is to allow students in transportation courses hands-on experience in data collection. Six students simultaneously recorded vehicle count data at different points along an urban arterial approach to a signalized intersection and produced the  $N(x,t)$  (cumulative count versus time) plot shown in Figure 4 as part of a homework assignment for a transportation operations course. This plot shows the cumulative number of vehicles to pass given points upstream of a traffic signal, such that the slope of each curve is the flow past that particular point. Using ITS-Count allowed them to easily record and combine their own data, making the assignment more valuable than a simple exercise with preexisting data. Students were asked to measure saturation flow and track queue formation and dissipation using the data that were collected.

Recently for a fall 2004 term project, four undergraduate students used the ITS-Count devices to measure saturation flows at two Portland intersections. The students compared measured values to the default values used in analysis software. In attempt to measure if the field experience enhanced student learning, we posed an open-ended question on the final exam asking, "How would you measure saturation flow?" Overall, student performance on the question was very poor. However, the four students who used the ITS-Count on the term project scored approximately 38% higher, with an average of 62.5%, than the rest of the 34 students who averaged 45%. This very simple analysis suggests that students benefited from a field experience with the device (perhaps as expected.)

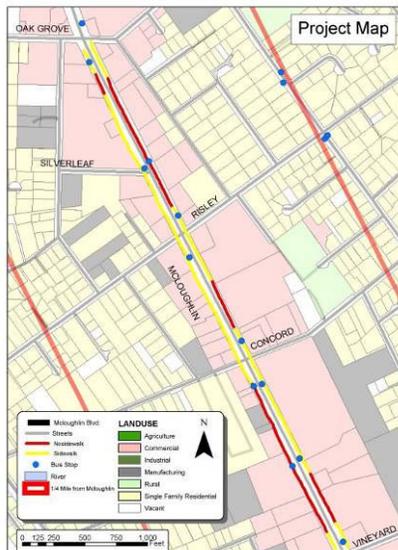


**Figure 4** ITS-Count: Plot Produced By Students From Several Exported Data Sets

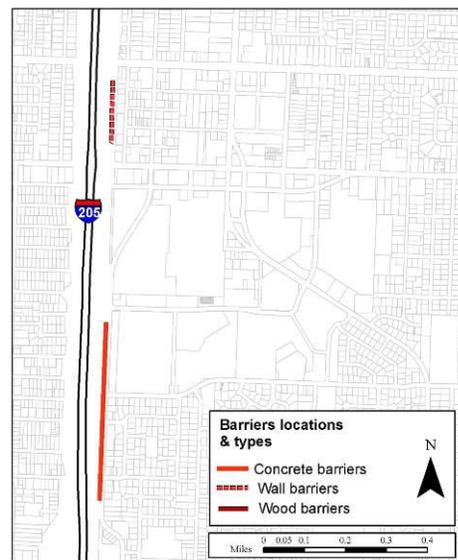
## Application 2: Field Data Inventory for Graduate Class Project and Research

As part of a graduate class project, ITS-GPS was used in an investigation of potential pedestrian improvements in Southeast Portland. In many urban areas, key gaps in sidewalks may impede pedestrian access to bus stops or other facilities. In fact, at this particular site, several segments of this road are entirely lacking sidewalks. While walking down both sides of the road, the ITS-GPS continuous feature logging system was used to record the presence of sidewalks. These data were retrieved from the handheld computer as an ERSI shapefile and loaded into ArcGIS along with layers containing roads, tax lots, and transit stops as shown in Figure 5(a). The total length of the missing sidewalk segments could then be calculated and an estimation given for the cost of completing the sidewalks in this area. Viewing the sidewalk information together with the transit and tax lot information also allowed an analysis of the impact of the missing sidewalks on pedestrians wishing to reach bus service or patronize one of the businesses along this road. Other methods for data collection considered include aerial photos or the use of a measuring wheel. The ITS-GPS software proved to be a much faster and more accurate method of data collection.

As part of a graduate research project, ITS-GPS was used in an assessment of traffic noise along interstates I-5, I-84 and I-205 on Portland metropolitan area. The research used the Federal Highway Administration Traffic Noise Model (TNM) for traffic noise prediction. One of the factors affecting the propagation of noise from the source to receiver is the existence of sound barriers. The main variables that affect noise level are the barrier type, shape, height, and elevation. There are currently no data inventories available for noise barrier locations for the study area. The research used the advantages of the ITS-GPS technology to collect data for both the spatial and the noise barrier types within the study area. Figure 5(b) shows a sample of the data collected. Vehicle runs have been made for every direction of the studied highways recording the locations as line features and the type of the existence noise barriers using ITS-GPS.



(a) Presence or Absence of Sidewalks, Portland, Oregon



(b) Noise Barrier Inventory, Portland, Oregon

**Figure 5** Data Collection Samples

### Application 3: Travel Time Research

ITS-GPS has been used extensively in research projects conducted at the Intelligent Transportation System Lab at Portland State University. ITS-GPS equipped probe vehicles were deployed to validate the Frontier Travel Time system which reads and matches license plates of passing vehicles to estimate corridor travel time.<sup>2</sup> ITS-GPS devices recorded location (latitude and longitude) at three-second intervals, making it possible to map each vehicle's location and speed as a trajectory between camera locations. The distance between two reported latitude and longitude coordinate locations was estimated with the spherical geometry method. Test vehicle trajectories (plots of vehicle location versus time) were compared to the travel times predicted by the license plate reading cameras.

In an upcoming Transportation Research Record article, Bertini and Tantiyanugulchai demonstrated how automatic vehicle location (AVL) data can be used to characterize the performance of an arterial.<sup>3</sup> Bus dispatch system (BDS) data of the Tri-County Metropolitan Transit District (TriMet), the transit provider for Portland, Oregon, was gathered. Then, the performance characteristics as described by bus travel on an arterial were compared with ground truth data collected by probe vehicles equipped with the ITS-GPS devices traveling with normal (non-transit) traffic on the same arterial on the same days. Test vehicle trajectories, shown in Figure 6, were compared to bus trajectories. Comparisons were drawn between the two methods and some conclusions were drawn regarding the utility of the transit AVL data.

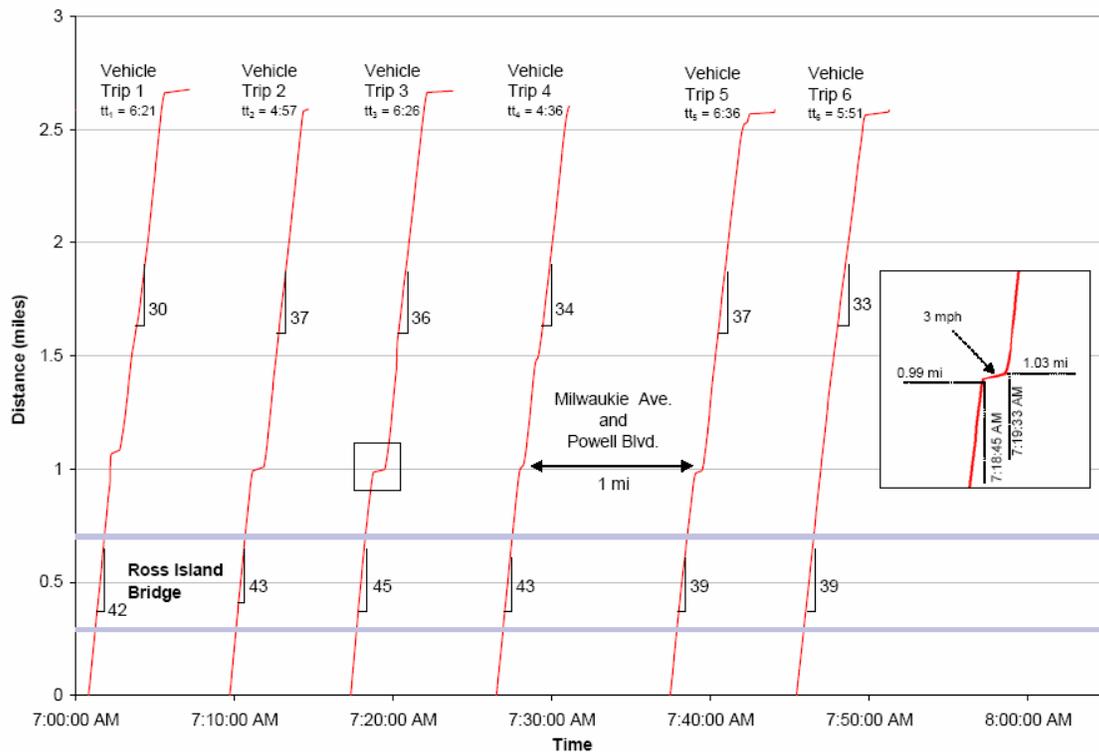


Figure 6 Test Vehicle Trajectories

#### Application 4: Travel Time Study by Practicing Professional

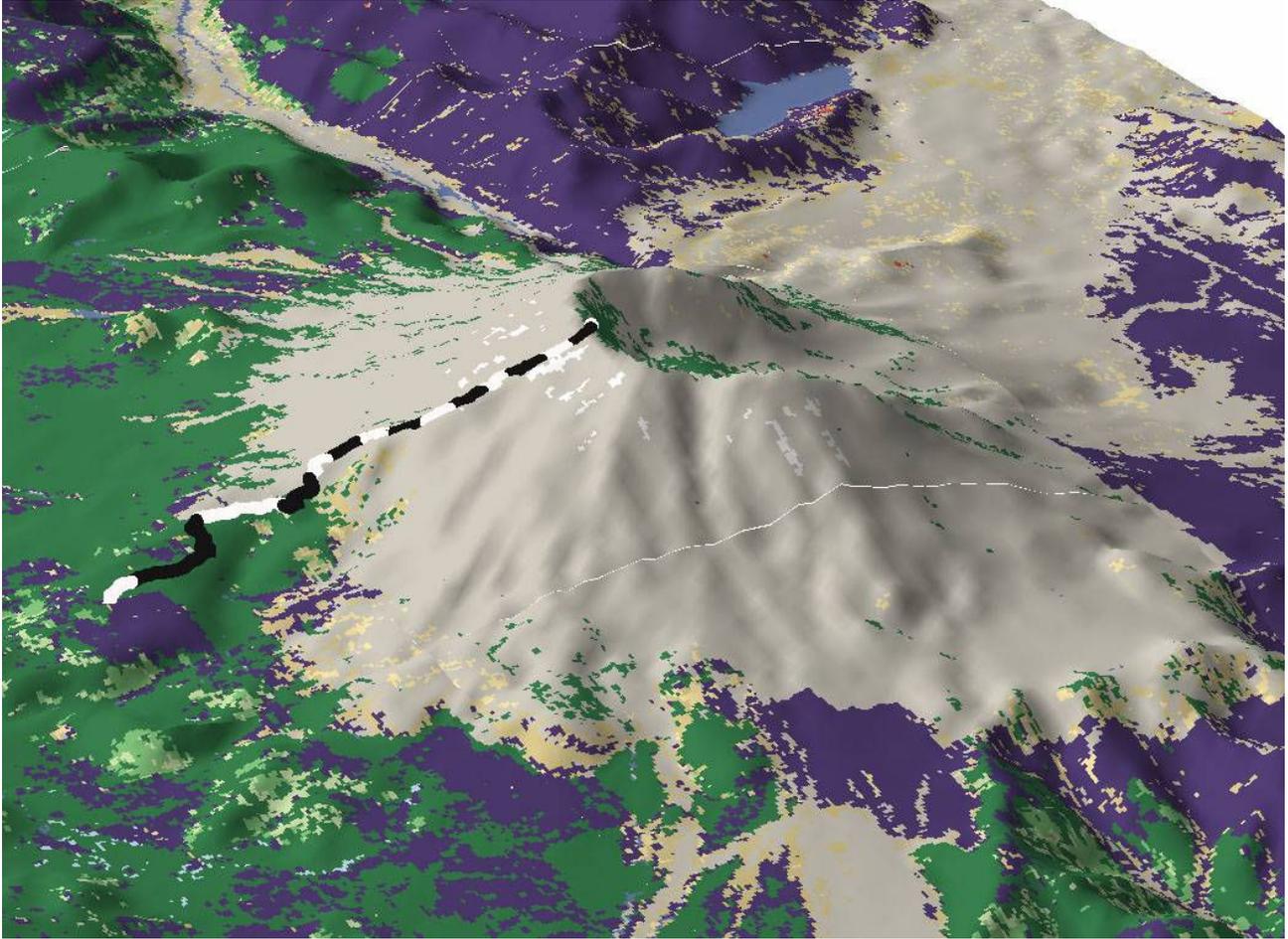
ITS-GPS has also been used by professional engineering firms. DKS Associates' offices in Portland, Oregon, used the more basic position logging functionality as part of a traffic study in Sherwood, Oregon. No continuous features were logged in this particular case. The speed data calculated by the retrieval program were plotted thematically in a GIS system on the arterial where the data were collected. The vehicle recording the data made six passes down the length of the road, and all six speed profiles were plotted together for comparison as shown in Figure 7. DKS has also used ITS-GPS in similar ways in Berkeley, California, and for recording light rail transit vehicle speed profiles in Tacoma, Washington.



**Figure 7 Thematic Travel Speed Data, Sherwood, Oregon**

#### Additional Applications

The tool has not been strictly confined to transportation data collection efforts. On a recreational hike to the crater rim of Mt. St Helens National Volcanic Monument, one of our lab students carried the tool with him. Upon returning to the lab, he created the three dimensional image in Figure 9 using the collected data, United States Geological Survey (USGS) topographic maps, and ArcGIS 3D analyst. The plot shows 250 foot elevation changes in alternating black and white segments; that the students created additional plots showing speed and time over distance. Other students have used the device for similar recreational trips. This “ad-hoc” learning experience was an unexpected outcome.



*Note: Each alternative black and white segment on trail indicates 250 feet elevation change*

**Figure 8**      **Route to Mt. St. Helens Crater Rim**

### **Conclusions**

This project has resulted in the creation of two software packages for Palm OS handheld computers, which, as discussed, have facilitated data collection in numerous transportation applications in education, research, and professional engineering practice. The handheld computers have advantages of small size, low cost, and ease of use that make them ideal data collection devices. The dynamic nature of the open-source software will allow others to customize the interface for their specific data collection needs and continue to build upon our interface.

There is high educational value of facilitating data collection experiences with the tool. In addition to the examples described here, it is easy to envision other transportation concepts reinforced by student use. The simplicity and portability of the tool encourages students to think of using the tool in other ways, such as the Mt. St. Helens hike example. We have also used the devices in outreach with local high school students to demonstrate traffic engineering concepts. These students quickly understood the basic data collection ability and suggested alternative uses for other science class projects (i.e., a wetland migratory bird study). Lastly, the flexibility of the tool was demonstrated by applications for research and professional practice. In closing, we plan

to continue to modify and enhance the tool for use in future research, education, and practice and encourage others to contact us if they wish to do the same.

## Acknowledgments

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## Biographies

### ROBERT L. BERTINI

Dr. Robert L. Bertini is an Associate Professor in the Department of Civil and Environmental Engineering and Urban Studies & Planning at Portland State University. As director of the campus wide Center for Transportation Studies, his research focuses on the integration of new technologies and works in partnership with local, regional, state, federal, and international transportation organizations toward making our transportation system more efficient, effective, and equitable. Bertini has Ph.D. in civil engineering from University of California Berkeley.

### CHRISTOPHER M. MONSERE

Dr. Christopher M. Monsere is a Research Assistant Professor of Civil and Environmental Engineering and is an affiliated faculty member of the Center for Transportation Studies at Portland State University. Dr. Monsere's primary research interests are in the areas of highway safety, freight transportation, and transportation engineering. Monsere has research experience in safety data analysis, freight data and modeling, commercial vehicle operations, and economic analysis. Monsere has a Ph.D. in civil engineering from Iowa State University.

### ANDREW BYRD

Andrew Byrd is currently pursuing an undergraduate degree in computer science at Portland State University, with future academic plans in transportation engineering or urban planning. He previously attended the Ohio State University and the University of Cincinnati in Ohio. Andrew worked extensively on writing custom data collection software for Palm OS-based handheld computers and the Portland Regional Tran. He has also begun work on a project that will eventually archive all inductive loop detector data from the Portland area for use in research.