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

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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 Intelligent Transportation Systems Laboratory of Portland State University, Oregon, 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 applications. Data collection problems addressed include recording position over time, recording geographic location of features, and performing cumulative vehicle or pedestrian counts.

Transportation researchers and educators routinely deal with sizable and dynamic transportation data in their efforts to understand, model, quantify, and validate transportation systems. Where appropriate, these data can be incorporated into transportation courses as lecture material, assignments, or laboratory work to promote active student learning. Education research and experience have shown that engaging students in active learning can substantially improve student outcomes (1). The use of existing data to illustrate and emphasize theory, however, precludes student exposure to the data collection process. It is felt that 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. Although desirable, the collection of effective data for educational purposes tends to be time-consuming, requiring many people and many hours of their time, and it is highly manual. Typically, equipment to automate data collection is costly and not available for classroom purposes. These constraints usually mean that if any data collection is incorporated in transportation coursework, it is typically of short duration and relatively simple (e.g., intersection vehicle or pedestrian counts or parking surveys).

An attempt has been made to incorporate the data collection “process” into the classroom and laboratory by creating tools and using equipment readily available at low cost (often referred to as “commodity hardware”) and custom open-source software. Software has been developed for Palm OS handheld computers, which, when coupled with Global Positioning System (GPS) devices, allows 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 this approach allows a number of devices to be acquired and used. That encourages the collection of a greater amount of data by students over multiple years. Furthermore, it has been found that the tool is robust enough to be used in research and professional practice (as discussed later). That synergy is an added feature of this tool—allowing students the opportunity to participate in research or practice.

There are three broad classes of data collection scenarios that the authors 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. Typically, past data collection efforts have 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 that solution does not allow it to scale well, and the software provided with most GPS receivers tends to be somewhat inflexible.
- Associating features with geographic locations. By electronically recording where 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. That is of particular interest in places such as 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 measuring saturation flow, tabulating turns at intersections, or determining the mix of vehicle types present on a facility. That general class of problem 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. By using more than
one device and observer, that can be done over the length of a facility, for example, an intersection approach or freeway segment.

This paper briefly describes the hardware, software, and cost of the tool developed to automate these three data collection procedures. For illustrative purposes, because the software has been made available free to other users, a “user manual” type of description of the software is also presented. Four applications to demonstrate robustness of the tool are then described: (a) data collection and analysis used in an undergraduate course; (b) field data inventory in a graduate-level project in urban and regional planning; (c) travel time studies for graduate-level research; and (d) use of the tool by practicing professionals. In conclusion some insights are offered about the way this tool has improved the research environment as well as the outreach efforts to high school students in the Portland metropolitan area.

CUSTOM DATA COLLECTION TOOLS

All three data collection scenarios are location-specific and time-based, they may involve collecting data in moving vehicles, and the locations are often quite far from the lab or classroom. Time and location information can easily be gathered using GPS receivers. Notebook computers were first considered. However, previous experience with notebook computers indicated that, while portable, they were too large, expensive, and complex for these purposes. GPS receivers for use with laptops are available for between $100 and $200. Software bundled with these units is targeted primarily at the consumer market for autonavigation 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 costs for the notebook approach would be $1,000 to $1,800 per setup, perhaps less for used items.

Handheld computers were considered next as the hardware platform. On the basis of software needs and availability, the Palm OS platform was considered. Palm OS–based handheld computers were readily available at prices that allow the purchase of several devices. Basic used or new Palm hardware was available from Internet auction sites for between $50 and $100. GPS receivers for use with handheld computers are available at a cost of between $180 and $300, and less expensive receivers can also be found for older handhelds. Software bundled with those units is also targeted primarily at the consumer market for autonavigation systems. Used Palm V handhelds and Magellan GPS Companion GPS receivers were purchased for this project. Total costs for the handheld approach were $100 to $300 per setup.

Two software applications were then developed, ITS-Count and ITS-GPS, which provide solutions to the three main data collection scenarios. Open-source software for the Palm OS provided some core GPS functionality that was already available. The open-source development model was chosen for its compatibility with the desire to share the collection tools with the education and research communities. The authors continue to invite those interested in using or improving the software to contact us—the software is provided for free download at www.its.pdx.edu. This software has been used with the Palm V, IBM WorkPad c3 devices, and Magellan GPS Companion GPS receivers. It is likely that the software will work with other devices, but additional 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 device, compute additional information, and save it on a desktop machine in various file formats [dBase (DBF), comma separated value (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

The first software program, ITS-GPS, handles the first two data collection scenarios—recording location over time and associating features with geographic coordinates. Both of those problems depend on recording position information, so both can be solved using a GPS receiver as the main data source. ITS-GPS was built on the base of an open source GPS application called TZGPS, which was originally developed by Tom Zerucha (see 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 types of 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 that point, the user specifies information related to the current data collection session, starting by giving the data log file a name. While data are being recorded, 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 3 s. If users want to record only position versus time, the feature name fields may be left blank. If they wish to record additional information, the appropriate feature name fields must be filled in.

Two types of features are handled by ITS-GPS; they are referred to as continuous and point features. Point features, the simpler of the two, are used to record discrete events or physical objects occurring at one specific point in space. While data are logged, 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 are used to record features that persist over distance or time (i.e., features that 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 among four different options. The types are referred to as A and B, and the choices in each type are numbered 1 through 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 continuous and point features is by example. If users were interested in recording information about a highway facility, they might want to use continuous features to record the number of lanes and the speed limit all along the facility, whereas point features could be used for marking entrance or exit ramps.

After setup is complete, the program will begin logging time and position information from the GPS receiver at the time interval spec-
ified 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 screen with the stylus. An annotation button is provided that allows the user to associate arbitrary text information with the current position in the log file. The upper half of the display provides users with status information while they are logging data. There is some concern about the expected accuracy of positions reported by commodity GPS hardware, but testing of ITS-GPS has indicated that reported speeds and positions are reliable.

**Counting and Classification Data: ITS-Count**

The second data collection software product, 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 education and research. These include measuring saturation flow at intersections, performing intersection turning counts, and finding gap times for pedestrian crossings. Manual counts from closed circuit television surveillance video with ITS-Count can also be used to verify automatic vehicle counts from inductive loop detector systems.

Before data collection begins, users are presented with a configuration screen (see screen capture in Figure 2) on which they 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. Users need not provide names for both categories if they will be recording only one type of event.

Once the software is configured, the software switches to the event counting screen as shown in Figure 2. The user may at that 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. The on-screen buttons were found 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 users return to the office, classroom, or lab, they can use an accompanying application on a desktop PC 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 CSV, 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 Microsoft Excel. DBF files are intended for database software but can also be loaded into spreadsheets and GIS software. The ESRI shapefile option allows the saved data to be imported directly into ESRI 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.
EXAMPLE APPLICATIONS

Only a few possible applications will be discussed here—users are encouraged to find new uses for the software and provide feedback via the authors’ website. These examples demonstrate the flexibility of the tool for use in education, research, or practice.

Application 1: Cumulative Passenger Vehicle Counts for Undergraduate Assignment

One primary purpose of ITS-Count is to provide students in transportation engineering courses with hands-on data collection experience. In this application, six students simultaneously recorded vehicle

![Figure 2](https://example.com/figure2.png)

**FIGURE 2** ITS-Count screen captures: (a) configuration screen and (b) event counting screen.

![Figure 3](https://example.com/figure3.png)

**FIGURE 3** Example data from ITS-GPS, viewed in Excel.
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. Students commented that the data collection tool “made the assignment more realistic” and “added greatly to the learning experience.”

A team of four students using the software as part of an intersection analysis for a transportation design course commented that the software allowed them to collect more data simultaneously than would otherwise have been possible. They felt that much of their learning occurred in the analysis of data and that using data that they collected themselves made the experience more valuable. They also mentioned that ITS-Count’s recording of individual vehicle arrival times as opposed to simple counts allowed them to readily collect more than 2 h of intersection count data from which they could identify saturation flow and other characteristics.

**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 the road are entirely lacking sidewalks. While students walked 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 ESRI shapefile and loaded into ArcGIS along with layers containing roads, adjacent lots, and transit stops as shown in Figure 5. 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 land use 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 considered for data collection included aerial photos or the use of a measuring wheel. Students commented that “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 in the Portland metropolitan area. The research used the FHWA traffic noise model for traffic noise prediction. One factor 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. Currently no data inventories are available for noise barrier locations for the study area. The research used the advantages of the ITS-GPS technology to collect both spatial and attribute data for the noise barriers in the study area. Figure 6 shows a sample of the data collected. Vehicle runs have been made in both directions on the studied highways using ITS-GPS to record the location and type...
of noise barriers present. Students commented that ITG-GPS “made the data collection process safer, more robust, and less labor-intensive” than other methods.

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 (2). ITS-GPS devices recorded location (latitude and longitude) at 3-s 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 with the travel times predicted by the license plate–reading cameras.

In an upcoming publication, Bertini and Tantiyanugulchai demonstrate how automatic vehicle location (AVL) data can be used to characterize the performance of an arterial (3). Bus dispatch system data of the Tri-County Metropolitan Transit District, the transit provider for Portland, Oregon, were 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 (nontransit) traffic on the same arterial on the same days. Ground truth refers to the data with which the transit data were compared. Test vehicle trajectories, shown in Figure 7, were compared with bus trajectories. Comparisons were drawn between the two methods, and some conclusions were formulated about the utility of the transit AVL data.

FIGURE 5 Presence or absence of sidewalks, Portland, Oregon.
FIGURE 6  Noise barrier inventory, Portland, Oregon.

FIGURE 7  Test vehicle trajectories (t = travel time).
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, as shown in Figure 8. The vehicle recording the data made six passes down the length of the road, and all six speed profiles were plotted together for comparison. DKS has also used ITS-GPS in similar ways in Berkeley, California, and for recording light rail transit vehicle speed profiles in Tacoma, Washington.

Additional Applications

As a possible means of attracting students to the field of transportation, the tool has not been strictly confined to transportation data collection efforts. On a recreational hike to the crater rim of Mount St. Helens National Volcanic Monument, one of our lab students carried the tool with him. On returning to the lab, he created the three-dimensional image in Figure 9 using the collected data, United States Geological Survey topographic maps, and ArcGIS 3D analyst. The plot shows 250-ft elevation changes in alternating black-and-white segments. 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 and is shown to high school students who regularly visit the ITS Lab as an interesting example of location-based data collection.

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, which make them ideal data collection devices. It should be noted that positional accuracy is a function of the hardware selected, and GPS accuracy is expected to continue to improve in the future. The dynamic nature of the open-source software will allow others to customize the interface for their specific data collection and to continue to build on our interface.

There is a high educational value in facilitating data collection experiences with the tool. In addition to the examples described here,
it is easy to envision other transportation concepts being reinforced by student use. The simplicity and portability of the tool encourage students to think of using the tool in other ways, such as the Mount St. Helens hike example. The devices have also been used 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 in other science class projects such as a wetland migratory bird study. Last, the flexibility of the tool was demonstrated by applications in research and professional practice. In closing, the authors 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.

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REFERENCES


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