Integrating GIS and GPS

Keith W. Cunningham, Ph.D.
Spatial Data Research, Inc.
14 East Eighth Street
Lawrence, KS 66044
800/238-1911

GPS has long been a tool for GIS data collection. Now users are finding that GPS is becoming a valuable tool for efficient GIS data use. Besides the benefit of GPS as a navigation aid, GPS is an important component of a GIS database maintenance system. This paper examines practical methods of GPS/GIS integration, specifically for GIS database maintenance, as well as trends in the industry.

Data Collection and Data Use

The Global Positioning System (GPS) is entering a new stage of maturity for geographic information system (GIS) applications. Historically, GPS has been embraced as a GIS data collection tool. Today, GPS is being bound directly to GIS applications for a variety of applications, but principally real-time GIS data use in the field and for database update.

Off-the-Shelf Data Collection Tools

Several components are tightly integrated to create the typical GIS data-collection tool. Controlling the total data collection system is the field computer, typically military-spec. Linked to the field computer are the GPS receiver, antenna, and external power supply. Software integration typically includes a user-definable hierarchical menu of prompts designed by the user to describe the feature located where a GPS point is being collected.

For data collection, these tools still remain some of the most efficient means of large-scale GIS data capture. The use of hierarchical menus with repeating data fields simplify data entry and reduce input error, and are much simpler to use in the field than other graphical user interfaces.

However, the integration of the typical data collection tool with GIS applications often remains an afterthought. The GIS export is usually the final step, in a several-step process. Even the most popular GIS data collection tool on the market places obstacles in the path of the professional data collector dealing with multiple GPS data files being collected each day for the same GIS application.

While some of these issues are not problems for the generic, occasional person collecting data, they become real problems for the professional who has large volumes of information to collect. Professional GPS data collectors are intimate with the needs of the GIS they are creating, and require custom tools to make their tasks easier.

The Transition to Data Use

Paper maps are the traditional method of taking GIS data into the field. The paper map is used for navigation and to manually indicate updates and corrections, a process sometimes called “red lining.” The field-marked corrections are then later added to the GIS. Today, GIS is becoming more tightly integrated with the GPS, allowing the user to make all updates and corrections directly from the field.

However, like the off-the-shelf data collection tools, these more-tightly integrated systems have focused on generic GIS data collection systems, and the preponderance of the interface remaining focused on the management of the GPS positions being collected, not the management of the GIS attributes. This is, a symptom of the GPS industry vendors developing a generic system that may not satisfy the very specialized needs of the “power” GIS user.

Examples of the failures to integrate GIS with GPS include poor ergonomics, high-equipment costs, dismal computer displays in sunlight, cumbersome systems

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integration, poor battery lives, and the slow performance of the GIS application in the field. But none of these are really the controllable fault of the GPS vendor; rather these technologies were simply premature for their intended purpose.

Early Integration Methods

Early software developers were limited to two methods of GPS integration with their field applications. The simplest integration method utilizes an ASCII interface, while more sophisticated solutions utilize a binary GPS interface. The ASCII interface is based on the NMEA-0183 protocols, which are ASCII sentences generated by the receiver and communicates with the host application via a serial data connection. The NMEA (National Marine Electronics Association) specification is in the public domain and is the standard for interfacing with most forms of navigation electronics.

Most GPS manufacturers have also created their own proprietary binary interfaces. The binary protocols specify how the GPS receiver's firmware controls the inputs and outputs of the GPS equipment. Besides being more compact, binary protocols allow each vendor to create custom applications for their GPS equipment, thus offering a richer set of features and messages not available from NMEA. Just as each vendor's binary protocols are specialized for each GPS receiver, each vendor may also have proprietary NMEA sentences to take advantage of their receiver's special qualities.

NMEA

A very common method of GPS/GIS integration has been the use of the NMEA-0183 protocol. This generic ASCII interface complements all of the other interfaces for navigation equipment such as ship rudder sensors, thermometers, and chart plotter drivers.

Examples of the NMEA 0183 interface include the ASCII sentences $GPGGA. The position sentence is formatted as follows:

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$GPGGA,hhmmss.ss,xxxx.xx,a,yyyy.yy,a,
x,xx,x.x,x.x,M,x.x,xxxx*hh<CR><LF>
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The message is defined with the sentence header (GGA), UTC (time), latitude, N/S, longitude, E/W, GPS fix quality (none-autonomous-differential), # satellites used, HDOP, antenna height, antenna height units, geoidal separation, differential age, differential reference ID. Other NMEA sentences are:

- GLL – Position fix (lat/long), fix time, and status.
- VTG – Track made good and speed over ground (for navigation).
- GSA – GPS DOP and active satellites.
- GSV – Satellites tracked and their status.
- ZDA – UTC day, month, year, and local time zone offset.

NMEA-0183 is the simplest method of GPS integration, but its simplicity is also a limitation. GPS receivers interfaced via NMEA cannot utilize all of the specialized functions of a GPS receiver, which may have been developed for very specific mapping applications. Also, the sentences can be "wordy" and if you only need a specific piece of information, there is data overhead to manage.

Another method of interfacing with GPS receivers is to develop in the native binary data format of the GPS receiver. The problem with this approach is each GPS vendor has its own protocol that may not be well documented or even published. Also, proprietary formats can change with new receiver firmware versions and popular GPS receivers may have had their software "rev'ed" several times.

Binary

An example of a GPS vendor having a proprietary protocol is Trimble. Their TSIP (Trimble Standard Information Protocol) is a set of binary messages used for two-way communication with their GPS receivers. The binary TSIP protocol is efficient and makes use of the special qualities of each receiver, with custom information packets and custom receiver controls being the norm. The Trimble TSIP manual is over 200 pages long, accounting for the different binary messages used by each GPS receiver. Thus the developer working with these proprietary messages has a considerable amount of work to utilize the binary messages.

Besides TSIP, Trimble also has GPS receivers that utilize different protocols. The Trimble GPS receivers used for vehicle tracking employ TAIP, Trimble ASCII Interface Protocol, which is efficient for radio network broadcasts. Trimble also utilizes another "flavor" of

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ASCII interface with its survey-grade receivers. Ironically, many Trimble receivers do not support the generic NMEA interface.

Working with any of these interface methods requires the developer to learn the protocols used, their programming requirements, and even their strengths and weaknesses. Also, these interfacing standards are likely to evolve and change with new GPS receivers and new GPS features.

Like Trimble, the other large GPS manufacturers also have their own binary interfaces. And like Trimble, each GPS receiver has its own specialized messages, thus there is not a general set of binary packets that will work with all GPS receivers, rather the binary packets that are for a specific receiver.

Technology Convergence for Data Use

Several technologies have converged over the past year to make the integration of GIS with GPS a reality. These converging technologies include hardware and software.

Among hardware improvements are the incessant increase of CPU power and field computing technology. Laptops have shrunk, have become more powerful, have longer battery lives and improved displays. Sub notebooks with Pentium class processors using Microsoft Windows 98 are now about two pounds. There has also been the burgeoning field computing market and in this realm are operating systems such as Windows CE and more vertically focused systems such as on the Palm Pilot and PSION's EPOCH. Besides the focus of these operating systems on field computing and better interfaces for field data input are the tremendous strides being made with improved power consumption.

Software development has also made several advances over the past years, the chief being the simplification of software development using ActiveX controls. ActiveX is the umbrella marketing term from Microsoft for software development components and standards.

Simplifying both methods of integration are new software development tools allowing programmers to simplify their integration. These software development kits (SDKs) are typically based on ActiveX controls. ActiveX is a standard for software development that includes "embeddable controls" and "automation objects" supplied by the GPS manufacturer to simplify software development. However, ActiveX technology only simplifies the development of new, custom applications. Different vendors of ActiveX technology for GIS/GPS integration may have dramatically different levels of functionality and support.

ActiveX

A recent trend in software development has been the use of customizable software components to speed software development with "embeddable objects" and "automation controls." Many GIS vendors are even basing their future versions of AM/FM/GIS software on these basic programming functions. Intergraph's GeoMedia and ESRI's MapObjects are examples.

Software developers can use these software controls to create custom applications with their own look and feel, but without having to do a lot of complex coding. The details of the programming controls are left to the developer of the ActiveX controls, who creates the critical components that can be assembled later by other software developers who do not necessarily have to understand all of the details. Thus, less experienced and knowledgeable programmers can build custom applications by simply binding the controls they need to their custom application.

A few GPS manufacturers have begun developing ActiveX controls to simplify the integration of their GPS hardware with the special needs of the user. Leica bundles an ActiveX control with each of their high-end receiver sales. Trimble has a set of controls that operate with their Mapping and GIS GPS receivers.

These controls offer many advantages over traditional programming interfaces such as NMEA and binary protocols. The professional GPS developer will note that these controls provide robust interfacing with the host GPS receiver allowing the configuration of several settings and the formatting of data outputs.

For example, NMEA does not provide interfacing standards for important GPS features such as GPS receiver settings to optimize the use of GPS to balance accuracy with productivity, including elevation masks, controls for RTCM inputs from beacons and satellites, and bi-directional communication with the receiver.

More significantly, one GPS ActiveX control even allows the user to generate and save GPS data for later

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post-processing, which is a significant savings in software development that would be impossible to accomplish with NMEA and difficult at best with the proper binary sentences.

Improved GPS/GIS Integration

The data use paradigm requires a very different type of GPS and GIS integration. Unlike the data collection tool, where an emphasis is placed on a generic, off-the-shelf solution, the data use tool must place a focus on the efficient use of the GIS data components carried to the field. Also, the level of GPS integration required can be highly variable with each application.

Several components are required to create a proper GIS/GPS data use tool. The first is an understanding of what the user intends to do with the system. This approach is contrary to the off-the-shelf approach used by most GPS vendors. After defining the needs of the user, then the proper GPS receiver, field computer, and databases structures can be defined. Binding all of these discrete components together is the software created especially for the user's application.

Receiver Controls

The primary software component is the controller for the GPS receiver. This control manages the GPS receiver's settings, so they can be optimized for how GPS positions are to be collected shared with the GIS application. Some users require setting for optimal GPS *accuracy* while other users are more likely to require that the GPS receiver set to maximize their *productivity*. This control should also monitor the status of the GPS constellation and set special filters and masks to exclude noisy and suspect GPS data, including satellite elevation masks, signal-to-noise ratios, and dilutions of precision (DOP) – especially Positional DOP.

Since most GIS/GPS applications require real-time differential corrections, the GPS receiver control should also manage real-time correction sources to achieve submeter accuracies. Today, differential corrections are more commonly broadcast by navigation beacons (US Coast Guard), and third-party satellite correction services. Often these corrections are collected by an external radio or satellite telemetry link and the correction data are fed to the PC via an external serial port. Some of today's more highly integrated GPS receivers have a real-time antenna and receiver integrated directly with the GPS antenna and receiver. This receiver control must manage the application of these correction signals to the GPS receiver, including factors such as signal frequency and data age limits.

Coordinate/Units Controls

As GPS operates in spherical world coordinates, and most GIS data are in local planar projections, the GPS coordinates must be transformed. In Missouri, this means that the latitude, longitude and altitude produced by the GPS receiver must be converted into the Missouri State Plane Coordinate System, with heights measured above mean sea level (or above the ellipsoid) and units in feet. Ideally this task is managed by another control, which the user can manipulate so they can view their coordinates in lat/long or in Universal Transverse Mercator, too.

GIS Controls

To bind the output of the GPS locations to the GIS requires another set of controls. These controls will both update the map with the current location (an "event" in programming terminology) and save the GPS information to a GIS file. Depending on the GIS application being used in the field, the GPS data may have to be buffered before it is written to the GIS database, to improve GIS data processing efficiencies. This control would also determine what GPS data are written to the GIS file, such as DOP, GPS date, GPS time, differential correction status, etc. The same control would also manage how GPS data are displayed in the GIS.

The Wrapper

All of these controls and the linkages to other programs, such as the GIS and database, need to be managed by a "wrapper" of software developed by the programmer. This wrapper is typically created with "visual" programming tools such as Visual Basic or Visual C. The wrapper also provides the interface presented to the end users, such as buttons, dialogs, and data displays. This portion of the GIS/GPS data use interface is critical to the success of the user, as a friendly and intuitive interface and makes a user dramatically more productive than a poorly designed interface.

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Conclusions

The GIS/GPS market will continue to diverge over applications requiring "Data Collection" while most future applications will emphasize "Data Use." Data Collection will continue to focus on efficient GIS data capture, while Data Use will emphasize returning GIS data to the field for daily business operations and data maintenance.

At SDR, ActiveX technology is used for much custom GPS integration and SDR has even created its own set of embeddable controls to speed software development. To date, we have integrated GPS systems directly with several GIS applications, including GeoMedia, Active FRAMME, ArcView, MapInfo, as well as Windows CE not to mention OLE/COM applications such as Microsoft Access and Excel.

Applications for these systems have ranged from utility facilities mapping, field network analysis of power distribution systems, road centerline mapping, E9-1-1 addressing, appraisal video imaging, and cable TV "strand" mapping. Significantly, each of these applications have required very different integration requirements that could not be satisfied with any single, off-the-shelf application or technology.

About the Author

Keith Cunningham has worked with Trimble Navigation, Sokkia Technology, and Leica on improving their understanding of the GIS/GPS market place and product requirements since 1993. His Ph.D., from the University of Kansas, is in the application of neural networks for image processing and GIS database construction.

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