33

Using GPS for GIS data capture

A F LANGE AND C GILBERT

Depending on the particular equipment utilised and the techniques used, Global Positioning Systems (GPS) are capable of recording position to a high level of accuracy. Differential GPS is required to obtain the accuracy required by many GIS data capture applications. Differential GPS requires the use of a base station at a known location to remove systematic errors from the GPS signal. Modern GPS/GIS data collection devices have the capability to collect a wide range of GIS attribute data in addition to position of the feature of interest; attributes include point, line, and area features. Since GPS can be used in many diverse GIS data capture applications (including applications as diverse as road centreline mapping, utility pole mapping, and wetland boundary mapping), it is important to understand the limitations of GPS in order to derive full benefits from the technology.

1 FUNDAMENTALS OF GPS

The explosion in interest in GIS as a management tool has been accompanied by the development of a number of enabling technologies, one of the more important of which is the Global Positioning System (GPS). While GIS technology offers tremendous capabilities for more informed management decision-making, rendering competent decisions still depends on having reliable data. In order to realise the benefits of GPS, and not to mis-apply the technology, it is important to understand its limitations. This chapter describes how GPS works and how to obtain reliable data using it. Accuracy (in the surveying sense) of GPS data is an important consideration. The first part of this chapter covers how the GPS accuracy is obtained and the second part discusses how to use GPS for GIS data capture. The term 'GPS' is used interchangeably here to refer to satellite-based navigation systems in general and the ground-based geographical data collection instruments in particular.

1.1 Overview of GPS

The Navigation Satellite Timing And Ranging Global Positioning System, or NAVSTAR GPS, is a satellite-based radio-navigation system that is capable of providing extremely accurate worldwide, 24-hour, 3-dimensional (latitude, longitude, and elevation) location data (Wells 1987). It is one of two such satellite systems, although its Russian counterpart, GLONASS, will not be discussed here. The system was designed and is maintained by the US Department of Defense (DoD) as an accurate, all-weather navigation system. Though designed as a military system, it is available with certain restrictions to civilians. The system has reached its full operational capability, with a complete set of at least 24 satellites orbiting the Earth in a carefully designed pattern.

1.1.1 The fundamental components of GPS

The NAVSTAR GPS has three basic segments: space, control, and user. The space segment consists of the orbiting satellites making up the constellation. This constellation is comprised of 24 satellites, each orbiting at an altitude of approximately 20 000 kilometres, in one of six orbital planes inclined 55 degrees relative to the Earth's equator. Each satellite broadcasts a unique coded signal, known as pseudo random noise (PRN) code, that enables GPS receivers to identify the satellites from which the signals are coming (Hurn 1989). The satellites broadcast the PRN codes as modulation on two carrier frequencies, L1 and L2. The L1 frequency is 1575.5 MHz and the L2 frequency is 1227.6 MHz.

With 24 satellites in the constellation, and the design of the orbits and the spacing of the satellites in the orbital planes, most users will have six or more satellites available at all times. There are a number of different programs used to plot the satellite availability for any geographical location. The universal reference locator (URL) for a World Wide Web (WWW) site with a GPS satellite visibility program on-line is *http://www.trimble.com/satviz*.

The control segment, under the United States Department of Defense's direction, oversees the building, launching, orbital positioning, and monitoring of the system. It provides two classes of GPS service: Standard Positioning Service (SPS) and Precise Positioning Service (PPS). Monitoring and ground control stations, located around the globe near the equator, constantly monitor the performance of each satellite and the constellation as a whole. A master control station updates the information component of the GPS signal with satellite ephemeris data and other messages to the users. This information is then decoded by the receiver and used in the positioning process. Of the two classes of service, the PPS is only available to authorised government users while the SPS is available for civilian use.

The user segment is comprised of all of the users making observations with GPS receivers. The civilian GPS user community has increased dramatically in recent years, because of the emergence of low-cost portable GPS receivers (Figure 1 and Plate 23) and the ever-expanding areas of applications in which GPS has been found to be useful. Such applications include surveying, mapping, agriculture, navigation, and vehicle tracking (Figure 2; Plate 24). The civilian users of GPS greatly outnumber the military users.

Fig 1. A hand-held 12-channel GPS receiver.

Fig 2. Off-road navigation using GPS.

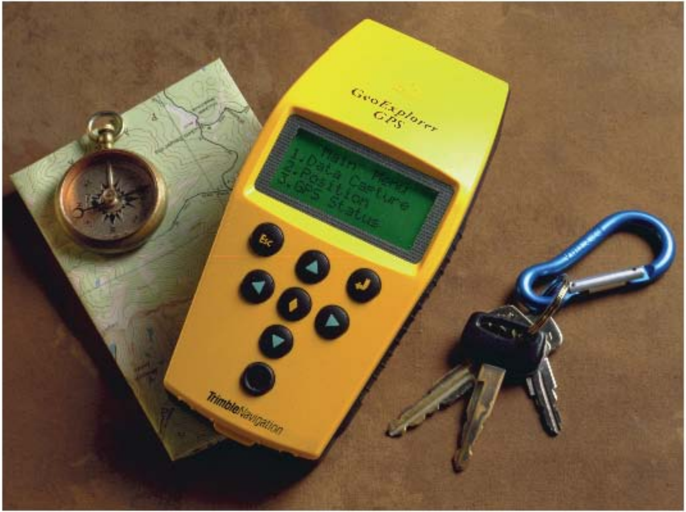

Plate 23
A hand-held 12-channel GPS receiver.

Plate 24
In-vehicle use of GPS.

1.1.2 The limitations of GPS

Although in theory GPS can provide worldwide, 3-dimensional positions, 24 hours a day, in any type of weather, the system does have some limitations. First, there must be a (relatively) clear 'line of sight' between the receiver's antenna and several orbiting satellites. Anything shielding the antenna from a satellite can potentially weaken the satellite's signal to such a degree that it becomes too difficult to make reliable positioning. As a rule of thumb, an obstruction that can block sunlight can effectively block GPS signals. Buildings, trees, overpasses, and other obstructions that block the line of sight between the satellite and the observer (GPS antenna) all make it impossible to work with GPS. Urban areas are especially affected by these types of difficulties. Bouncing of the signal off nearby objects or the ground may create another problem called *multi-path interference*. Multi-path interference is caused by the inability of the receiver to distinguish between the signal coming directly from the satellite and the 'echo' signal that reaches the receiver indirectly. In areas that possess these type of characteristics, as in the urban core of a large city, inertial navigation techniques must be used to complement GPS positioning.

The receiver must receive signals from at least four satellites in order to be able to make reliable position measurements. In addition, this number of satellites must be in a favourable geometrical arrangement, relatively spread out. In areas with an open view of the sky, this will almost always be the case because of the way the satellite orbits were designed. The dilution of precision, or DOP, is a measure of the geometry of the GPS satellites. When the satellites are spaced well apart in the sky, the GPS position data will be more accurate than when the satellites are all in a straight line or grouped closely together.

An additional limitation of GPS is the DoD policy of selective availability (SA). This policy limits the full autonomous accuracy only to official government users. This policy, and methods used to ameliorate its effects, are described in section 1.1.6. A Presidential Directive of May 1996 has declared that the policy of SA will likely be discontinued within a period of more than four years and less than ten years. However, even if SA is eliminated, GPS will not be accurate enough for many mapping and GIS data capture applications.

1.1.3 How a GPS receiver calculates position

The position of a point is determined by measuring the distance from the GPS antenna to three satellites for a 2-dimensional reading (latitude and longitude), and at least four satellites for a 3-dimensional position (latitude, longitude, and altitude). The GPS receiver 'knows' where each of the satellites is at the instant in which the distance was measured. These distances will intersect at only one point, the position of the GPS antenna. How does the receiver 'know' the position of the satellites? Well, this information comes from the broadcast orbit data that are received when the GPS receiver is turned on. The GPS receiver performs the necessary mathematical calculations, then displays and/or stores the position, along with any other descriptive information entered by the operator from the keyboard.

The way in which a GPS receiver determines distances to the satellites depends on the type of GPS receiver. There are two broad classes: *code* based and *carrier phase* based.

1.1.4 Code-based receivers

Although less accurate than their carrier phase counterparts, code-based receivers have gained widespread appeal for applications such as GIS data capture. Their popularity stems mainly from their relatively low cost, portability, and ease of use.

Code-based receivers use the speed of light and the time interval that it takes for a signal to travel from the satellite to the receiver to compute the distance to the satellites. The time interval is determined by comparing the time in which a specific part of the coded signal left the satellite with the time it arrived at the antenna. The time interval is translated to a distance by multiplying the interval by the speed of light. Position fixes are made by the receiver roughly every second, and the GPS receivers designed for use in GIS data capture applications enable the user to store the positions in a file that can be downloaded to a computer for post-processing or analysis.

Under normal circumstances, autonomous position fixes made by code-based receivers would be accurate to within 25 metres. This is the specified accuracy for the SPS. The DoD, however, began imposing its selective availability policy in July 1992, and this limits position fix accuracy to within 100 metres. The purpose of selective availability is to deny potential hostile forces accurate positioning capabilities. Military P(Y)-code receivers are not affected by SA, and are not available to the general public. In order to ameliorate these limits in positioning accuracy, differential GPS (DGPS) techniques have been developed. DGPS enables the user to improve on the SPS, and to remove the effects of SA and some other sources of error. These differential correction techniques can produce positions generally accurate to within a few metres. If and when SA is eliminated the accuracy of GPS will be more accurate than SPS specifications, to about 10 to 15 metres. This is not good enough for most GIS data capture applications and differential GPS will still be required.

There are also now code-based receivers capable of sub-metre differential accuracy. Some sub-metre receivers require longer data collection times (up to 10 minutes). They perform best under very favourable satellite geometry, and with an unobstructed view of the sky. Some newer receivers can provide a sub-metre accurate position each second. These receivers cost more at the outset, but provide a good return on the added investment by facilitating substantially higher productivity.

It is very important that users of code-based receivers understand the positional accuracy limitations of the receiver. Because of SA, each coordinate viewed on a non-differential GPS receiver's display is only accurate to within 100 metres. This accuracy may be improved on by taking an average of 200 or so repeated position observations of the same point. The resulting accuracy would nevertheless still be below what many users would consider acceptable quality. In order to produce acceptable results, GPS data collected in the field *must* be differentially corrected either in real-time, or by post-processing of the data.

1.1.5 Carrier phase receivers

Carrier phase receivers, used extensively in geodetic control and precise survey applications, are capable of sub-centimetre differential accuracy. These receivers calculate distances to visible satellites by determining the number of whole wavelengths and the partial wavelength. Once the number of wavelengths is known, the range may be calculated by multiplying by the wavelength of the carrier signal. It is then a straightforward (but cumbersome) task to compute a baseline distance and azimuth between any pair of receivers operating simultaneously. With one receiver placed on a point with precisely known latitude, longitude, and elevation, the calculated baseline can be used to determine the coordinates of the other point (Leick 1990).

The relative cost of the carrier phase receivers is high, but technological advances have made the dual frequency (using both L1 and L2) carrier phase receivers much more efficient than the single frequency (using L1 only) receivers that were state-of-the-art only a few years ago. Dual frequency receivers allow for correction of ionosphere delays, and are therefore inherently more accurate at longer baseline lengths over 50 km. With some of the most recent dual frequency receivers very precise measurements (± 1 cm) can be made in real-time. These receivers are used in machine control applications requiring a high degree of accuracy.

1.1.6 DGPS

Differential GPS can be employed to eliminate the error introduced by SA and other systematic errors. DGPS requires the existence of a base station, which is a GPS receiver collecting measurements at a known latitude, longitude, and elevation (Hurn 1993). The base station's antenna location must be known precisely. The base station may store measurements (for post-processed DGPS) or broadcast corrections over a radio frequency (for real-time DGPS), or both.

The assumption made with the base station concept is that errors affecting the measurements of a particular GPS receiver will equally affect other GPS receivers within a radius of several hundred kilometres. If the differences between the base station's known location and the base station's locations as calculated by GPS can be determined, those differences can be applied to data collected simultaneously by receivers in the field (Figure 3). These differences can be applied in real-time (especially applicable for accurate navigation) if the GPS receiver is linked to a radio receiver designed to receive the broadcast corrections. In some GIS mapping applications, these differences are applied in a post-processing step after the collected field data has been downloaded to a computer running a GPS processing software package. GPS processing software is typically integrated with GPS hardware and thus is provided by the receiver manufacturer. As a rule, post-processed DGPS is considered slightly more accurate than real-time DGPS.

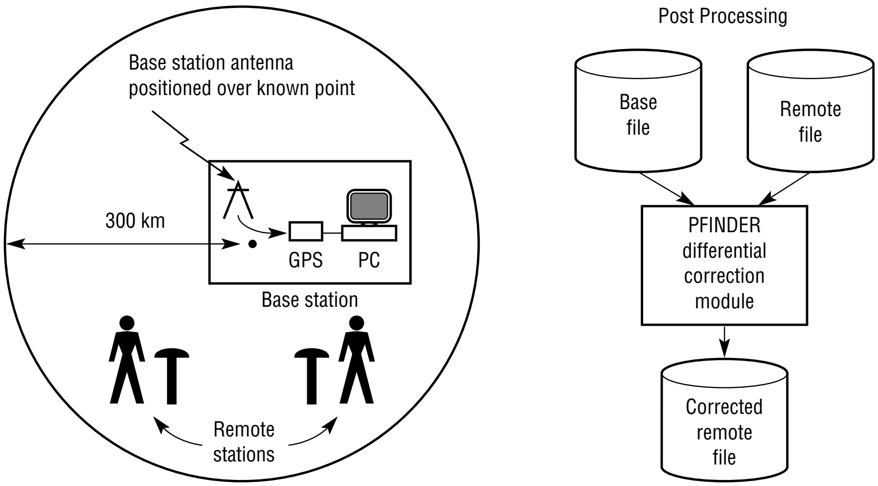

Fig 3. Use of base stations for precise global positioning.

1.1.7 Base stations – the source for reference data for DGPS

There are many permanent GPS base stations currently up and running in the USA that can provide the data necessary for post-processing differentially correcting positions to the users of code-based receivers over an electronic bulletin board.

In many parts of the world a real-time DGPS beacon system is operational. These stations are part of a large network of coastal and river valley stations. These beacons broadcast in the frequency range of 285 to 325 kHz. The range of many of these stations is 300 to 500 kilometres. These stations can provide differential accuracy in the 1-metre range, depending on distance from the station and the quality of the roving receiver.

Carrier phase base differential processing, for centimetre accuracy, does not have the range of code-based differential GPS. To obtain centimetre accuracy, it is now necessary to have the carrier base station within approximately 10 kilometres for real-time carrier differential (sometimes called real-time kinematic) operation. Extending the range of carrier differential beyond 10 kilometres is an active GPS research topic.

1.2 GIS data capture considerations

Several key issues need to be explored when considering whether GPS is an appropriate tool for capturing coordinate data for a GIS database. First and foremost is the need to determine the position accuracy requirements. If the data will be used for site-specific analysis that requires position accuracy to be within a metre, high-quality code-based differential GPS receivers will be necessary. If still higher accuracy is required, of the order of 10 centimetres or better – as for property boundary mapping – then carrier phase differential GPS techniques will be required.

Every GIS database must be referenced to a base map or base data layer, and the reference datum of the various data layers must be the same. Ideally, the database should be referenced to a very accurate base map. If, however, the base map is 1:125 000 or smaller, there could be problems when attempting to view the true spatial relationships between features digitised from such a map and features whose coordinates were captured with GPS. This can be a real problem if the GIS analyst decides to use a particular GIS data layer that was originally generated using small-scale base maps as a base to which all new generated data are referenced (see Weibel and Dutton, Chapter 10). The best way to avoid such incompatibility is to develop an accurate base data layer, based on geodetic control and photogrammetric mapping.

Map datum

Understanding the concept of a map datum is important if useful results are to be obtained from any GPS mapping exercise. A datum is a mathematical model of the Earth over some area. GPS, being a worldwide system, has a datum applicable over the whole earth. This is called the

World Geodetic System, 1984 (WGS-84). There are many local datums like European Datum 1950 (ED-50), North America Datum 1927 (NAD-27), and North America Datum 1983 (NAD-83) that have been used to make local maps. A particular point on the surface of the Earth will have different latitude and longitude coordinates depending on the reference datum. For GIS applications, it is recommended that all data be collected and displayed in the most up-to-date datum available. In the US this datum is NAD-83. Fortunately for users in most areas of the world, region-specific datums are quite similar to the GPS natural datum, WGS-84. It is important to use the same datum for all data layers if the data are going to be overlaid in a GIS.

2 USING GPS WITH GIS

There is a range of ways in which GPS is used alongside GIS. First, GPS may be used to identify or refine the geographical coordinates associated with satellite imagery. GPS is used to reduce distortions and to improve the positional accuracy of these images. When three or more distinctive points (the more the better) can be located both on a satellite image and on the ground, GPS receivers can be used to collect accurate geographical coordinates at these locations. The rest of the image can then be adjusted so that it provides a better match to the real-world coordinates. Second, GPS can be used in the ground truthing of satellite images. When a particular satellite image has a region of unusual or unrecognised reflectivity or backscatter, the coordinates of that region can be loaded into a GPS receiver. The GPS receiver will then enable the user to navigate directly to the area of interest so that the nature of the vegetation or the Earth's surface can be examined. With real-time differential GPS, users can even navigate directly to an individual 1m pixel. Third, GPS has developed into a cost effective tool for updating GIS or computer-aided design (CAD) systems. Using GPS to collect data is analogous to digitising a map by moving a mouse or digitising puck over a map. The users of GPS equipment simply move along the surface of the Earth and the geographical coordinates of where they went are computed and stored as a continuous series.

However, GPS technology is better suited to some data collection applications than others. For example, GPS is not particularly well suited to recording the corner stones of skyscrapers because the building itself blocks a large percentage of the sky, and hence the GPS signal. Traditional survey techniques would probably be more efficient. GPS is not necessarily the most efficient tool for evaluating subtle gradational changes in vegetation across a large region. Satellite imagery might be better suited to this task. However, GPS is an excellent tool for data collection in many environments where the user can generally see the sky and is able to get close to the objects to be mapped.

2.1 How is GPS used for GIS attribute collection?

The typical GPS-based data capture tool is a GPS receiver combined with a hand-held computer. These two components may be connected by a cable, or they may be combined as a single, integrated, hand-held unit. The hand-held computer is used for attribute entry and display of data to the user. There are several variations on this theme, including the use of pen computers, laptop computers, and small, hand-held units. The design goal is that the user can focus on observing and entering attribute data, since the position data 'just happens' automatically. Figure 4 illustrates how a bar-coded system may be used to record the locations of utility conduits.

Mapping roads is an important application. By driving the road once, users can record the location of the centreline and both kerbs by noting the offset between the line traversed by their GPS antenna and the linear feature of interest, such as a kerb (see Worboys, Chapter 59). Additionally, they can record a number of attributes such as name, width, condition, materials. The amount of attribute data that can be collected is limited only by how fast the operator (or accompanying colleague) can enter them while driving past. The concepts employed in road mapping can be extended to any type of linear or polygonal feature, such as shorelines, paths, forest fire boundaries, land usage zones, vegetation boundaries, powerlines, and utility right-of-ways: see Plate 24. Presently there are many consulting firms that use GPS to record the attributes and location of thousands of kilometres of road every month.

Recording the location and attributes of point-like features is another very popular application of GPS. To record a point-like feature with GPS, the user will typically walk or drive up to the object to be mapped (such as a pole, storm drain, or soil sample site) and then place the GPS antenna on that location of interest. While the user is busy for a few moments

Fig 4. Use of GPS in utilities mapping.

observing and entering attribute data, the GPS receiver is automatically recording position data.

Unlike the hand digitising of a paper map, there is no 'scale' directly associated with this form of 'GPS digitising'. If the user is doing detailed, high accuracy work, it might make sense to record a storm drain as a small polygon (remember the best GPS receivers are accurate to better than 1-centimetre). On the other hand, if the data will be used to populate a crude map, the user might choose to define an entire airport as a point feature. Users are free to define their features as required to best fit their application. GPS is readily used to record the attributes and location of street furniture (such as lamp posts, telephone poles, storm drains, drainage aperture covers, valves, etc.). It is not uncommon that some users see their productivity increase from a typical 100 to 200 points/day before GPS to over 1000 points per day after GPS. The increased productivity allowed by GPS can be stunning.

The use of GPS can be extended to mapping objects which are difficult or dangerous to occupy. By combining the use of a hand-held laser rangefinder with a GPS, users are able to record the location of an object even if they cannot physically occupy that location: see Plate 25. The user can remain in a location that is either convenient or more conducive to good GPS signals, then measure the distance and direction (an offset) to the object of interest with a laser rangefinder. In some GPS, the laser can be connected electronically so that the laser measurements are transmitted directly to the GPS data collection system; alternatively, the user could enter the offset information by hand. The location of the GPS antenna and the offset measured by the laser are automatically combined to compute an accurate location for the object of interest.

There are many other types of electronic sensing devices that can be used in conjunction with a GPS receiver. Typically when sensor data are coupled with GPS positions, the user has the intention of later presenting these data in the form of a thematic map. The contours of these maps may represent information as diverse as radiation levels (isorad maps: Runyon et al 1994), temperature (isotherm maps), water depth (bathometry: Chisholm and Lenthall 1991), signal strength for cellular telephones, or even biological density.

Some features of modern GPS data collection systems make them extremely effective tools for attribute collection. One common (and quite effective) way that GPS users prepare for data collection is to predefine a customised list of the features and attributes that are to be collected in the field. This list is then transferred into the GPS data collection system so that, in the field, the user will be prompted by the GPS for the appropriate attributes at each location. For example, if the user approaches a telephone pole in the field, the first step is to select the item 'telephone pole' from the screen of the GPS. After having selected the feature name, the GPS would then automatically prompt the user for

Plate 25
Use of a hand-held GPS receiver.

whichever attribute details are appropriate to telephone poles. These attributes (such as material, condition, identification number, etc.) are taken from a list that was created by the user, are displayed at the appropriate time and in the appropriate sequence, and match the structure of the target database.

When attribute data are collected, they should always be stored in the appropriate form. Alphanumeric and numeric data are stored in the appropriate field types, and numeric values are validated so that they are within predefined maximum and minimum values. Character strings are automatically checked so that they do not exceed the maximum allowable field length of the target database. Whenever appropriate, precise date and time attributes are generated by the GPS, and manually entered date and time values are checked so that they fall within valid ranges. When the attribute is an image, perhaps from an attached digital camera, the data collector is able to store the filename of the image as an attribute value. The attribute values that are collected may be edited at any time after they have been collected – either in the field or during subsequent processing. Collectively, features like the ones described above will greatly reduce field data collection errors.

GPS also feature pause and resume functions which, although apparently simple, are nevertheless invaluable in the field (Gilbert 1994a). Imagine what the path you digitised would look like if you could not momentarily pause the data collection when your hat blew off! When recording roads, many users find that they wish to interrupt data collection every time they stop at a traffic signal or a gate. A problem occurs when a GPS receiver is stationary and continues to record positions once per second, since the resulting road features contain periodic, puzzling clumps of tangled vertices in the roadway.

The ability to repeat previous attribute values is another function which is very simple, yet is often crucial to efficient data collection. After entering 200 attributes for the previous utility pole you will surely appreciate the ability to press one button and have most or all of your attributes transferred to the next pole. The repeat function can also be very useful when recording linear features that contain dynamically changing attribute values. For example, on approaching the end of a block of buildings, a user may wish to end one segment of the road and immediately begin another segment that shares a common node. A well-designed GPS data collector will allow the user to terminate the first segment and initiate the second while retaining most, or all, of the same attribute values for both nodes – with as little as one keystroke.

Many GPS receivers are unable to collect accurate coordinates effectively while they are moving. This is not a limitation of the satellite GPS themselves, as the best GPS receivers can provide centimetre level results while moving at high speeds. This limitation is simply a by-product of some of the receiver designs and software products on the market. It is sometimes desirable to record point features while moving. One very powerful data collection function allows users to store point features accurately while driving or flying over the point of interest. If it is not possible to travel directly over the point of interest, some GPS will even allow the user to define an offset distance from the GPS antenna to the object of interest. Typically, the direction of the offset is defined as being either to the left or the right, and orthogonal to the direction of travel. Depending on the variability of the attribute data, such a data collection system can allow a skilled user to record thousands of point features per day. It is important to recognise, however, that such rapid recording is often less accurate than even a one second static occupation – most commonly because of user errors in pressing the button at the precise moment the feature is being passed.

2.2 Exporting GPS data to a GIS, CAD system, or database

The final stage of the process of GPS-based data collection for GIS is to transfer the data from the field device to the target database. In the interests of preserving valuable memory, most GPS store data internally in their own proprietary formats. This data transfer is most often accomplished by running a translation program that will convert the data from the compact internal storage format to the database interchange format of the user's choice.

At the most basic level, this task can be accomplished in a very simplistic manner – that is, simply dumping the coordinates and attributes in a comma delimited file. However, most users prefer to employ a translation program that will allow them to modify slightly the output data, so that it matches the characteristics of the target database as closely as possible (Gilbert 1994b). Some of the more important considerations of a translation program are as follows.

2.2.1 Creation of metadata

A useful feature of a data translation program is the ability to generate metadata (Guptill, Chapter 49; Goodchild and Longley, Chapter 40). The resulting output file(s) will contain not only the attribute values that were entered in the field by the user, but also a variety of additional attribute data that are generated by the translation program (Gilbert 1996). Some of these generated attributes are common to the entire dataset, such as the receiver type used to collect the data or the name of the original data file. However, the most useful of the generated attributes are specific to the individual features. Several examples of GPS metadata are described in the following paragraphs.

Quality information about the accuracy of the GPS coordinates is very valuable (see Fisher, Chapter 13). This may take the form of a single quantitative accuracy estimate, or it may be presented as a variety of accuracy indicators that can be used individually or together to infer data quality (Veregin, Chapter 12). Although a single accuracy estimate is simple to use, it may be less reliable. The user must develop an understanding of whether any particular manufacturer's algorithm is reliable enough. Additionally, the user often has no way to tell how the GPS accuracy value was computed and whether it represents a probability of 99 per cent, 95 per cent, 68 per cent, or even as little as 50 per cent. There is also the uncertainty as to whether the reported value refers to horizontal accuracy or 3-dimensional accuracy. It is not uncommon for the horizontal and vertical accuracy of a GPS coordinate to differ by a factor of two. There is no industry standard on to how the GPS report spatial accuracy (see Smith and Rhind, Chapter 47, for a discussion of industry spatial data standards).

Alternatively, the translation software may report a variety of accuracy indicators that can be used individually or together to infer data quality. Such indicators may include occupation time, number of satellites used, maximum dilution of precision, quantity of GPS data collected, or the type of differential processing that was performed, if any. Although this is more complex, it does provide the user with greater understanding and flexibility. When these indicators are available individually as metadata, the users are free to establish whatever data quality rules they desire for their applications. Some agencies will define multiple quality assurance guidelines that vary depending upon the intended use of the data. Storing multiple accuracy indicators has the added benefit that they can be used to verify that the field operator adhered to the appropriate data collection procedures.

2.2.2 Creation of macro files

The transformation of GPS data to an appropriate format can be greatly enhanced by the automatic creation of macro or batch files. While the data are being translated to the desired format, some translation programs will read and compute the information required to create a set of command scripts. These scripts are unique to the translated data and are used to complete the import process quickly and easily. They can automatically create new layers and tables (or append existing ones), automatically associate attribute values with the coordinates, or even create additional data such as labels positioned at the centroid of a polygon feature.

2.2.3 Geodetic datum transformation

As stated in section 1.2, the native geodetic datum of GPS data is WGS-84. Programs that translate GPS data into GIS or CAD compatible formats are usually able to transform the coordinates to the projection, coordinate system, and datum of the user's choice. Most of these translation utilities include a long list of datums and coordinate systems. The more sophisticated programs will also allow the user to create a customised coordinate system.

2.2.4 Configurable ASCII data translation

There are many GIS and CAD compatible import formats. Despite the abundance of formats, GPS manufacturers have discovered that some of the GIS community utilise home-grown, customised import formats. Therefore, even a translation program that supports the dozen most popular formats will seem incomplete to some users. The mainstream GPS data collection systems are all equipped with powerful and flexible configurable ASCII export programs. Such programs give users the ability to translate their GPS data into customised formats that the GPS manufacturers could never have anticipated.

SUMMARY

Depending on the particular equipment utilised and the techniques used, GPS is capable of a wide range of accuracy, from tens of metres to centimetres. Differential GPS techniques are required to obtain the accuracy required by many GIS data capture applications. Differential GPS requires the use of a base station at a known location to remove systematic errors from the GPS signal. Modern GPS/GIS data collection devices have the capability to collect a wide range of GIS attribute data in addition to the position of the feature of interest, including point, line, and area features. GPS can be used in many GIS data capture applications, including applications as diverse as road centreline mapping, utility pole mapping, and wetland boundary mapping. It is nevertheless important to understand the limitations of GPS to derive full benefits from the technology.

References

Chisholm G, Lenthall P 1991 Combining GPS and echo sounders to monitor river siltation. *GISWorld* 5(2): 46–8

Gilbert C 1994a Attribute collection with GPS part 1: Variety is the spice of attributes. *Mapping Awareness* 8(9): 28–30

Gilbert C 1994b Attribute collection with GPS part 2: Assessing ease of use in the field. *Mapping Awareness* 8(10): 30–2

Gilbert C 1996 The software with your GPS Part 1 – data export. *Mapping Awareness* 10(8): 32–4

Hurn J 1989 *GPS: A guide to the next utility*. Sunnyvale, Trimble Navigation Ltd

Hurn J 1993 *Differential GPS explained*. Sunnyvale, Trimble Navigation Ltd

Leick A 1990 *GPS satellite surveying*. New York, John Wiley & Sons Inc.

Runyon T, Hammitt R, Lindquist R 1994 Buried danger: integrating GIS and GPS to identify radiologically contaminated sites. *Geo Info Systems* 8(4):28–36

Wells D 1987 *Guide to GPS positioning*. Fredericton, Canadian GPS Associates