RAPID ACCURATE GIS UPDATES WITH IMPROVED LINKS TO SURVEY SYSTEMS

Martin Nix and Dr. Craig Hill
Leica Geosystems AG
Heinrich-Wild-Strasse, Heerbrugg, 9435
SWITZERLAND

Email: martin.nix@leica-lsg.com
Craig.hill@leica-geosystems.com

5th Global Spatial Data Infrastructure Conference

23 May 2001
Cartegena, Columbia

BIOGRAPHIES

Martin Nix is the Chief Business Development Officer of Leica Geosystems and is responsible for strategic planning, technology management and communications. He has had many international management positions with Leica Geosystems, most recently as President of the Americas sales region located in Atlanta, USA where he led the North & South American sales, marketing, service, finance and logistics groups for 3 years. For the previous 5 years he had various marketing and product management positions in Switzerland. He was Leica's Survey Division Manager in Australia from 1987 to 1992, having held product management positions in software and GPS. After receiving his Bachelor Degree in Surveying from the University of New South Wales, he surveyed in private practice in Sydney receiving his License in 1982. He received a Masters degree of Surveying Science (GIS) in 1990.

Craig D. Hill, Ph.D., M.App.Sc., B.App.Sc., MIS Aust., is currently working for Leica Geosystems AG in Heerbrugg Switzerland. Prior to recommencing employment at Leica, Craig completed a Ph.D. at RMIT University with a research focus on developing field procedures and data processing methods for a combined surveying system using satellite positioning and terrestrial surveying technologies. Craigs current tasks involve designing field and office software solutions for surveyors.

RAPID ACCURATE GIS UPDATES WITH IMPROVED LINKS TO SURVEY SYSTEMS

ABSTRACT

Continuous improvement to surveying technology supports improved decisions being derived from GIS data. Recent advances in field surveying systems technology and software and data processing show that more accurate GIS data can be gathered faster.

When data is more accurate and is up to date, decisions can be more effective. Likewise, the most accurate GIS data which becomes available as soon as the geographic event occurs would provide a more powerful decision support GIS. Surveying systems such as total stations and dual frequency GPS provide the utmost accuracy but in many cases have not been able to collect the quantity of data at a speed or cost adequate for many GIS projects. One of the drawbacks in project specific accuracy and timeliness is that the data may not be suitable for subsequent applications and thus not be adequate for decisions where time changes and heritage tracing are needed.

While demand for more accurate real time geo-referenced data increases, the cost of providing the data is lowering. There are many examples of improvements in field surveying technologies that influence the trend toward real time higher accuracy GIS data with lower acquisition costs. One example is the increased infrastructure of CORS reference stations. Telecommunications infrastructure, the Internet and GPS processing algorithms for robust long range RTK combine to make GPS more cost effective for populating high accuracy GIS databases.

Different methods of visualizing GIS data provide different perspectives for decisions and thus contribute to improved decision making. 3D models and perspective views are regular outputs from a GIS. New laser scanning technology provides new data gathering technology for a GIS. The Cyrax laser scanner can collect up to 1000 coordinates per second to produce accurate 3D views. This innovation sets a new trend in gathering and visualizing 3D GIS data.

Improved data formats ensure that the data path from survey sensor electronics to GIS is as automatic as possible. Fastest integration of survey data into a GIS has been the single objective of a joint project between ESRI and Leica Geosystems' developers. The resulting software product is *ArcSurvey*. Not only does *ArcSurvey* provide a solution for the relation of survey data and features it also provides solutions for three important emerging GIS issues. The importance of quality in a GIS, the importance of metadata concerning data heritage in a GIS and the importance of a possibility to continuously update the geometric accuracy of an existing GIS are considered in the review.

INTRODUCTION

Geographic Information Systems (GIS) contain two fundamental data types, namely:

- Spatial data (i.e. information relating to the location of features); and
- Non-spatial data (i.e. data that describes features).

RAPID ACCURATE GIS UPDATES WITH IMPROVED LINKS TO SURVEY SYSTEMS

Applying GIS technology to support decisions for different applications has created varying structures of spatial data. The application also dictates the content of the non - spatial data. Two other factors influence the validity of the decisions being derived from GIS technology. Is the level of spatial accuracy appropriate to the application? Is the spatial and non-spatial data the most current?

The required accuracy of the underlying spatial data is dependent on the application. For example, zip code areas could provide sufficient spatial accuracy with non-spatial demographic data to plan the location of a new fast food restaurant. 100 meters difference on the spatial data is unlikely to affect the decision. On the other hand, calculating a land valuation for a parcel of land in a high rent city district that could hold a 50-floor skyscraper requires boundary definition to at least a centimetre. The value of the square meter error over the 50 floors could be substantial.

To ensure valid decisions, the underlying GIS data must be both current and appropriately accurate. The process of ensuring the data is current is referred to as the update process, and the process to improve the accuracy of existing GIS data is called the upgrade process.

Many GIS data sets exist and are readily accessible, however, they are far from being universally useable because the accuracy and currency of the data is only suitable for the original intended application or a subset of applications that require the equivalent level of accuracy or less. Worse, the accuracy and currency of many existing spatial data sets is often not known and thus the risk of incorrect decisions being formed exists. Consequently, the process of upgrading accuracies and rapidly updating GIS data is a major topic for improving the wider use of GIS databases.

Whilst spatial quality and currency is the issue discussed here, the non-spatial component of GIS data sets represents an equally important issue.

COST BENEFIT OF HIGHER QUALITY?

Increasing the quality of GIS data increases the costs of data collection. For example, if centimetre spatial accuracy is required instruments or systems with survey accuracy operated by personnel with pertinent procedural expertise must be used for data collection. The potentially wider use of the GIS data is certainly a benefit but only if the spatial and non-spatial data is still current by the time it is re-used.
For example, Foote and Huebner (1995) state that the cost per point to accurately survey the locations of features for utility companies (e.g. pumps, wires, pipes and transformers) is between US$5-20. Determining a suitable compromise between cost and quality is one of the main decisions for a GIS project management.

Although high accuracy data collection is costly, it may deliver significant savings. If underground utility features are added to the GIS with sufficient accuracy, savings could be realised when the feature is being relocated for maintenance. Digging a smaller hole, less interference with other property or utilities. A centimetre accurate city cadastral database has the additional benefit of providing a GIS layer for zoning decisions. Whilst centimetre accuracy is unlikely to be needed for a zoning application, it does negate the need for a second set of data. The cost of duplication is avoided even though the zoning decisions do not need the higher accuracy cadastral data.

As mentioned, centimetre accuracy GIS requires different data collection procedures and data sets from different types of measuring instrumentation such as total stations or dual frequency GPS systems. Integration of the higher accuracy data into existing GIS data structures requires special technical consideration.

INTEGRATING SURVEY DATA INTO GIS

Traditionally, separate software packages have been used to process and manage survey data and conduct GIS analysis. However, following a combined development effort by Leica Geosystems and ESRI, this tradition can be reconsidered with the creation of the *ArcSurvey* extension that will add survey functionality to ArcInfo (Anon., 2000).

ArcSurvey is a unique innovation to provide survey tools that extend the functionality of ArcInfo. The extended functionality includes:

- An interface between survey data formats and the GIS database;
- Data storage models and processing methods for survey measurements;
- Survey measurement visualisation;
- Advanced survey measurement editing and management;
- Storage of survey computations within the database; and
- The ability to associate the original data (e.g. survey measurements) with features in the GIS.

Traditionally, before survey data was introduced into a GIS system it was first processed within a computations package and then imported into a CAD package to prepare the features for import into the GIS system. There are 4 main steps to introduce new survey data into a GIS for both update and upgrade activities:

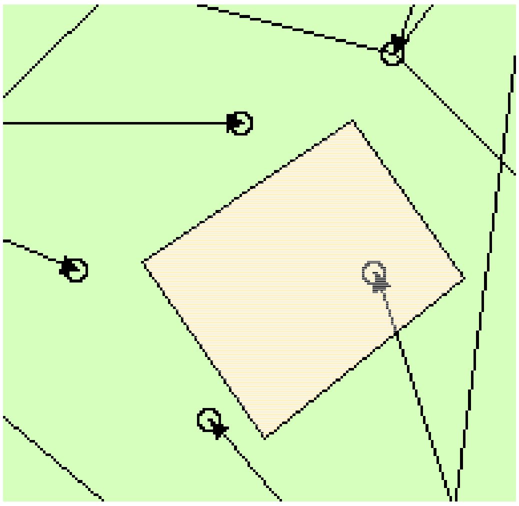
- Collection of survey data in the real world;
- Processing of survey measurements;
- Creation of features from survey points; and
- Features available within the GIS system.

ArcSurvey integrates all of these steps within the one environment.

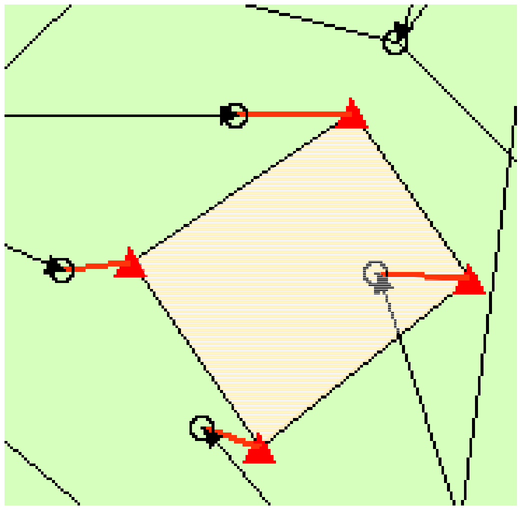
Traditional sources of GIS data have been analogue maps converted to digital formats using methods such as digitising, scanning, and in some cases the manual entry of point, line and polygon features. Often these solutions don't provide the spatial quality required to accurately locate the geographic features and perform meaningful analysis activities. Consequently, survey equipment and methods are required to improve the spatial quality of features. *ArcSurvey* provides an ideal environment to upgrade GIS data.

The following diagrams show the process of upgrading the spatial accuracy of a building within *ArcSurvey*. The upgrade process can be broken into four main steps, namely:

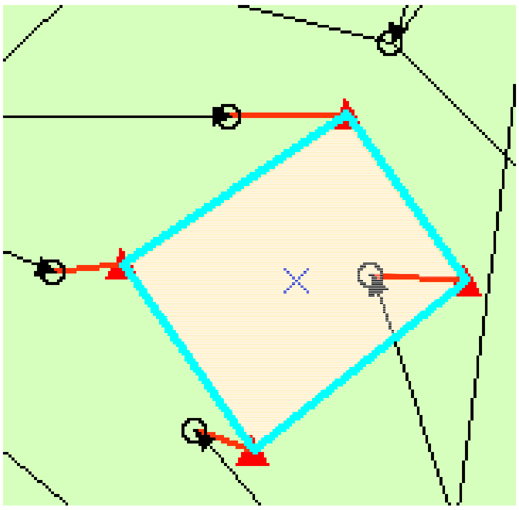
- Step 1: Create survey points (i.e. import, edit and process survey data);
- Step 2: Link existing feature vertices and survey points;
- Step 3: Select the feature; and
- Step 4: Upgrade the spatial accuracy of the feature.



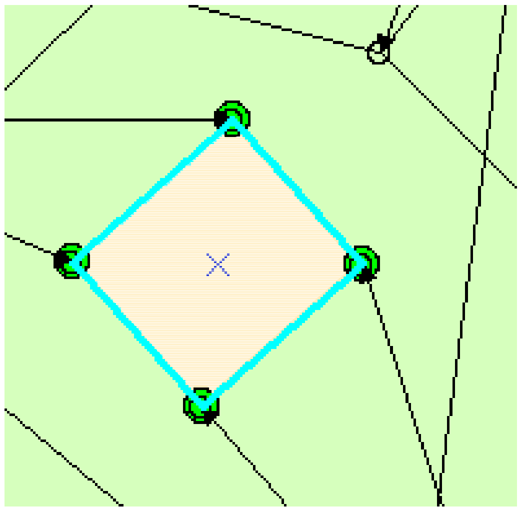
Step 1: Create



Step 2: Link



Step 3: Select



Step 4: Upgrade

An important feature of *ArcSurvey* is that once features are linked with survey measurements the location of the feature can be upgraded upon re-processing the survey data. Re-processing of survey measurements may be necessary, for example, upon extending the network of survey measurements or upgrading the co-ordinates of control points. This functionality provides significant data management benefits.

ArcSurvey provides significant quality management benefits by linking measurements with features. Such functionality enables a detailed report to be created at any time that includes:

- The source and quality of all measurements associated with the feature;
- The computations performed on the measurements to create the survey point; and
- Full statistical information describing the quality of the survey point and hence the quality of the feature vertex associated through the link.

RAPID ACCURATE GIS DATA COLLECTION

Collecting centimetre accuracy data in the field requires a total station or dual frequency GPS system. Innovations in these field systems have improved the speed with which coordinate data can be collected. Total stations incorporating reflectorless EDM or automated tracking potentially lower the number of personnel needed to gather the field data. These types of innovations contribute to lowering the cost per point of collecting high accuracy spatial information. Improved data structures that define spatial relationships between coordinates during the field procedures and add attribute information make total stations and dual frequency GPS viable high accuracy GIS data collectors.

GPS is no longer the domain of geodetic engineers only. Dual frequency GPS systems are increasingly being used to collect survey data. Single frequency or code only GPS receivers are widely used by GIS professionals requiring meter or sub-metre accuracy. System cost and additional field procedural requirements to gain the higher accuracies are the two main reasons for the lower use of high accuracy GPS systems by GIS professionals. Yet, new innovations give present and future viability of high accuracy GPS data collection for GIS.

A special GIS software option is available for the surveying GPS system, *Leica GPS System 500*. The option supports the methodologies of collecting GIS data such as streaming or nesting data. Collection of points, lines and polygons with associated attributes is a standard operating feature. The data is stored directly into an *ESRI* shape file format giving a seamless flow of data to and from GIS data files. The system has the capability of two-way data flow permitting attributes and coordinates to be loaded into the GPS field system. Navigate to the feature and update the attribute information. The capability is ideal for maintenance and inspection work in particular.

Special infrastructure, in the form of differential GPS services, is widely available to support sub-meter accuracy GPS positions so that only one GPS receiver is needed in the field. Higher accuracy GPS requires a base-station and roving unit as a minimum. The distance between a base-station and a rover has been limited to around 10 kilometres due to limitations in radio communication systems and the reliability of calculated RTK GPS positions. The future may be different. Networked continuously operating dual frequency GPS base-stations (CORS) are being deployed at an increasing rate by public authorities and private consortiums. Improved GPS signal processing techniques can provide reliable RTK GPS positions with around 40 kilometre separation between base-station and rovers. GSM telecommunications networks overcome range limitations of radios. The combination of improvements and growth in CORS infrastructure create the potential for centimetre accuracy spatial data collection in manner similar to differential sub-meter GPS.

ANOTHER TREND

Progress in field surveying systems and methods of integrating high accuracy spatial data into GIS data will change perceptions about accuracy needs in a GIS. Meanwhile GIS systems are being used for localized project management such as mines and airport construction blurring the distinction between facilities, engineering, architectural and GIS software solutions. Photogrammetry and a GIS were used on the Hong Kong airport to provide overviews of as-built surveys. Three dimensional views of GIS data have increasing relevance and new field systems offer rapid accurate data collection capabilities for creation of 3D models. The *Cyrax 2000* can collect up to 1000 points per second using LIDAR technology. The processing software *Cyclone* is able to process clouds of thousands of points into wire mesh models and subsequently fit shapes to create 3D models all to centimetre accuracy. Current applications such as plant and facilities maintenance are early beneficiaries of the productivity gains from this speedy and accurate form of measuring and modelling. One can imagine a future where LIDAR is deployed for GIS applications. A GIS database that catalogues existing building structures in a suburb is possible at a greatly reduced acquisition cost. Where land values are greatly affected by views, sun aspect, heritage or aesthetics decisions about new buildings can be more effective.

BENEFITS

The new software technology, *ArcSurvey*, offers many advantages to current systems, namely:

- Measurements from a number of sources (e.g. GPS, total stations, manual entry from plans, etc.) can be stored with the features they were used to create, consequently, providing enhanced functionality to trace the data source;
- Survey data processing can be performed within the GIS system and computation results can be stored with the computed points. Consequently, invaluable information for quality management is provided;
- Storing all information allows iterative enhancements of data quality over time;

Meanwhile continuous improvements in field systems developed for surveying also contribute to the viability of collecting high accuracy GIS data.

SUMMARY

The boundaries between surveying and GIS applications blur as field systems and data integration of higher accuracy data become viable. GIS project managers should consider the potential future uses of the GIS data they are about to collect keeping an open view about higher accuracies and future currency. They may well be creating an asset with future value.

REFERENCES AND BIBLIOGRAPHY

Anon., 2000, ArcSurvey: A White Paper for Managers of Survey Information Systems, ESRI and Leica Geosystems AG, Wednesday March 15th.

Foote, K.E. and Huebner, D.J., 1995, The Geographer's Craft Project, Department of Geography, University of Texas at Austin, http://www.utexas.edu/depts/grg/gcraft/notes/error/error.html

Goodchild, M.F and Gopal, G. (editors), 1989, *The Accuracy of Spatial Databases*, Taylor and Francis, 290 pp.

Euler, H-J. and Ziegler, C., 2000. *Advances in Ambiguity Resolution for Surveying Type Applications.* ION GPS 2000 Proceedings, September, 2000