CADASTRAL SURVEYORS
TIME TO GO FORWARD DIGITALLY AND COORDINATE ACCURATELY

M.H.Elfick.
Geodata Information Systems

ABSTRACT

Historically, Cadastral layers in GIS systems did not have a critical need for survey accurate data, as the information in the databases was spatially ‘pictorial’. Limited hardware capabilities and GIS software design also restricted accuracy. New hardware technology, more powerful software and wider accessibility to GPS has highlighted the inadequacies of the existing data and GIS compilation methodologies.

The concept, implementation and management of a survey accurate “coordinated cadastre”, is investigated and where such a system fits in the overall GIS information scene is outlined.

The future is with coordinate based cadastral systems whether we like it or not because point based survey technology is replacing measurement based systems.

The increased utility and the economics of asset management are some of the reasons why an accurate digital cadastral GIS database is necessary.

GIS AND SURVEY SYSTEMS

From a very slow start about 25 years ago, the GIS industry has made an increasing impact on the whole land management process. Part of the reason for this slow start was that GIS systems require computers with powerful computational abilities and a large storage capacity. This requirement limited its use initially, but rapid advances in PC technology and the resultant low cost - high performance systems will see GIS being introduced in many new areas.

Surveyors often provide data for GIS systems, but in general do not use GIS very much in their day to day operations. The software systems that most surveyors use are structured quite differently to GIS. They are focussed on computation rather than display and are generally limited in the size of data sets that they can handle. Typically, in these systems each point has an identifier (ID) such as a point number and coordinates are just one of the attributes of each point. A point can be thought of as an "object" and it can have attributes such as an x and y coordinate, multiple height values (ground level, finished surface etc.,) a name, a point type etc

Objects such as land parcels or polygons are defined by the point numbers at each corner and a change of coordinates does not alter the definition of the lot. Two corners are coincident if they have the same ID on the corner point, so matching is by point ID and there is only one coordinate for each point.

In these systems, there is no concept of topology in the GIS sense. Polygons may or may not be closed and polygons may or may not overlap or abut each other. There may also be redundant data and the dimensions around a polygon may not "close" mathematically. The data is often from measurements (which are not perfect) and coordinates are computed using the best fit of the measurements. If you add more data in the form of measurements, the derived coordinates can change but the definition of objects (by point number references) does not change.

A GIS is quite different, for it uses a coordinate as the *definition* of a point and matching is by position rather than by ID. Two corners are coincident if they have the same coordinates. To facilitate this matching, GIS systems use integer arithmetic for the storage of coordinate data and this has limited the available precision of their data.

When a GIS is initially set up, the extents of the project in east and north are defined and the largest dimension is then divided by the maximum possible integer number to determine the working units for the project. All coordinates are then converted to working units as they are read into the GIS. If the extents are small as in a local GIS, the working units may be only several millimetres in size, however if the extents are large as would be required for an country wide system, then the working units could be over a metre in size. GIS requirements of “topology” that is, the rules used to ensure that data on different layers can be referenced to each other by virtue of their position, also degrades their coordinate data and the wider the extent of a GIS coverage, the lower the precision of the coordinate data.

It has been common for GIS managers to say that it is unnecessary to provide accurate coordinates for data items. In fact, the real reason for limiting the accuracy of positional data has often been because of the limitations within the GIS system rather than the needs of users.

The next generation of GIS software which will start to be released in 2006 will use the 64 bit integer technology which is becoming available on new PC’s. This will provide coordinate data to sub millimetre precision regardless of the extent of the GIS coverage and eliminate most of the coordinate changes generated by enforcing GIS topology on data sets. Just as GPS has caused a revolution in measurement technology, 64 bit systems will cause a revolution in GIS technology. They will be able to move from being a display and coarse analysis system to one which can also carry out detailed design and precise calculations.

IMPLICATIONS FOR GIS

The new systems will remove some of the constraints which have previously existed with GIS. For example there may no longer be a need to specify the extent for any data set as the new coordinate systems can hold millimetre accuracy for a world wide coordinate system. However, they will require spatially accurate data if they are to be used anywhere near to their potential.

Most GIS systems have been fabricated from data digitized from existing maps and plans. Some service authorities (power, water etc) have maintained a high quality charting system and their plans may be accurate to about half a metre. Elsewhere, boundaries are mainly shown on maps in their approximate location for charting administrative details and the positional accuracy is very poor.

Over time, as additional data is added, the accuracy of the fabric is upgraded by various methods and many organisations have used other data such as orthophoto maps to provide extra control. However there is a limit to how much you can apply mathematical gymnastics, because the fundamental accuracy of a data set is limited by the accuracy of the source data. Adding additional data and adjusting by various means will really only influence the points near to the control and often degrade the quality of the new data as it tries to fit in with the old data from digitized maps.

Because most of the GIS systems in the world have been originally built from digitized data the problems flowing from inaccurate cadastral data are widespread.

CHANGES IN GIS DESIGN

In 2000 ESRI released “Survey Analyst” to manage survey datasets within a GIS environment and this year they will extend the functionality to assemble and manage cadastral networks using data from survey plans. This is part of a new generation of software to integrate GIS and survey and cadastral systems.

The new processes provide:

- methods for the direct data entry and *analysis* of cadastral survey data,
- a special database structure to store and manage this dimensional data,
- methods to import, export and update coordinates values in cadastral dimensional networks and
- Methods to apply the effect of movement in coordinates in the cadastral network to feature classes in the GIS.

The database structure and the methodology for managing cadastral boundary networks are based on systems developed over the last 15 years by cadastral surveyors in Australia. By integrating these processes within a GIS, the source data (cadastral dimensions) can be kept in database tables in a secure environment and at the same time be used generate and manage GIS layers displaying the cadastral boundaries. These processes build on the concepts behind Survey Analyst which holds survey data as the building blocks for GIS. The survey data can be manipulated using special tools which work in a similar way to traditional surveying systems and these tools also generate and adjust GIS layers based on the survey data.

With this new generation of GIS software it will be much easier for individual organizations to build their own systems directly from accurate survey data and it is likely that systems dependant on digitized maps will become increasingly irrelevant.

FUTURE DEVELOPMENTS FOR GIS

At present, there are problems in generating GIS data from survey information and these problems stem from the different types of logic in the two systems. For example, the process of converting coordinates stored as floating point numbers to GIS integer numbers can produce gaps or overlaps between polygons and in some GIS systems, curves are represented as a series of short chords and not as a geometric structure.

These problems are progressively being addressed to allow survey data to generate a GIS layer which is topologically correct. This is an essential part of any transformation software. If the ensuing GIS layer is topologically correct in a GIS sense, there will be no need for the data to be “adjusted” within the GIS.

The types of calculation and data manipulation processes which surveyors currently use also need to be easily accessible from within GIS. As surveyors will often be operating from a laptop or lower powered PC, the systems need to be modular so that they have access to the components which they need, but their system is not overburdened with too much system overhead.

CHANGES FOR GIS MANAGERS

Accurate position based data poses both an opportunity and a series of problems for GIS managers.

First there is the difficulty it in merging it into existing data sets. While it may be convenient to simply fit the new to the old to minimise the changes needed to associated layers, this is simply putting off the need to adjust layers to match the ground truth in position. If new data has to be fitted to the old until sufficient data is available for a major revision, then the accurate coordinate data should also be held so that it can be used at a later date.

There needs to be an increased focus on data quality and the need to hold information regarding its positional accuracy. There should also be an understanding of the way that surveyors think and a respect for their information. Survey data should be used to control the layers, and must not be corrupted with ad hoc topological processes. So the focus can move away from manipulation and fitting new work to a process of simply adopting the new and using the system to carry out the merging and upgrade process.

Because many GIS systems are complex and difficult to use, the operators need considerable training before they can become competent. This complexity acts as an intimidation to new users and is a great disincentive in their making full use of these systems.

. The success of the PC world wide has been mainly because it is a technology which is easily accessible to a wide variety of people who can operate the system to carry out their day to day tasks without special training. Similarly, if we want to expand the usage of GIS, the key will be to develop very user friendly systems for specific applications. GIS systems can be tailored specifically for particular users and operations. If this is carried out in a careful manner each user can be confronted with a menu system which suits his or her application and is not confused with a plethora of apparently meaningless options.

In any organisation, it will be a challenge for GIS managers to set up systems to encourage surveyors to use GIS in a dynamic way as part of their day to day activities. As part of this process it will be necessary to get to understand the processes that surveyors use in their normal activities and then set up the appropriate menus and tools for their applications. There is no point in simply saying “here is the system – go use it”.

IMPLICATIONS FOR GOVERNMENT

Cadastral boundaries are a fundamental data set for most GIS systems as most data is related in some way to land ownership. A high quality coordinate based cadastral system is essential for this data to match in position the information held on other data sets. For example, it greatly devalues the worth of a high quality GIS map if the parcel layer will not overlay correctly because of its inaccuracy.

In those countries which have a dimension based cadastral system (such as the USA, Australia and the Philippines) a high quality coordinate based system can be built and maintained directly from the metes and bounds data using the facilities now available in GIS systems.

There is no “magic bullet” and the initial cost of the transition is quite considerable because of the need to rebuild the cadastral framework directly from data in source documents such as survey plats. However it can be shown that benefits both in reduction of overall maintenance costs and increase in utility make the exercise very worth while. In many cases, the capital cost of conversion is similar to the amount currently spent annually by GIS systems as a whole in maintaining the current outdated system.

It is not really a decision as to whether a change should take place. The question should be whether we can still afford to continue to maintain a cadastral system based on measurements taken from ground marks. To re-establish a boundary using traditional surveying procedures is very labour intensive and requires a person with a high level of skill and training. In the past, there was little option, however the new processes can now allow a complete rethink in this area.
The new GIS tools provide the means to use all of the existing documentary data such as maps, plats, legal land descriptions etc to build and maintain a numerical cadastre. New

Zealand has recently co-ordinated the cadastre in all of their urban areas and the Northern Territory in Australia has almost completed coordinating the cadastre for the whole state. Projects already completed in Australia and New Zealand show the practicality of this new approach and benefits which flow from the change.

THE CHANGING ROLE OF SURVEYORS.

Traditionally surveyors have provided the base data for maps and plans as well as carrying out a variety of other work for projects of various sizes. Each project is usually on a local coordinate datum and when completed it is filed away as a separate data set. At a later date, if another project is commenced nearby, parts of the old data may or may not be used in the new project and so the cycle continues. Over time, a considerable amount of data is accumulated but its use is limited because of the way that it is held and the isolated nature of each data set.

In the past, it was always easier to measure a line than fix the absolute position of a point. The situation is now reversed and the rapid development and implementation of other satellite navigation systems such as Glonass and Galileo will increase the accuracy and reliability of the current systems. The developing GNSS technology which encompasses both satellite and ground based systems can provide centimetre accuracy levels in real time and will completely dominate location based data capture technology in the future.

Surveyors need to take full advantage of this technology and work with geodetic coordinates rather than local coordinates. This will require a different approach when using coordinates as issues like projection scale factors will have to be accommodated. However, the long term benefit from having all jobs on the one datum greatly outweighs the technical difficulties in some computation procedures. Perhaps it is time to abandon the multitude of State coordinate systems and adopt UTM metric coordinates for all work. After all, the USA is one of the last countries in the world that has not fully adopted the metric system.

Surveyors have traditionally measured and located features and boundaries from reference marks which they have placed. These marks range from trigonometrical stations managed by geodetic survey organisations to local marks traversed from boundary corners.

It is likely that GNSS technology will provide the reference system for the future and surveyors may be already wasting their time placing and fixing reference marks in the ground. There was a reasonable excuse for this type activity when GPS was an unknown quantity, but we cannot use this excuse now that position fixing technology is firmly established.

However, there is no point in changing the survey referencing system unless you start seriously to consider the use of coordinates in all aspects of surveying including the land titling process.

The new GIS systems can provide the management tools needed to process and store surveying data sets based on geodetic coordinate data. For this to happen though, surveyors will have to embrace GIS technology and use it as a core element in their processing and storage of data instead of simply exporting a finished data set to a GIS user.

In those countries which have a measurement based cadastral system, surveyors should actively support moves towards adopting a coordinate based system. It should be the responsibility of surveyors who are familiar with the existing systems to show the lead in making the transition to a coordinate based system.

By taking the lead, surveyors will be able to shape the way that the new systems develop as well as being able to take advantage of the considerable business opportunities that will develop during the conversion process.

Surveyors need to start using GIS directly as a base management and storage medium for their data as the future GIS systems will be all about fabrics built and managed from real data rather than being pictorial representations from derived data of dubious quality.

CONCLUSION

Change is always difficult and the survey world has been subject to considerable technological upheaval over the past 30 years. However, there is no sign that this rate of change is slowing and surveyors will have to adapt and lead in the use of this technology if they are to survive as a profession in the future

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