A Cadastral Geometry Management System

M.H.Elfick.
Dept. Civil Engineering and Surveying
University of Newcastle, Australia

ABSTRACT

This paper looks at methods of building and managing a digital cadastral system directly from dimensional data.

Introduction

Over the last ten years there has been an increasing interest in land information systems, and with it considerable attention to the cadastral framework which is often used as a fundamental building block.

Most of these cadastral frameworks have been digitised from maps and the end product from such a process inherits all the problems associated with the quality and integrity of the source data. They are relatively easy to update but more difficult to upgrade as the cadastral framework changes[7].

There have been many reasons for selecting a map digitising process, and these include cost constraints and the influence exerted by computer software and hardware suppliers in their marketing of systems based on CAD/CAM packages. A major consideration from a management point of view has been that digitising used a well established technology and provided a relatively quick response at a reasonable cost to existing user demands[7].

It is proposed that a cadastral geometry database should ideally be operated as a separate entity by experts in cadastral data who could focus on the problems of its management without the distraction of the wider problems associated with a general land information system. If such a database were set up from the existing survey data, then the process of checking and charting new plans could be used to maintain an accurate digital cadastre.

This paper looks at the structure of the cadastral system and at techniques to build and maintain a digital cadastre from dimensional data.

Coordinates and Boundary Definition

A co-ordinate is an estimate of the current geographic location of a point. It is simply an attribute or type of dimension, and is subject to revision from time to time as better information becomes available.

Provided that they are regarded as a dimension, there is no difficulty in coordinates being part of the chain of evidence used to define boundaries. It is a mistake to think of a co-ordinate as a fixed entity, any more than one can say that a boundary is a certain length exactly, or a certain bearing exactly.

Within ten years the Global Positioning System (GPS) will become common place as a precise measuring system used by all sectors of the community and coordinates will be more easy to obtain than dimensions.
This will place pressure for all boundaries to be coordinate based. To do this there is the choice of either remeasuring, or deriving coordinates from existing data. The determination of the **legal position** of a parcel corner requires careful consideration of a chain of evidence and survey plans of subdivision provide dimensional information which should be used as part of this process.

Cadastral Records and Historical Data

New South Wales has a numerical cadastral system based on individual survey plans with the accuracy of the data being dependent on the date of survey. At present there is relatively little geodetic control, but each survey is connected to the adjacent surveys. Despite this lack of geodetic control, the day-to-day operation of subdividing parcels and defining boundaries does proceed without a great deal of controversy as is evident by the low level of litigation in this area. This success is largely due to the level of knowledge and skill within the surveying profession and the vigilance of the Land Titles Office and the Board of Surveyors in maintaining standards.
In NSW, early surveys for alienation of land from the Crown were performed by government surveyors, but after about 1850 most subdivisions and many crown surveys have been carried out by private survey firms.

To-day, most of the source data, and most of the detailed knowledge about the cadastre is held by the private survey firms who carry out changes to the system.

Surveying practices have extensive record systems which include copies of survey plans for a large proportion of their operational area, and original field notes and work sheets going back for many years. Much of this data is unique, for less than a third of all cadastral surveys in NSW result in a plan being lodged in the Land Titles Office (LTO). When a plan is lodged it often does not show all of the current survey information in that area since the surveyor may only include sufficient to justify his boundary definition.

It is essential that the resources of the private sector be tapped in the initial process of building a coordinated cadastre. This point has been recognised to some extent by government and the Land Information Centre (LIC) has involved over 100 firms in collaborative projects since 1991 [7].

The Nature of the Cadastral Data

The cadastral framework is made up of two basic data types:

The first is in vector format where points are linked by bearing and distance to adjacent points. Original Crown surveys, older subdivisions, rural subdivisions, and the surrounds of modern subdivisions are of this data type. The dimensions are those measured when "running" the actual boundaries and reflect the actual measurements taken in the field.

Modern surveys in built-up areas where boundaries pass along physical features such as walls also fall into this category as do older subdivisions where it was the practise to leave the misclose in the surround and distribute the error through the lots. These subdivisions are difficult to recompute with simple coordinate geometry computer programs.

The second type is where the framework is defined by its structure using either a 4GL language or by an interactive coordinate geometry program. The surround is first closed, and the misclose distributed before any calculation of lot boundaries takes place. There are no miscloses in the internal lots, and all dimensions are computed from the adjusted surround.
This type of computer software has been in use by surveyors since 1966, and most survey firms now use the technique for multi-lot subdivisions.

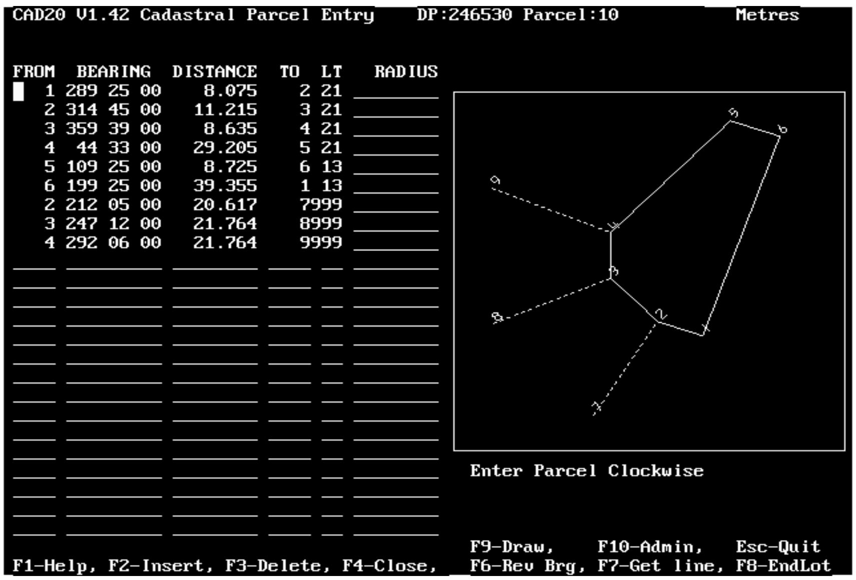
Both forms of source data (vector and structure) will continue to exist for the foreseeable future and a cadastral management system must be able to apply appropriate techniques to process source files of these data types.

Building the Initial Framework

The initial framework can be built directly from original source documents such as cadastral survey plans and written parcel descriptions. The work can conveniently be broken into three stages; Data Entry, Parcel Joining, and Adjustment of Parcel Networks.

Data Entry of Parcel Dimensions

This work can be carried out by people who have good keyboard skills, and who may have limited knowledge of survey procedures. The data entry system should be designed for direct input from survey plans with checks on closure, parcel area, and provide a graphical display of the input data.



Cadastral Package Data Entry Screen

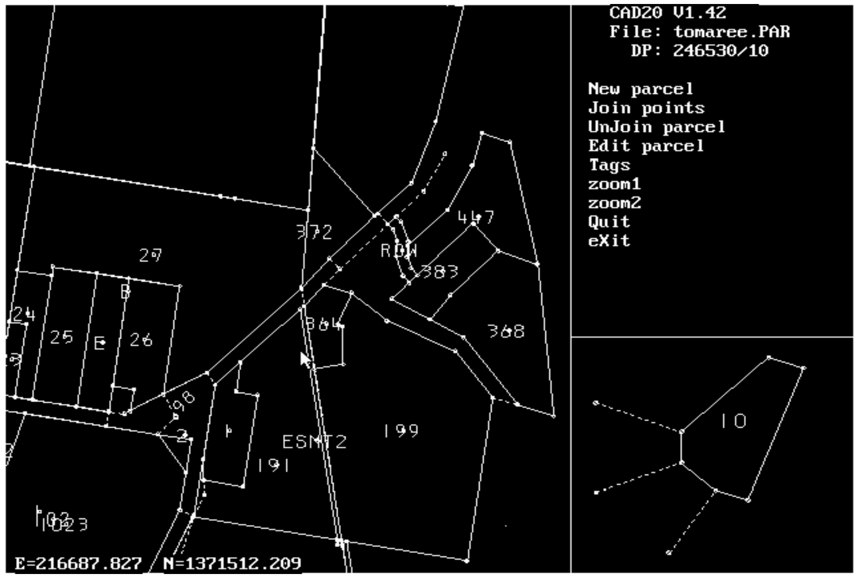
Experience to date shows that operator training can best be carried out on the job, by starting with simple plans and moving on to the more complex as experience is gained. Any plan which looks difficult should be put aside, the aim being to proceed with the straight-forward parcels, and not get bogged down on complex input problems which possibly could be solved by other means. Plans which are put aside initially can be handled later by the normal processing system after the operator has had more experience.

A standard routine should be followed such as starting at the top left corner and proceeding in a clockwise direction. Double entry procedures for data checking are not very useful since most errors tend to be in the interpretation of the plan and are therefore are not eliminated. If the computed area matches that on the plan and the misclose is within tolerance then the parcel should initially be accepted. Any problems can be corrected at the parcel joining phase when more information is available.

Operators should always type what they see, and the data entry program should accept a variety of input types such as decimals, feet and inches, quadrant bearings as well as whole circle bearings etc. Operations such as reversing a bearing should be available through the function keys and if a drawing appears on the screen as the data entry proceeds, then the operator can see obvious errors such as missing lines or a bearing being entered in the wrong direction.

Parcel Joining

Parcel joining defines the full "connectivity" between parcels. It can best be carried out interactively on a computer screen where one can visually select common points, and points which lie on parcel sides. The joining program should then indicate how well each point in the new parcel fits to the network and allow the operator to edit or make changes as needed.



Parcel Joining using the Cadastral Package

Points and lines to be joined are selected after inspection of each plan. Editing facilities in the joining program can be used to add, change, or delete lines to resolve any remaining data problems. The joining process will show up any lack of fit between parcels this can be used to locate errors which were not be obvious at data entry.

Consequently, the initial data entry staff can concentrate on getting the bulk of the data in to the system, and let the person joining up the data resolve difficult areas and add those connections which may be important to the definition.
If there are no internal miscloses, a group of parcels can be treated as a single entity or "structure" when joining into the parcel network. The software can automatically extract a surround from the structure data and this can be used in the joining and adjustment process. The internal parcels for each structure can be brought in and automatically fitted by the system after the main network has been adjusted to control.

Adjustment of Parcel Networks

The coordinates generated by any joining process depend to a large extent on the order in which the parcels were joined since each parcel is progressively fitted to the group. Such a coordinate system could be based on an arbitrary origin and have an azimuth determined by the first parcel.

The adjustment process computes a coordinate system with a "weighted best fit" to all of the dimensions in the system using a least squares variation in coordinates procedure similar to that used in most geodetic adjustment programs.

To be effective, an adjustment program for cadastral data must carry out a substantial amount of automatic data checking and build the adjustment with a minimum of intervention from the operator. Weighting of the data should be according to predetermined rules which may be based on the date of each survey. The parameters we have used have been determined from experience after looking at the survey practice regulations in force at various times. It is likely that more suitable parameters will be selected after more experience and it may be useful to provide facilities to override these parameters for some parcels during the joining process. Constraints could also be placed on connections across roads etc.

Automatic weighting does provide relatively trouble free adjustments with no intervention from the operator provided that the network is complete and of a reasonable shape. Cadastral patterns are quite complex, with each point being connected to its nearest neighbours providing a high degree of interconnection between well shaped polygons. This structure provides the overall strength for the adjustment, and the weighting allows later surveys to have greater influence than earlier ones.

After adjustment comparisons can be made on each line after a common scale factor and azimuth swing has been applied for all lines in each parcel. These values can be used as a measure of the quality of the data.
The average standard error for all the lines can then be computed, and lines with differences exceeding two standard deviations from this value can be tabulated to provide a quick reference to the main problem areas.

**** Lines with an error exceeding two sigma ****

DP46734	**Parcel 23**	**From**	**16**	**To**	**23**	**C-O**	**0.54**
DP3146	**Parcel 84**	**From**	**316**	**To**	**331**	**C-O**	**1.33**
DP21467	**Parcel 2**	**From**	**411**	**To**	**65**	**C-O**	**0.46**

Sigma for C-O = 0.146

Sample Output from Cadastral Adjustment

The separation of the data entry, joining and adjustment processes permits a very flexible approach to the formation of a digital cadastre. Data can come from a variety of sources, and parcels collected into logical groups to be joined and adjusted. In rural areas where control is limited, groups of parcels can be treated as a "structures" and their surrounds used as "parcels" to be joined and adjusted to control with the internal parcels being fitted later. This technique allows rapid propagation of coordinates over a wide area while at the same time giving an assessment of the quality of the network.

The network can indicate where control is most needed, therefore it is more cost effective to place control after the cadastral framework has been analysed.

Cadastral Archival System

For practical reasons it is better to work in groups of about 200 parcels for data entry, parcel joining and adjustment. This simplifies the initial data capture as it avoids working with large and complex networks of data. When an area is completed it can be archived, and additional checks carried out to ensure the integrity of the data.

An initial approach to the setting up of a cadastral archival system was to use a proprietary data base accessed via the "Neutral Cadastral File Format" (NCFF) [5] of the NSW Land Information Centre. The NCFF was found to be unsuitable as a transfer medium for despite being very verbose (the LIC example shows that over 80 lines of input are needed for a simple two lot subdivision), it has no provision for line points or curve centres and therefore cannot fully define cadastral geometry.[3]

Most data base software packages are mainly designed for text data using files of fixed format. They tend to be wasteful of storage space, and not efficient at geographic referencing. They have features for the preparation of written reports, and for selective retrieval of items according to categories, but lack features needed for efficient management of cadastral geometry data. Many software packages such as Geocomp, ACS-Geom, Landmark, Civilcad etc., can manipulate and present cadastral data in a variety of forms, so the main requirement is for an efficient archival system which can import, export, validate and store blocks of numerical cadastral data.

After much consideration it appeared better to design a system from scratch rather than try to adapt an existing data base package. Such a program could have quality assurance procedures for the cadastral data built in, and interface directly to the file structures currently in use by surveyors. The storage could also be kept in a compact form and have an efficient spatial data access system.

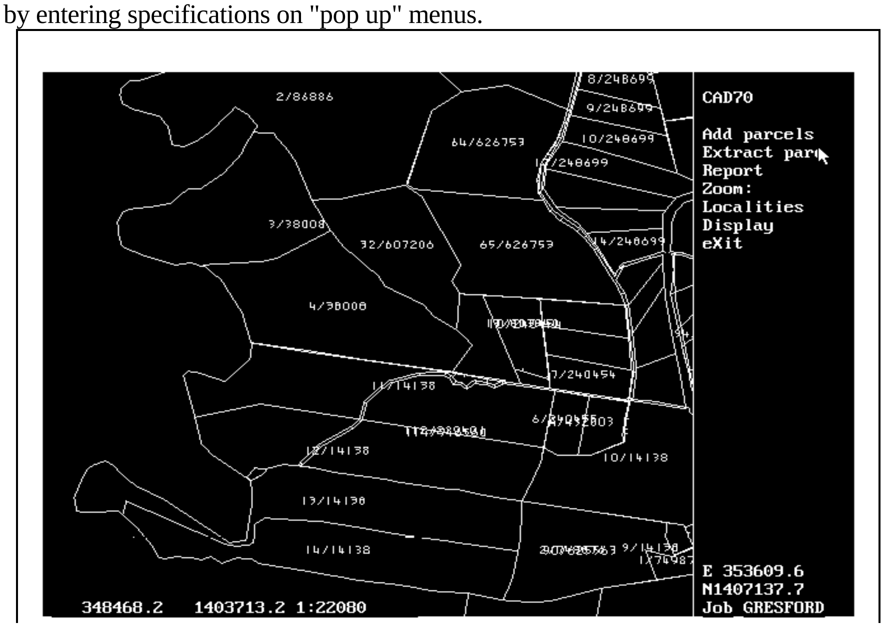
The Cadastral Package Data Base

The system is designed to manage very large data sets and the storage and index files automatically adjust in size as data is added.

For an average parcel of say seven lines, 250 bytes of storage are required. This comprises 170 bytes of parcel data, 72 bytes of coordinate data, and the remainder being index files for the plan and geographic referencing systems. Thus a survey practice which may wish to store about 100,000 parcels will require less than 30 megabytes for their archive files.

Data is imported and exported via the parcel and coordinate files as used by the cadastral software, and there are translators available to read and write data to other packages such as Civilcad, Geocomp etc.

Data can be accessed by geographic position, or by plan and parcel number. Parcel boundaries are continuously displayed in a graphic window which the operator can zoom or pan and selection can be by mouse, or by entering specifications on "pop up" menus.



Cadastral Data Base Viewing Screen

Reports can be generated showing details of the geographic and plan indexing systems, as well as data content etc.

Cadastral Maintenance

When a new subdivision is to be added, cadastral data for the local area of interest is extracted and stored as parcel data. Extracted points are numbered in a local point numbering sequence and the very large point numbers used in the master files are kept 'transparent' to the user.

The new subdivision is entered and joined using the software used to build the initial system. If new data is supplied as a structure, the cadastral software can automatically extract a surround ready for joining.

The joining process gives an initial assessment of the new data and serves to find any obvious blunders in data entry or parcel joining. Control is added if necessary and the area adjusted to test how well the subdivision fits with control and the existing data. If the results are satisfactory, any internal parcels within structure surrounds can be automatically incorporated and the archive updated.

Each "joined" parcel is then written to the data base parcel file with the local point numbers being changed to the database point numbering system as each line is added. If the parcel already exists then the old data will be overwritten. New parcels are written to the next available space and the plan index file and the geographic index files updated.

Each new subdivision can be tested against existing data, additional control can be added and the results used to progressively increase the quality of the total data set.

Processing Costs

For the initial study at Gresford [1] our object was to keep the total processing costs below six dollars per parcel and this comprised two dollars for data entry, two dollars for the joining process and two dollars for the adjustment and report. While there may be some discussion as to whether this target was met exactly at the time, more recent work both in Australia and New Zealand have shown that these figures were very conservative. On plans of various quality and complexity, the cost of data entry has averaged under two dollars per parcel [9]. Where the plans are new and easy to read the costs are considerably reduced [2].

Unit cost for data entry by structure is about $1.40 per parcel using the ACS-GEOM software using their 4GL language (see [1] and [2]). Interactive graphics systems for geometry design tend to require more operator time and have higher unit costs, but they are widely used and the operators require less training. The cost of parcel input can be greatly reduced if the data can be obtained on diskette from the surveyor responsible for each plan.

Total processing costs can be below four dollars per parcel for modern plans with reasonable control and these improvements have come about because of refinement of the software and a more methodical approach to project management.

Summary

While the current generation of cadastral referencing systems based on digitised maps has provided a valuable management tool in the short term, there is no doubt that technology such as GPS will build expectation for better coordinate values. "Rubber sheeting" techniques to adjust to new survey data does assist in upgrading digitised coordinates to a limited extent, but this in turn causes problems for users who have difficulty in coping with continually shifting coordinate values.

This paper has discussed ways that a coordinated cadastre can be built from dimensional data together with methods of managing and assuring quality control. It is important to build and analyse the existing cadastral framework first before considering where control is needed. In this way effort can be directed at the problem areas and not wasted.

The processes can isolate and correct errors in the data and maintain a "complete cadastre" which improves in quality as extra data and control is added. It provides a "survey accurate" coordinate system which can be used as part of the checking and charting process for new plans and can provide a means of transition from the current "dimensional" cadastral system to one based on fixed coordinates.

REFERENCES

[1] Elfick, M.H. and Fryer, J.G.(1991) "Cost Benefit Study on Management of Cadastral Data", *TUNRA Report to NSW Land Information Centre*.(40 pages)

[2] Fletcher, M.J.(1992) *Report to N.T. Dept. of Lands and Housing* on the Cadastral Coordination of the Town of Batchelor.(42 pages)

[3] Fryer, J.G. and Elfick, M.H. "Electronic Lodgement of Plans", *The Australian Surveyor* Vol.37, No2 pages 196-201.

[4] Elfick, M.H. "Management of Cadastral Data in a Land Information System", *Proceedings of LIM Conference Sydney 1991* pages 107-114.

[5] LIC 1992 "Guidelines & Specifications for Projects to Introduce a Co-ordinated Cadastre" by the *LIC Cadastral Development Unit*. (30 pages)

[6] Hesse W, Williamson I.P "MAGIC revisited: An Object-Oriented Solution tp the Cadastral Maintenance Problem" *The Australian Surveyor* Vol.38, No.1 pages 39-49.

[7] Kelly, P.C. (Deputy Surveyor General) 1993, *Personal communication*.

[8] Goh, P.C. and Aw Y.B. "Modernising Survey Controls with GPS in Singapore" *GIS User* July 1994 pages 33-37.

[9] Elfick, M.H. 1993 "Report on Techniques to Generate a Coordinated Cadastre for the New Zealand DCDB." *Report to the New Zealand Department of Survey and Land Information*. (16 pages)