

MANAGING A CADASTRAL SDI FRAMEWORK

Boundary Dimensions as Basis

Cadastral information is a fundamental layer in the Spatial Data Infrastructure (SDI) and many GIS systems use it as a base framework. The authors introduce an approach to improve and maintain the spatial accuracy of cadastral boundary geometry that can concurrently improve the geometry of referenced layers.

A multi-purpose cadastre is the goal of most countries today and, in many, "metes and bounds" define boundaries. This system evolved during a period when it was relatively easy to measure lines but very difficult to find the exact coordinate location of a point on the earth's surface. Boundary dimensions and reference to physical objects on or near the boundaries are shown on cadastral survey documents. The accuracy of data in these documents is a reflection of the measurement technology at any given point in time. Over the years developments in the technology for measuring distances and angles have steadily improved. Today precise GPS systems can locate points to centimetre accuracy, in real time.

Digitising Maps

The most common current method of building the land ownership layer in GIS systems is by digitising boundaries from cadastral maps. Many of these were designed simply to show the relationship of various attributes one to another, rather than being compiled to an accurate coordinate base. Consequently, accuracy of position varies from place to place, and any mistakes in original map compilation are carried forward into digitised records and other spatial layers. There are many systems in use to improve the accuracy of this type of data, including "rubber sheeting" or adjusting to control from GPS or photogrammetric sources. These systems improve positional accuracy near each control point but do nothing overall to correct inaccuracies in base data. To overcome this problem it would be necessary to have a control point at nearly every corner.

Boundary Definition

A primary intention of a cadastral survey document is to convey instructions from the surveyor on how to locate, in the field, the physical corners that define the boundaries of a property. Cadastral survey documents describe each parcel of land by the bearings and distances around its perimeter. The basic module for the data is therefore a closed polygon, and this may have additional "connections" to corners of other parcels or survey reference marks. Bearing and distance dimensions are derived from measurements in the field, and they may not "close" the polygon exactly. The size of the misclose in each parcel is a measure of the accuracy of the data, and is used by surveyors to check their work. Since the point models the physical location whilst the coordinate models the current representation of that point, a software system treats coordinates as derived quantities held as attributes of a point, rather than as a definition of the point itself. A cadastral fabric built from survey data can be made very accurate using limited control by the employment of a least-squares adjustment that uses all of the survey information (including historic) to distribute error throughout the fabric.

Coordinate-based Data

Many of the physical services represented in the spatial data infrastructure, such as pipelines, underground cables and so on, are physically positioned at known offsets from property lines usually represented by the physical markers placed or found by the surveyor. The traditional cadastral survey documents used for relocating property boundary corners may be interpreted in various ways. Hence boundary location disputes can arise when different surveyors use differing data to re-establish the location of a boundary. A coordinate can provide a unique and unambiguous record of a point, and GPS now provides the necessary survey technology for fast and accurate relocation at that point. For maximum benefit from existing data, the building process should not only extract data from the documents and build the boundary network but should also analyse the data and provide a measure as to the reliability and accuracy of the computed coordinates.

Conceptual Model

Cadastral survey documents may take the form of deed titles, registered title diagrams or subdivision plans; we refer to them inclusively as plans. A network of connected boundaries, often referred to as a cadastral fabric, define the conceptual layer for land ownership within the spatial data infrastructure. The parcels, boundaries, points, coordinates, boundary network and plans are all elements that must be emulated. Our use of parcel simply means a unit of land. The fabric may have any number of different types of parcels, variously described as lots, blocks, sections and so on, as needed. Fabric history is unique in that it does not follow the archive model. It is a living history that actively contributes measurement information in the processes that improve cadastral fabric coordinates, including those that define historical parcels. Original dimensions and related attributes are not edited; only the coordinates are updated to the current best estimates generated by the least-squares analysis.

Updates to the cadastre are generally modelled as job-workflow transactions against the cadastral fabric. Each cadastral job is a collection of parcels that can be modified, adjusted or extended. A job is edited by a special set of tools that properly updates the cadastral fabric using the parcel as the unit of work. The goals of this cadastral editor are specifically the following. To capture all possible dimensional information recorded on legal documents, to build a boundary network using common points between record sources and to use control

points and all available records within an area to provide the best possible solution for the coordinates by least-squares adjustment. Once a job is completed it can be used to update the cadastral fabric. The current cadastral fabric is the up-to-date representation of the land status, and therefore represents all parcels excluding those marked as historic.

Data Model

A GIS can implement a variety of applications that use a geographic database to store information. A geographic database is often called a "geodatabase". The cadastral fabric in the geodatabase is modelled with parcels represented by parcel line features, parcel point features and parcel polygon features, referred to in aggregate as parcel features. Along with its mapping shape geometry, each parcel stores other textual information relevant to parcel-data maintenance, including, for example, attributes in the parcel-point feature class for representing its CoOrdinates, and Coordinate Geometry (COGO) attributes in the parcel-line feature class which represent its dimensional information and accuracy level. Another key attribute is a parcel id in the parcel-polygon feature class. These parcel, point and line feature classes are the core representation of the cadastral fabric.

Within the geodatabase system the fabric is a continuous surface of connected parcels with an explicit topology defined by common parcel corners and neighbours. Ideally, digital parcel-data sources have attributes on the boundary lines that circumscribe each parcel. These attributes are usually intended to represent the record data from the cadastral documents. Hence it is important when converting from other digital sources that COGO attributes be converted during transfer into the cadastral fabric. The cadastral fabric provides a way to organise parcel data based on the form in which the data is originally recorded. The (digital) plan in the cadastral fabric is used to hold information about the subdivision plan record, such as date, surveyor, entry units, scale factor, etc.

Coordinate Systems

Cadastral field surveys conducted in Australia and the United States have traditionally proceeded in a local coordinate system, which is sufficient for the cadastral records required and for the large scale typical of recorded plans. By contrast, a fabric contains many contiguous plans that, cumulatively, are used for mapping larger areas of the fabric at small scales. The fabric therefore requires a well-defined geographic or projected coordinate system.

Implementation

The quality of source data will vary from place to place and will generally depend on the age of surveys and the degree of regulation of the cadastral survey process.

The cadastral editor is used to enter data directly from survey documents, join the parcels together, add survey control as necessary and then apply least-squares adjustment to the completed cadastral network. The job is then loaded into the geodatabase and the system will merge the new data so that the geodatabase can store and present a seamless fabric. The key to success is to progressively test the data as it is entered and assembled so that the operator can detect and resolve any problems early on. The cadastral editor provides a simple interface for entering this data, with immediate generation of misclose information. Bearings and distances are entered in sequence around the parcel and the lines and their local reference numbers are displayed on the screen as data is entered.

The approach used to build a property boundary layer from survey documents is to enter all the data, assemble and analyse the boundary network and only then apply control according to the results of the analysis. While this is almost a reversal of "standard surveying practice", it allows for checks to be made on the internal consistency of data before the complications imposed by the addition of geodetic control. This approach has the benefit of showing where additional control is needed, thus reducing costs when collection of new control in the field is required. The parcel-joining procedure is designed to define the "connectivity" between parcels in the property-boundary layer. As each connection is made, transformation parameters are computed by a least-squares procedure and the residuals displayed. The operator can accept or reject the result and try other points for the join. If accepted, parcel-point numbers are changed to network-point numbers. The joining process establishes the topology of the network and it has checks to ensure the integrity of the system.

Layer Update

Other GIS layers are edited using the cadastral fabric as background reference. Since the cadastral fabric may be frequently adjusted with shifts of a large number of coordinates, discrepancies will appear between the cadastral fabric and these layers. It is important that these layers be adjusted similarly, thereby maintaining relative positioning. An edit of the cadastral fabric may include an adjustment of the coordinates of a group of parcels. When an edit is inserted in the cadastral fabric the new coordinates for existing points are compared against the old coordinates for the point and a set of displacement vectors stored in a table. Thus the cadastral fabric holds a sequential record of adjustments for each point. These displacement vectors can then be used to adjust any other feature class.

Because adjustment areas can overlap it is important that adjustment order is applied correctly and displacement vectors for each adjustment are tagged with a sequence ID. The logical grouping of these vectors allows ad hoc adjustments to feature classes.

Concluding Remarks

GPS makes it possible to quickly coordinate data points to centimetre accuracy, and the software systems which take advantage of the new 64-bit computer technology will allow millimetre precision for coordinates, regardless of the extent of coverage. This means that GIS can hold master datasets for information with engineering, modelling and design systems, alongside traditional GIS data. All that is required is recognition of the specific requirements of survey and cadastral data and suitable subsystems that properly manage them. As the cadastral dataset is a fundamental layer upon which so many others are based, it is important that it be as accurate and complete as possible.

Further Reading

- Michael Elfick, Australia, Tim Hodson, South Africa and Curt Wilkinson, USA, "Managing a Cadastral SDI Framework Built from Boundary Dimensions", FIG Working Week, Cairo, 16-21 April 2005.