FUTURE TRENDS FOR MODERN DCDB'S, A NEW VISION FOR AN EXISTING INFRASTRUCTURE

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Abstract
A legal cadastral model allows for a seamless three dimensional description of interests in the cadastre. The delineating of these interests is achieved through definitions within the relevant acts, dimensions and notations on registered documents and the position of real-world features.

Our current digital cadastral databases were originally designed to emulate and replace the traditional paper based working maps. This usually models the cadastre as a series of flat layers. For example layers of cadastre for base cadastre, strata, secondary interests and administrative boundaries.

As cadastral interests become more geometrically complex and the requirement for information integration increase a new model of the digital cadastral database is required.

Introduction
Legislation and case law enshrines a legal model for our cadastre. This legal model allows for the definition and reinstatement of the extents of an interest in land. For example a plan of survey may contain a lot defining an interest, using metes and bounds. Common Law doctrines determine the extent of the interest in height (Brown, A.G. 1980).

This legal cadastral definition provides for a seamless three dimensional topological definition of interests. Within our digital cadastral database we are attempting to (partially) model the spatial extents of these interests.

Digital cadastre databases continue to evolve and be used in a broad range of contexts. The delineation of what data belongs in a cadastral database becomes more diluted as the integration of once separate information themes become seamless to the user.

Cadastral data could be defined as "the geographic extent of the past, current, and future rights and interests in real property including the spatial information necessary to describe that geographic extent" (FGDC 2003). Another more general definition may be, any data required for the purpose of supporting land administration processes.

Legislation in Queensland requires the creation and maintenance of the State digital cadastral dataset (Survey and Mapping Infrastructure Act 2003). This digital cadastre is required to contain a digital graphic representation of each parcel of land in the State, a unique description for each parcel of land and the approximate coordinates for the corners of the parcels. Parcels of land shown on a building format or volumetric format plan of survey are not required to be included.

Additionally a digital graphic representation of roads; and natural features forming a boundary of land and the approximate coordinates of the roads and natural features is also required within the State digital cadastre dataset.

Current State
The introduction of the Queensland Digital Cadastral Database (DCDB) replaced some four and a half thousand working maps throughout the department. These maps were used to create a base cadastral coverage at scales from 1:25000 to 1:2500 depending on the density of parcels.

Working maps were maintained by a variety of sections within the department including Titles, State Land and Valuations. Each section used the working map as a textural spatial index to relate their information to the cadastre.
For example the location of Identification Surveys, Permanent Survey Marks and showing notations like Proposed Road Closure actions.

In 1981 the department initiated the capture of the cadastre from these working maps. Working maps remained available at the public counters until 1992 when the completion of the Notings system meant all information previously shown on these maps was now captured within departmental systems.

The original intent of the DCDB was to provide a pictorial representation of the cadastre and to allow for the overlay and spatial orientation of the information that was previously displayed on the various departmental working maps. The maintenance of this digital cadastral dataset has since been enshrined in legalisation within the Survey and Mapping Infrastructure Act (2003). It should be noted that this does not call for a high degree of accuracy in the representation.

This method of creation of the departments DCDB is typical of how digital cadastres are initially created. As with many computerised information systems, the digital cadastre has been used in ways that were not originally designed for. This has driven requirements for greater accuracy and integration with other data themes. In conjunction with Local Authorities, numerical updates of the DCDB have been undertaken to improve the accuracy to a level that is more suitable for these secondary uses. Additionally in the western part of the State, imagery is being used to align the cadastral linework with visible evidence of occupation (eg. fence lines).

Figure 1 Cadastral boundaries over imagery.

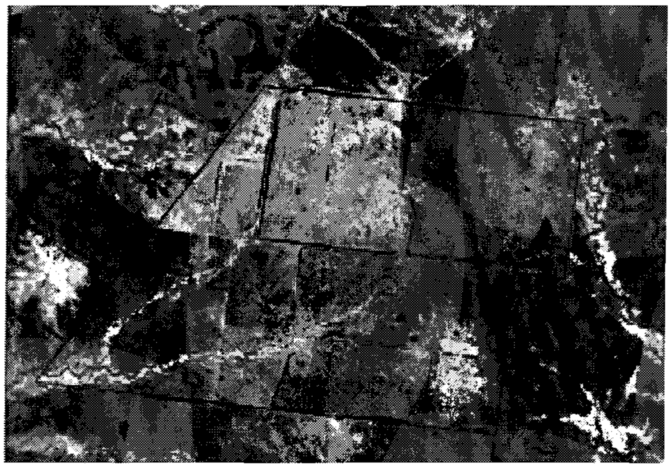

Figure 2 Cadastral boundaries aligned with imagery

Furthermore the cadastre has matured and more complex definitions for interests in land have been introduced. These include volumetric lots that are defined using three dimensionally located points to identify the position, shape and dimensions of each bounding surface, and building format lots that are defined using the structural elements of buildings (Land Title Act 1994).

Emerging Trends

Spatial data management has become a mainstream industry and there is a huge demand for clean, accurate spatial information. Digital cadastres are being used for land planning, management and monitoring at all levels of government and within private the private sector.

Emerging trends within digital cadastral environments include:

- An ability to maintain history (temporal)
- Requirement for higher spatial accuracy of cadastral corners
- Three dimensional cadastre with 3D topology
- Closer alignment with the legal cadastre it is trying to represent
- Use of the digital cadastre to define legal extents of interests
- Greater integrability with other data themes to support maintenance and land administration processes
- Distributed and automated maintenance
- Standards based delivery of cadastral information

- Three dimensional visualisation of the cadastre
- Greater integrability with other jurisdictions digital cadastres

Temporal

A temporal or time component may be used to show within a DCDB, when the database was updated, when cadastral lots existed, when tenures existed, or the absolute position of cadastral corners at a point in time.

A history of cadastral parcel update records the pattern of land use/ownership for historic studies. In the past, paper maps would be archived at certain intervals. There is the potential with a database which is maintained in an up-to-date form that this history will be lost.

System update is distinct from the cadastre update, but the two concepts are often confused. As the database is updated, a history of the updates must be maintained. That is to say, it is necessary to be able to view the database as it existed at times in the past. This arises from the need to supply updates to other parties (accompanied with "before images") and from the statutory need to be able to determine the "state of knowledge" of the government as at a particular time.

In the current Queensland DCDB, only the system update time dimension is carried, with it being used as an approximation to the legal update time dimension. The result of this is that if an error is located and corrected in the database, that error becomes part of "history", in that any information that pertains to a time period earlier than the correction will contain the error.

A tenure whose spatial extents are described by a cadastral parcel within the DCDB may only exist for a predefined period. At the end of this time the tenure (and parcel?) do not exist within the cadastre.

Changes in the spatial reference system and continental drift result in a change of the spatial coordinates of land parcels. No coordinate values are meaningful unless qualified by the spatial reference epoch.

Cadastre Alignment

To allow a digital cadastre to more closely align with the legal cadastre it is necessary to model the legal concepts within the digital cadastre. For example a standard format lot is spatially described in two dimensions on a plan of survey. Common law defines the extents of this lot (interest) in height. Whilst the digital cadastral may store this lot in two dimensions, it must be remembered that the actual interest is three dimensional in fact. Therefore a three dimensional intersection should be possible with a volumetric format lot that is described and can be stored in three dimensions.

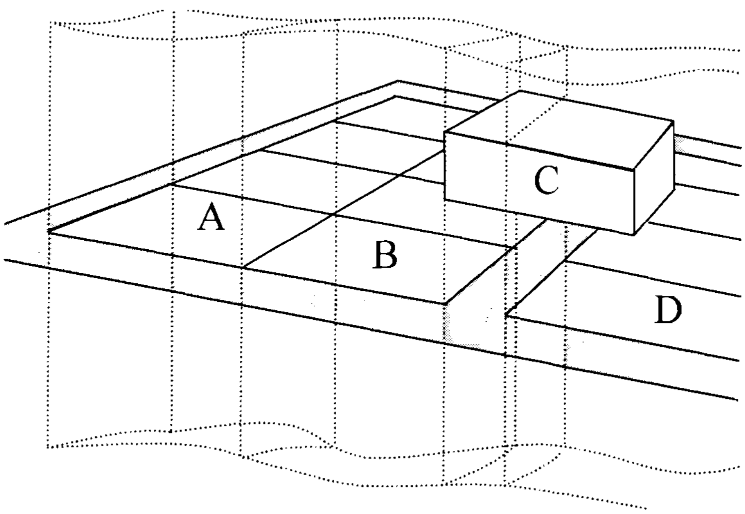

Figure 3 Intersection of volumetric lot with standard format lots.

A digital cadastral model may need to allow for the inclusion of parcels that are described in zero, two or three spatial dimensions. For example we may not be required to observe a meets and bounds description for a building format lot as it is legally defined by structural elements of a building. As such we cannot currently produce accurate three dimensional spatial extents for the lot within a digital cadastre, because this information is not available in a format that can be entered. A representation of the boundaries of the lot could be added to the digital cadastre from building plans etc., but there is a distinction between this and the volumetric plan.

If we wish to be able to fully provide a spatial representation of the extents of the legal cadastre then additional information over what is required for the legal definition will have to be captured and maintained within the digital cadastre. Once captured it is desirable to be able to enforce topological principals between both two and three spatially dimensioned lots.

Multi Dimensional Cadastre

The ability to define and register volumetric or restricted height parcels within a cadastre is at different states of maturity within cadastres around the world.

These concepts are highly developed and well understood within the Queensland Cadastre, but in common with most of the world (Stoter and van Oosterom 2006) no attempt has yet been made to include a height dimension within the Queensland digital cadastral database.

While the cadastre maintains the definitions of 3D objects, these are not stored in 3D in the DCDB. Only the parcel footprints are recorded in the DCDB. The term "footprint" needs some definition. The DCDB stores in effect the "shadow" of the parcel, not the intersection of the parcel with the ground (as is implied by the word "footprint").

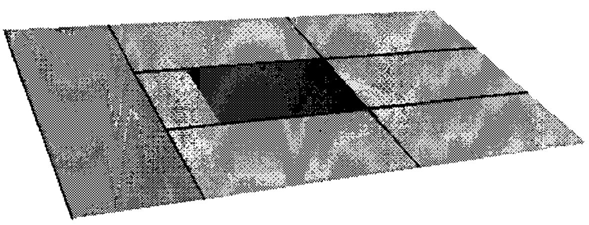

Figure 4 Standard format lot and volumetric lot footprint as stored in DCDB.

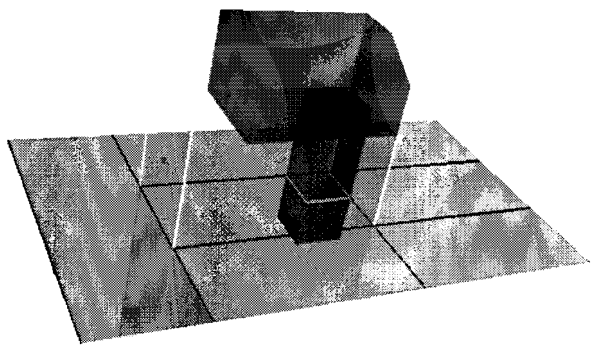

Figure 5 Standard format lot and volumetric lot shown with third dimension.

Research is currently being undertaken around the world on how 3D topology can be implemented within a digital cadastral system.

Digital Cadastre as a Legal definition

As digital cadastres mature into a digital representation of the legal cadastre and survey (plan) accurate information is used to determine and adjust the cadastral corners within the DCDB there may be an opportunity to use this information in reinstating the boundaries of the cadastral parcels on the ground.

To adopt the definition of cadastral corners within the adjusted digital cadastre would require change from a system of reinstatement based around monumentation as proof of the location of the boundary to one of coordinates. This then raises the question "In what instances are we willing to disregard the prior definition on the ground and its intention for a coordinate?" (Degg M. 2001).

Within the Queensland cadastre not all boundaries can be directly represented within a spatial cadastre. For example a parcel boundary may be defined by a real world feature such as a river bank or event such as the position of high water mark. This boundary is observed and a point in time representation for this boundary is then inscribed on a plan of survey. The plan determination is then spatially captured and stored within the digital cadastre. The digital cadastres position for the boundary may differ from any future directly observed determinations of the natural feature boundary due to natural movement or refinements in how the boundary is observed. In practice, the representation in the cadastral database will not reflect the current legal boundary. Nevertheless, the current legal boundary is fully defined, and remains coincidental with the real world feature.

Coordinate Survey Areas may be identified within the cadastre where the coordinates are highly considered in a hierarchy of evidence. These coordinate should support the existing monumentation not be in conflict to it. Coordinate survey areas will probably require a network of coordinated reference marks (monuments!) to allow for the local reinstatement of the cadastre.

Ultimately in a point-of-truth digital cadastre there is the potential for a subdivision of the extents of an interest to occur and be registered without the need to receive boundary definitions or observations from the real world. This automated cadastral system would contain the recognised legal extents of the cadastral lots. At a later time, if required, monuments could be placed showing the extents of these.

Land Information Management Integration

Within land management processes there is a need to relate many interests in land to the cadastre , (such as easements for power wires). Many interests that may affect the rights or obligations of a landowner and cause restrictions on land use are described in spatial terms. To identify if and where these interests affect a parcel of land they must be spatially related to the cadastre.

This requires the cadastre to be integrable within a wider land information management environment to allow for these interests to be correctly identified. Information models are being developed for the exchange and integration of data themes on both national and international levels. One example is the ICSM harmonised data framework which includes a metadata specification and a data model incorporating cadastre, topography, place names and street addresses (ICSM 2002).

Often the same entity is represented and maintained within multiple information systems. For example the extents of a particular road are included within the cadastre. This road is also exists within topographic, digital road network, addressing, place names and imagery themes of information. Within an information management environment it is desirable to be able to identify that they are all different representations of the same road. For example the process of changing the name of a road should be able to be managed once and propagated through all systems.

Major relational database management systems (DBMS) now include support for the ISO spatial data types and allow for spatial searching. In some DBMS this includes support for the storage and maintenance of topologically structured information. Commercial products are available that allow for enforcing topological alignment between layers of information. For example a secondary cadastral layer can be topologically aligned with the base cadastre layer and an administrative regions layer. These relationships can be maintained during an adjustment of the base cadastre.

There is a need to maintain information and relationships between cadastral entities at a level lower than a land parcel polygon or solid. For example to allow an adjustment to occur the relationships between land parcel corners, observations, and coordinated marks needs to be known. Also the type of boundary may determine the required adjustment method. For example a natural boundary may be adjusted differently to a right line boundary.

Persistent Identifiers (PID) are starting to be used to be able to uniquely identify points in the cadastre. These PID's can be used to define the relationships between parcel boundaries, cadastral corners, reference marks, coordinated marks and observations. This allows, for example, a cadastral corner to have a history of positions, each determined as a result of an adjustment of the surrounding cadastre.

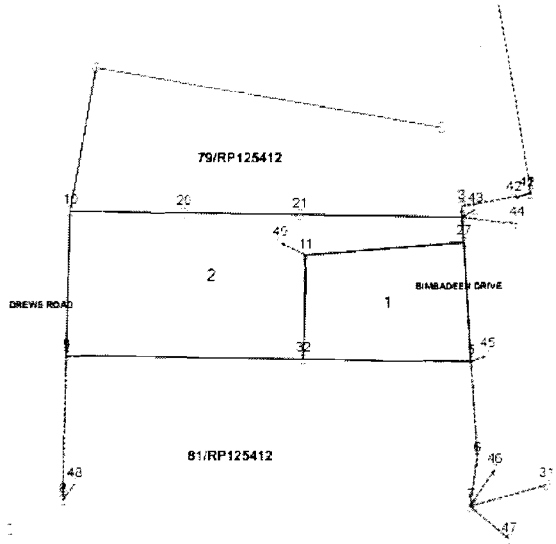

Figure 6 Snapshot from ePlan Capture application showing PID's at cadastral corners and reference marks.

Maintenance
As the structure of the digital cadastre data becomes more complex the necessity for automated maintenance processes increase. ePlan is one such project that is being coordinated by the ICSM Electronic Lodgement and Transfer of Survey Data Working Group. This project is formulating standards on a national level for the interchange of survey plan information between private industry, local authorities and state governments. Similarly investigations are underway into the feasibility of storing and representing proposed subdivisions, prior to registration, to support the land development planning and assessment process.

Internationally work is being done on creating models for the sharing of cadastral data. For example the core cadastral domain model (CCDM) is being researched and developed in Europe. This model based on a view of the requirements of many Cadastral jurisdictions around the world, including Queensland, will help in creating standardized information services for an international context (van Oosterom1, P. and Lemmen, C. 2006).

Utilising the ePlan survey plan schema the Department is working towards allowing Surveyors to automatically check their digital survey plans for general lodgement conformance prior to lodgement. It is intended that in the future this check will include validating the topological conformance of the new survey with the existing cadastre in three spatial dimensions.

An issue to be addressed is: Do the current documents we use for the lodgement of changes to the cadastre provide enough detail information for the maintenance of the digital cadastre to the extended requirements as described above? A digital cadastre needs additional/different information to the legal cadastre that it is trying to model, particularly when requirements outside the basic legal requirements of a cadastre are to be accommodated.

Visualisation

Historically a plan of survey has also been used to convey a pictorial representation of parts of the cadastre. This representation has been cartographically produced to provide detail for an unambiguous description of the boundaries of the parcels shown on the plan. For complex parcel formats (eg. a volumetric lot) isometric views and lateral aspects are used to provide enough detail. With the electronic lodgement of survey plans will arise the requirement to be able to reproduce the cartographically produced representations of the cadastral parcels.

Visualisation tools exist for 3D, but showing only 3D cadastral parcels, in the absence of building outlines in 3D, they present a very sparse picture. The Berlin model deserves consideration, being a true representation of the city cadastre, which is maintained and updated. Beyond the "fly through" it provides real functionality to identify buildings, properties, roads etc, and to display data pertaining to them (Döllner *et al.* 2006).

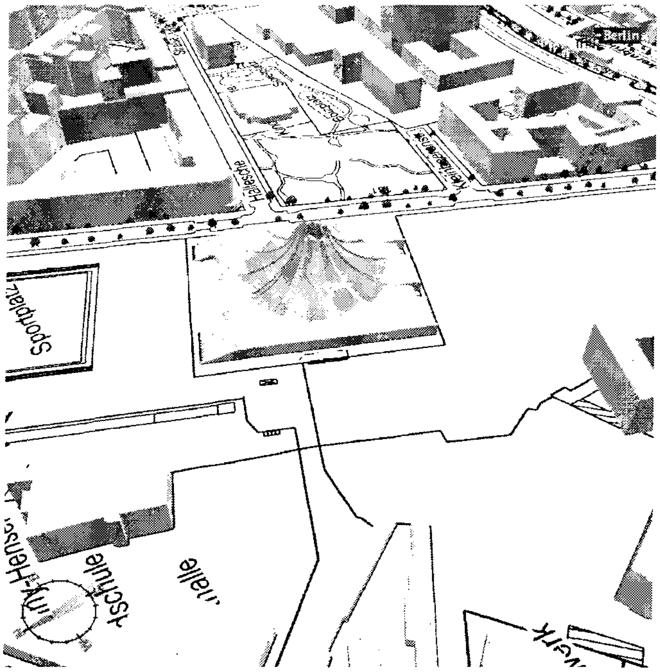

Figure 7 Example of cadastre and buildings in Berlin 3D Stadtmodell

Conclusions

The digital cadastre dataset is one theme of information within a wider land information environment. Within the department this information includes; survey control infrastructure, topographic information, imagery, administrative boundaries, administrative notings, valuations, place names and addressing.

Digital cadastres are an integral part of the land administration process. They provide a mechanism for spatially presenting and determining the relationships between cadastral parcels and the rights and restrictions that may affect them. More effective determinations will be able to be made as digital cadastres adopt three dimensional representations for cadastral lots and naturally enforce topological constraints between cadastral parcels and layers of cadastre based restrictions.

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References

Brown, A.G. (1980),. Law Relating to Land Boundaries & Surveying. Association of Consulting Surveyors, Queensland.

Degg, M. (2001). Bringing the Pastoral Boundaries of the Northern Territory Online, *2001 A Spatial Odyssey - 42nd Australian Surveyors Congress,* Brisbane, Australia.

Döllner, J., *et al.* (2006), The Virtual 3d City Model of Berlin: Managing, Integrating and Combining Complex Urban Information, *25th Urban Data Management Symposiun*, Aalborg Denmark.

FGDC (2003), Cadastral Data Content Standard for the National Spatial Data Infrastructure, Version 1.3, Subcommittee on Cadastral Data, Federal Geographic Data Committee.

ICSM (2002), Harmonised Data Manual, Intergovernmental Committee on Surveying & Mapping, Available online at www.icsm.gov.au.

Land Title Act (1994), Office of the Queensland Parliamentary Council, Sec 48.

Lemmen, C., *et al.* (2003), A Modular Standard for the Cadastral Domain, *Digital Earth Information for Global Sustainability*, Brno, Czech Republic.

Stoter, J. and van Oosterom, P. (2006), *3D Cadastre in an International Context,* Taylor & Francis, Boca Raton FL.

Survey and Mapping Infrastructure Act (2003), Office of the Queensland Parliamentary Counsel, Sec 46.

van Oosterom, P. and Lemmen , C. (2006), The Core Cadastral Domain Model: A Tool for the Development of Distributed and Interoperable Cadastral Systems, *International Conference on Enhancing Land Registration and Cadastre for Economic Growth in India*, New Delhi, India.