Introduction

The importance of managing stratified ownership land rights, restrictions and responsibilities (RRRs) are increasing due to population growth and land shortage, particularly in urban areas. As a result, stakeholders are looking for ways in order to manage land and property information more efficiently. Current approaches for managing and visualising land ownership rights are not efficient in very dense and complex urban areas. Figure 1 represents an example of complex modern structures.

Providing the required land and infrastructure facilitates sustainable urbanisation (UN-HABITAT, 2002). For this reason, efficient systems are required to record, manage and visualise ownership information.

Cadastre is a land information system containing a record of interests in land and includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel (FIG, 1995). Currently, cadastres are mainly based on 2D land parcels and use 2D representation methods (e.g Plans of subdivision—Figure 2) to visualise ownership rights. Although, ownership rights are currently registered using this approach, there are many shortcomings such as:

- Representing high-rise buildings and developments: due to the complexity of multi-level developments, numerous plans and sections are required;
- Lack of interactivity: it is not possible to rotate paper plans in different axes, or zoom to a specific component or get more information from the plans;
- Storage and updating: they are maintained in paper and PDF files, modifications are not easy or efficient;
- Queries and analysis: searching and measurement can only be done manually;
- Representing RRRs: Although, 3D ownership information is presented in plans of subdivision, it is limited to present some rights, restrictions and responsibilities. For example, height and depth limitations are not represented spatially in subdivision plans;
- Interpretations: Interpreting complex plans are not easy and it is very time consuming;

In addition to these issues and shortcomings, emerging three-dimensional (3D) technologies have encouraged specialists to utilise new technologies for cadastral applications. New 3D data acquisition techniques, 3D spatial databases such as Oracle for managing 3D data, 3D visualisation platforms such as WebGL, and 3D printers are some examples of the recent 3D technologies.

These 3D techniques can be utilised to develop cadastres to represent and manage ownership rights in 3D. By providing a 3D representation of RRRs corresponding to legal and/or physical boundaries, a 3D cadastre also has the potential to serve a wide variety of relevant applications such as property management, urban planning, real estate management, urban facility management, navigation, public, safety, disaster management, radio network planning, and noise emission mapping (Figure 3). 3D cadastres would assist in the management of layered and overlapping RRRs by being capable of storing, manipulating, querying, analysing, updating, and supporting the visualisation of RRRs in 3D.

Although many activities and studies have been conducted in the domain of 3D cadastre over the last decade, there is no fully-operational 3D cadastre in the world and the functionality is limited to some basic activities such as registering volumetric parcels (van Oosterom, Stoter, Ploeger, Thompson, & Karki, 2011). One reason is that the requirements of a fully-operational 3D cadastre are not clear enough for developers to design specific platforms.
For developing a 3D cadastre, various aspects need to be considered namely technical, legal and institutional aspects (Aien, Rajabifard, Kalantari, Williamson, & Shojaei, 2011). Within the technical aspects, visualisation is one of the most important elements of a 3D cadastre since 3D visualisation facilitates understanding of ownership boundaries especially in layered properties. A 3D cadastre enhances communication via visualisation between cadastral users as well as various stakeholders such as governments and private sectors such as developers, architects, councils, strata managers, surveyors, and real estate agents. In the following sections, 3D visualisation is discussed further for cadastral applications and a methodology for developing a potential visualisation system is described.

**3D Cadastral Visualisation**

In seeking to define cadastral visualisation requirements, certain questions arise. Who are the users? What are their uses? In the 3D cadastral domain, several prototype systems have been developed. However, in most of these developments, users, usages, and platform specifications have not been defined clearly. In this regard, Pouliot (2011) addressed some of these issues in 3D cadastral visualisation and suggested further investigations in these areas. Also Shojaei et al (2013) listed some of the main functions and technical requirements for developing a prototype system for 3D cadastre in Australia such as visualisation of above and underground objects, and using visualisation variables to represent cadastral objects.

The above questions are answered based on jurisdictional requirements since each jurisdiction might have different policies, data, laws, cadastral system, etc. This research intends to address these questions through a range of qualitative and empirical research methods (Shojaei, Kalantari, Bishop, Rajabifard, & Aien, 2013).

**A. Who are the users?**

Cadastral users can be classified into two main categories namely direct and indirect users. Direct users are involved in the land development process and play important role. Direct users are registrar, the public, surveyors, councils, architects, developers and real estate agents, etc. Indirect users are those users who are not directly involved in the land development process, but they benefit from that. Insurance companies, taxation offices, emergency services are some of the indirect users. They have different expectations and needs in visualisation. In this research, the visualisation requirements of direct users will be identified through surveys and meetings. These requirements are very important for designing and developing 3D visualisation systems for cadastral applications.

**B. What are their needs?**

Different users have different expectations. Also, each jurisdiction may benefit from cadastre differently. For instance, Victoria uses two types of representation methods (LASSI system and subdivision plans) to communicate cadastral information – this corresponds to two specific needs. Firstly, subdivision plans are used for titling purposes in order to delimit ownership boundaries and can be referred to for cadastral disputes as they include survey-accurate and authoritative observations. Indexing is the second need, required to facilitate information searches to locate parcels based on the address or the plan number. These two main types of usages are identified in the cadastral system in Victoria (Shojaei, Rajabifard, Kalantari, Bishop, & Aien, 2012).

To develop visualisation requirements, interviews with stakeholders were held, primarily with Victoria’s land administration agency, Land Victoria, and the Surveyor-General’s Office, as well as with staff at City of Melbourne, City of Geelong, City of Stonington, licensed surveyors, strata managers, and lawyers. Meetings with specialists and users of cadastral systems were held and their requirements for 3D visualisation were identified.

Based on the identified and developed requirements, a visualisation platform was designed and implemented. In this system, various users and their expectations were considered in the design phase. Further investigation was also conducted by evaluating the prototype system using a survey to finalise undeveloped parts and functions in the system. This evaluation could prove the efficiency of the system to represent ownership rights in 3D. Figure 4 represents a snapshot of the developed prototype system.
Conclusion

Multi-level developments and underground structures are examples of increasing three-dimensional land development and land use. However, current cadastral systems are not efficient for managing these complexities. Also, modern technologies emerged widely which can be used for cadastral applications. Accordingly, decision makers are looking for techniques and methods to manage land ownerships more efficiently.

This article addressed the current issues in representing ownership rights in current cadastres. In addition, it presented a methodology for developing efficient 3D visualisation systems for cadastral purposes based on users and usages. In this research, a prototype system has been developed which meets many users’ requirements.

About the Project

This research is part of an Australian Research Council Project titled “Land and Property Information in 3D” at the Centre for SDI and Land Administration, the University of Melbourne (Rajabifard, Kalantari, & Williamson, 2012). A variety of industry partners from government and private sectors who operate in cadastral domain are participating in this project. They include architectural, surveying, and property management companies, and property registration authorities. Authors would like to thank the research partners for their support and provision of data. However, the views expressed in this paper are the authors’ and do not reflect any of these parties’ points of view.

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