Development of a 3D ePlan/LandXML Visualisation System in Australia

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Key words: 3D Visualisation, 3D Cadastre, ePlan, LandXML, Australia

SUMMARY

The importance of managing properties and people's interests in complex multi-level developments is increasing, due to population growth and shortage of land in urban areas. As a result, cadastral systems are under pressure to change the way they capture, register and visualise 3D data of these multi-level scenarios. However, interests in land and properties in Australia are registered and visualised through subdivision plans. This visualisation method is often paper-based and includes 2D floor plans, cross-sections and isometric diagrams. These drawings are used to represent 3D properties and associated rights. Although this has been a common practice for experts such as land registration officers and cadastral surveyors, non-expert users such as the public, lawyers and real-estate agents often find these methods difficult to understand and interpret particularly in complex high rise buildings.

In order to visualise and represent properties and associated rights in 3D, a web-based prototype system was designed and developed utilising various technologies to enable a wide variety of users to explore 3D ownership rights. The prototype system's architecture is based on a three-layer framework including, data access, process and presentation layers to represent cadastral data such as Rights, Restrictions and Responsibilities (RRRs). For developing the prototype system, the subdivision plan components and the electronic surveying and subdivision plans (ePlan) were studied and analysed. In this web-based prototype system, 3D LandXML files are converted to KML data format using Extensible Stylesheet Language Transformations (XSLT) and are visualised in the Google Earth API. Furthermore, attribute information such as bearing and distance, attached to subdivision plans, is also represented in this system.

Although this prototype system is not able to visualise underground RRRs, it has potential to represent interests in land and properties through the Internet. This paper concludes that ePlan data model is able to contain 3D volume objects to store 3D interests in land and properties.

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1. INTRODUCTION

Population growth and shortage of land in urban areas increase the importance of land administration role in managing properties and people's interests in complex multi-level developments. Current land administration systems are mainly based on land parcels (Kalantari et al., 2008) and 2D land administration systems cannot effectively manage and represent RRRs in complex 3D structures (Rajabifard et al., 2012, Aien et al., 2012). For example, these complexities are various types of spaces above and below the ground level, underground developments, infrastructure facilities, high-rise buildings and apartments. Current registration of properties in most of countries and jurisdictions is paper-based (plan of subdivision) using 2D drawings (floor plans, cross-sections and isometric diagrams). Although plans, cross-sections and isometric diagrams are common practice for professionals, lay people find these drawings difficult to understand and interpret. Figure 1 presents a sample of cross-section diagram in a plan of subdivision in Victoria, Australia.

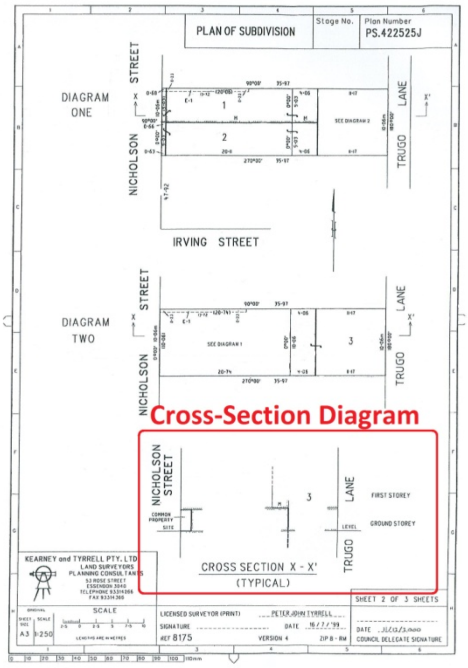


Figure 1. A sample of cross-section view in a plan of subdivision in Victoria, Australia

Paper-based subdivision plans (2D) are not an efficient method for RRRs representation and have the following limitations:

- Users have difficulty to measure the areas of properties. In plans of subdivision lengths are labelled, but area calculation is not possible. Also due to the 2D based drawings, volume computation is not feasible;
- Data are not stored digitally and storing and updating of cadastral data are not easy and efficient. For updating a subdivision plan, all drawings are repeated;
- RRRs are not registered digitally in a database and queries and analyses are not supported; and
- Visualisation is restricted to 2D paper or screen based representation and interactive visualisation is not possible.

In addition to needing to overcome the above limitations, the availability of faster and more efficient technologies is driving the replacement of these traditional 2D representation methods with 3D storage and visualisation methods. The available 3D technologies are used widely in various applications for simulation and visualisation. For example, game engine, virtual reality and augmented reality technologies are utilised to develop visualisation and simulation systems.

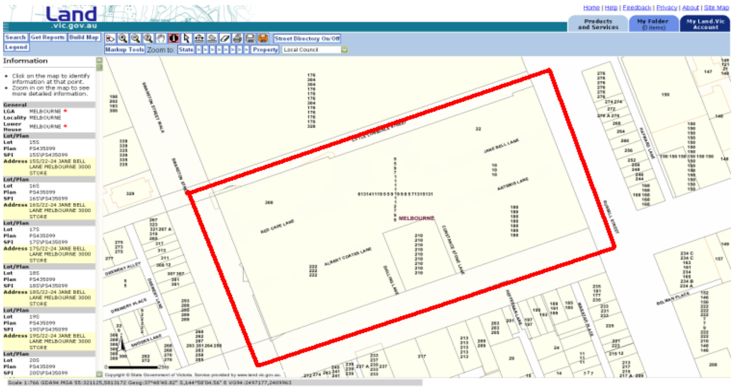
Due to the above-mentioned shortcomings and the availability of current 3D technologies, first there is a need to move from a 2D paper-based visualisation method (subdivision plan) to a 3D digital method. The Intergovernmental Committee for Surveying and Mapping (ICSM) developed the ePlan protocol for the transfer of 2D cadastral data between the surveying industry and government in Australia. The ePlan is the first attempt to record ownership information in a digital way to facilitate data flow for the process of land and property registration. Land surveyors can record ownership information and people's interests in 2D LandXML files based on ePlan protocol to submit their measurements and drawings to the authorities (ICSM, 2009). However, ePlan protocol in Victoria is based on 2D and does not support the third dimension (Aien et al., 2011a, Aien et al., 2012).

This paper first addresses the current status of 3D cadastre in Victoria, Australia. In section 3, a move from 2D to 3D is described and ePlan data model and Land XML schema are investigated. In section 4, visualisation of 3D cadastre and current practice in the world will be discussed. Finally, a prototype system for visualisation of ePlan/LandXML files is presented.

2. CADASTRE IN VICTORIA, AUSTRALIA

The cadastral system in Victoria is parcel based. In this system, structures above or below the ground level are not recorded in the cadastral map. However, tunnels and other underground structures might be recorded in the cadastral map (Aien et al., 2011b). In this system, ownership rights are registered based on 2D parcel in subdivision plans using paper diagrams. Although this method of registration can describe non-complex developments (e.g. one storey building) easily, this method is not efficient for multi-level and complex scenarios. For instance, Figure 2(a) shows the QV Building in Melbourne, Australia. Various types of RRRs exist in this development. This building has 962 lots which including underground car park, shops, restaurants and residential areas. In the Digital Cadastre Database (DCDB) of Victoria, ownership information is stored and presented in a web-based system (See Figure 2(b)). Based on Figure 2(b), this multi-level development is represented by one parcel. This parcel contains the information of lots (subdivision plan numbers) located in this structure. To access the RRRs information for each property, subdivision plans can be retrieved using the subdivision plan numbers.

(a)



(b)

Figure 2. (a) A view of the QV Building in Melbourne, Australia (Google Earth, 2012) and (b) the QV Building in DCDB in Victoria (http://services.land.vic.gov.au/maps/interactive.jsp)

Based on Figure 2(b), interests in 3D are visualised in a 2D web-based system which only represent 2D parcels and more detailed information is accessible through the subdivision plans which are paper-based and two dimensional. It is clear that these methods of representation are not efficient for visualising RRRs particularly in multi-level developments. To improve the ownership registration and visualisation, there is a need to move from a 2D cadastral system to a 3D system which is able to store, register and manage RRRs in 3D.

The 3D cadastre visualisation system could serve not only property management and land administration, but also a wide variety of other application fields, such as environment protection, climate change, urban planning and decision making, and disaster management (Erba, 2012).

3. MOVE FROM 2D TO 3D

Several steps are involved in the process of generating a 3D ePlan/LandXML file. In this process, all information in a paper-based subdivision plan is recorded in 3D ePlan/LandXML file. At first, it is essential to identify the components of a subdivision plan and an ePlan/LandXML file.

3.1 Subdivision plan

The plan of subdivision contains drawings that represent the layout of the lots (land, building, air space) and provide all necessary information about the development such as easements and restrictions (Libbis and Leshinsky, 2008). The plan of subdivision is registered in Land Victoria within the subdivision process. Subdivision plans are prepared based on the Subdivision Act 1988 and are certified by the responsible municipal council. Figure 1 presents a sample of a subdivision plan in Victoria.

Subdivision plan includes various details and based on the Subdivision Act 1988, subdivision plans in Victoria have a style for representing rights and associated information. A subdivision plan includes two main parts, face sheet and diagrams. The first part, face sheet, has some textual information such as the location of the land, notation, easement information, land surveyor signature etc. The second part includes diagrams to describe the geometry of rights and includes plans and cross-section diagrams. There are also other types of information attached to the subdivision plan such as surveyor's report, abstract of field records, survey observations, and coordinates to explain the rights clearly.

3.2 LandXML

LandXML is a XML-based data format which is widely used to exchange civil engineering and survey measurement data. LandXML schema has the following main components:

- Initialization
- Metadata
- Geometry
- Survey Data

Initialization specifies units, coordinate systems and application which is a description about the application that created a LandXML file. Metadata includes some description about the data such as name, version, date, and comments. Geometry is the main part of the schema and contains geometrical information such as coordinates, parcels, and surfaces. Survey Data includes information about the surveying process such as survey observations and metadata of the surveying configuration.

3.3 ePlan

In Australia, cadastral data were transferred by subdivision plans between the surveying industry and authorities for registration. In 2009, a working group sponsored by the ICSM developed the ePlan data model to transfer digital cadastral data. The ePlan data model was accepted as a national data model and adopted as a standard in Australia. Cadastral Information File (CIF) is called a LandXML file that contains information in a subdivision plan based on the ePlan schema. There is an automatic process, Streamlined Planning through Electronic Applications and Referrals (SPEAR), in Victoria which is used to control and examine the plans (CIF) (**http://www.spear.land.vic.gov.au/spear/**) at the submission time to reduce the errors and enhance the accuracy of DCDB. SPEAR system has changed the subdivision plan delivery process from a paper-based method (plans of subdivision and related documents) to a digital process (Kalantari et al., 2009).

3.4 Evaluating ePlan data model and LandXML schema to store 3D objects

In order to evaluate the potential of the ePlan data model and LandXML schema to contain 3D objects, a subdivision plan from Victoria was selected (Figure 1) and a prototype 3D ePlan/LandXML file was generated based on this subdivision plan.

In the ePlan data model, various geometric primitive objects such as point, line, curve, irregular line, polygon and volume are defined. The following structure is used in the ePlan for storing the geometry of objects:

- CgPoints (include attributes and position which can be 2D or 3D);
- Parcels (include attributes, CoorGeom (boundary of parcels defined by lines, irregular lines and curves) and VolumeGeom (volumetric parcels defined by its faces));
- Surfaces (digital terrain models); and
- PlanFeatures (generic geometric data like fence lines, as-built data (curbs, building outlines, etc.)).

In order to create 3D objects the following methods of volume representation have been identified by Lattuada (2005):

- Sweep Representation;
- Primitive Instancing;
- Constructive Solid Geometry;
- Boundary Representation;
- Spatial Occupancy Enumeration; and
- Cell Decomposition.

Among these methods of volume representation, boundary representation is used in the ePlan data model to define volumetric objects (VolumeGeom). In this method, an object is specified by its bounding surfaces. For example, for representing a box in 3D, six faces are defined (Figure 3).

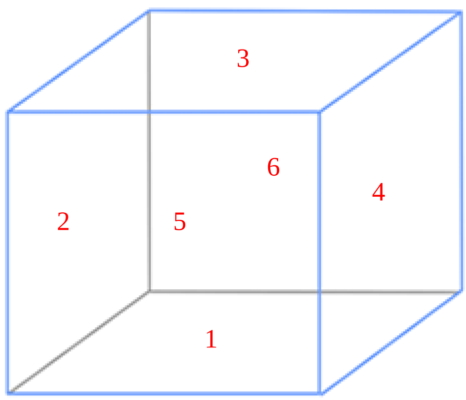


Figure 3. A 3D box made by 6 faces

Based on the LandXML schema, these six faces are defined by six CoordGeoms and each CoordGeom is defined by four lines. Furthermore, each line is constructed using two CgPoints as endpoints. Figure 4 demonstrates how a VolumeGeom can be created based on the ePlan/LandXML schema.

```
<LandXML>
        <Parcels>
                <Parcel>
                        <VolumeGeom>
                                <CoordGeom><Line></Line><Line></Line><Line></Line><Line></Line></CoordGeom>
                                <CoordGeom><Line></Line><Line></Line><Line></Line><Line></Line></CoordGeom>
                                <CoordGeom><Line></Line><Line></Line><Line></Line><Line></Line></CoordGeom>
                                <CoordGeom><Line></Line><Line></Line><Line></Line><Line></Line></CoordGeom>
                                <CoordGeom><Line></Line><Line></Line><Line></Line><Line></Line></CoordGeom>
                                <CoordGeom><Line></Line><Line></Line><Line></Line><Line></Line></CoordGeom>
                        </VolumeGeom>
                </Parcel>
        </Parcels>
</LandXML>
```

Figure 4. VolumeGeom element in a LandXML file

The case study (the subdivision plan) has three lots, one common property and one easement. Therefore, five volumes are defined to represent the subdivision plan. Figure 5 illustrates a 3D model of the case study property.

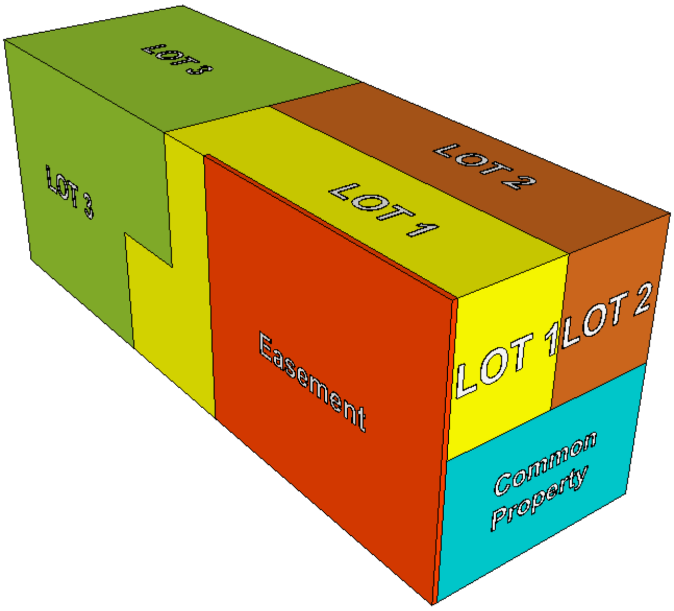


Figure 5. A 3D model of the case study property

For each a volume, a VolumeGeom is created and named based on the attributes in the subdivision plan. Lots, easements and common properties are classified using the attributes in the ePlan schema (Figure 6). The following Figure represents how different 3D volumes of the subdivision plan have been created.

```
<Parcels>
	<Parcel name="PS123456789">
		<VolumeGeom name="Lot1"> </VolumeGeom>
		<VolumeGeom name="Lot2"> </VolumeGeom>
		<VolumeGeom name="Lot3"> </VolumeGeom>
		<VolumeGeom name="Easement1"> </VolumeGeom>
		<VolumeGeom name="CommonProperty"> </VolumeGeom>
	</Parcel>
</Parcels>
```

Figure 6. VolumeGeom definition for a parcel

In addition to the geometry of subdivision plan, attribute information, such as header and observations are recorded in LandXML files in the same template as 2D LandXML files. In this section, an ePlan/LandXML file was generated based on a subdivision plan and ePlan data model. For visualising ePlan/LandXML files, various 3D technologies are investigated in the following section. Furthermore, current status of cadastral visualisation in some countries is described.

4. CURRENT VISUALISATION PRACTICE FOR 3D CADASTRE

Visualisation is an important component in a 3D cadastre and enhances communication with users. The current technology of visualisation is powerful enough to represent 3D objects such as buildings, vegetation, streets and underground utility networks. Currently, there are many 3D visualisation platforms for various applications. However, at this moment, there is no identified platform to fully support 3D cadastre.

In 3D cadastral visualisation, various issues need to be considered such as data exchange formats, data models, platforms (desktop, web and mobile-based systems), and data storage. Pouliot (2011) has described some of the important issues and problems regarding 3D cadastral visualisation.

Currently, 3D web-based visualisation software products are used widely in various applications. Google Earth, TerraExplorer (SkylineGlobe) and World Wind (NASA) are examples of 3D visualisation platforms. These platforms are developed for general 3D visualisation applications.

For 3D cadastre visualisation, some prototype systems have been developed. Stoter and Zlatanova (2003) used MicroStation Geographics (Bentley), ArcGIS (ESRI) and VRML for visualisation of 3D cadastral data. Another example of a web-based system was implemented by Trias et al. (2011) using Google Earth API to visualise ownership information.

Guo et al. (2011) used a combination of ArcGIS Server, Skyline TerraGate and SketchUp to visualise 3D cadastral data. Their system's architecture is a desktop platform, but TerraGate and ArcGIS Server can be utilised for web-based applications. Vandysheva et al. (2011) identified some functional requirements for developing a web-based visualisation system for 3D cadastre in the Russian Federation based on experience of the Netherlands and other countries. They have identified some functions and tools for the prototype system such as visualisation and interaction with 3D cadastral data (rotate, zoom, pan, select, etc.), display attribute data (id, cadastral number, and address), find and select based on attributes (Vandysheva et al., 2012).

Cadastral systems have a wide variety of users with different requirements and also various platforms with different functionalities are required for cadastral users to meet their requirements. There is a need to investigate what are these requirements and what kinds of platforms are most appropriate for different users.

FIG Joint Commission 3 and 7 Working Group on 3D Cadastres (Work plan 2010-2014) have prepared a questionnaire to survey the status of 3D cadastre in countries and jurisdictions in 2010/2011. Thirty-six countries or jurisdictions have responded to the questionnaire. The questionnaire has explored various aspects of 3D cadastre such as the current status of 3D cadastre, utility networks and infrastructures, construction and building units, height representation, temporal representation, RRRs and use of DCDB. Some of the findings which are related more to the visualisation are summarized in Table 1.

Table 1. The current situation of 3D cadastre in various countries and jurisdictions adapted from FIG Joint Commission 3 and 7 Working Group on 3D Cadastres (Work plan 2010-2014).

Country Jurisdiction	Does the DCDB contain representation of 3D legal objects? How?	Are there possibilities to store geometry of 3D legal objects in the DCDB?	What (GIS/CAD) software is used for updating, editing, analysis, and visualisation?	Do the survey plans carry 3D legal objects representations?	In what format are the 3D legal objects submitted for registration?
Victoria, Australia	Yes, in limited circumstances, tunnel, and bridges. Layered	No	Internal, LASSI.	Yes, by 2D plans with cross section	LandXML (2D)
Queensland, Australia	Yes, as 2D polygons in a layer above (below) the base layer	No	Microstation, 3D capabilities not used at present	Yes	At present, on paper, but will be submitted in LandXML (only internally)
Austria	No	No	ArcGIS	No	As paper docs or PDF
Quebec, Canada	Not directly	No	Arc/info , DXF, 2D PDF	Only vertical profiles of the properties.	On paper
Finland	No	-	-	Yes. Detailed plans which cover only underground volume.	As plans registered in the public (town) registers.
France	No	No	Specific software of French cadastre MAJIC and PCI	No	As drawings and literal description in the registry.
Germany	No	No	No common	Yes, but just	Currently

			approach	basic information	XML/GML
Indonesia	No, 2D parcels only	No	AutoCAD3D	Yes, in 2008, collaboration with BPN to develop the methods	Coordinates
Italy	Yes, Geometrically on different levels	Yes,building distinguished by storeys and classified by numbers	DOCFA and PREGEO for the moment does not have any 3D functionality	Yes	In PDF format
The Netherlands	No. Attribute values of parcels may indicate a 3D situation	No	Fingis (future Intergraph Geomedia). No 3D used.	No	As 2D drawings registered in the public registers.

Based on the first and second columns, none of the countries or jurisdictions have a complete 3D DCDB for storing and representation of 3D legal objects. In some of the countries and jurisdictions, 2D polygons in a layer above or below the base layer are generated and stored for representing 3D legal objects (Table 1, Queensland, Australia).

Based on Table 1, many countries and jurisdictions use CAD/GIS software products for visualisation purposes, but most of them do not use the 3D capabilities and functionalities which are available in these products. The last two columns are concerned with 3D legal object representations and formats for submission of 3D legal object data to the authorities. Half of the countries and jurisdictions do not represent 3D legal objects and most of the other countries use 2D paper-based representations such as cross-section diagrams. However, some countries including Australia, Germany, Italy, Sweden, South Korea, Austria and Indonesia submit legal objects in a digital format.

Based on table 1, currently databases are not used for storing 3D right objects. This reflects the limitations of databases for storing complex 3D objects. While CAD and GIS software products are used widely, due to the 2D-based cadastral systems their 3D capabilities and functionalities are not used.

5. IMPLEMENTATION OF THE PROTOTYPE SYSTEM

Based on Section 3, the ePlan protocol is able to contain VolumeGeom as a 3D geometry object. For visualisation of the 3D ePlan/LandXML files, a platform is required.

For a better understanding of 3D cadastre concepts and to support discussion of the potential and challenges in 3D visualisation, a web-based prototype system was designed and implemented to visualise ePlan/LandXML files. The main purpose of this system is to enable a user to interactively explore a 3D property through the Internet in a client-side 3D visualisation system. To facilitate this purpose, the system offers functionality for importing and processing input data in the form of an ePlan/LandXML file. This prototype system visualises ePlan/LandXML files by converting them to the KML format for display in Google Earth.

In developing the prototype system various technologies were investigated and utilized. At first, for converting of ePlan/LandXML files to KML files a mapping is required. In this mapping, geometrical and associated attributes are extracted and mapped to the related nodes in the KML schema. One of the challenges is a risk of losing information or object relations during this conversion.

This mapping was implemented by using Altova Mapforce software. Figure 7 shows a view of this mapping in Altova Mapforce. Altova Mapforce created an XSLT (Extensible Stylesheet Language Transformations) file which is a XML-based file used for transformation of XML documents.

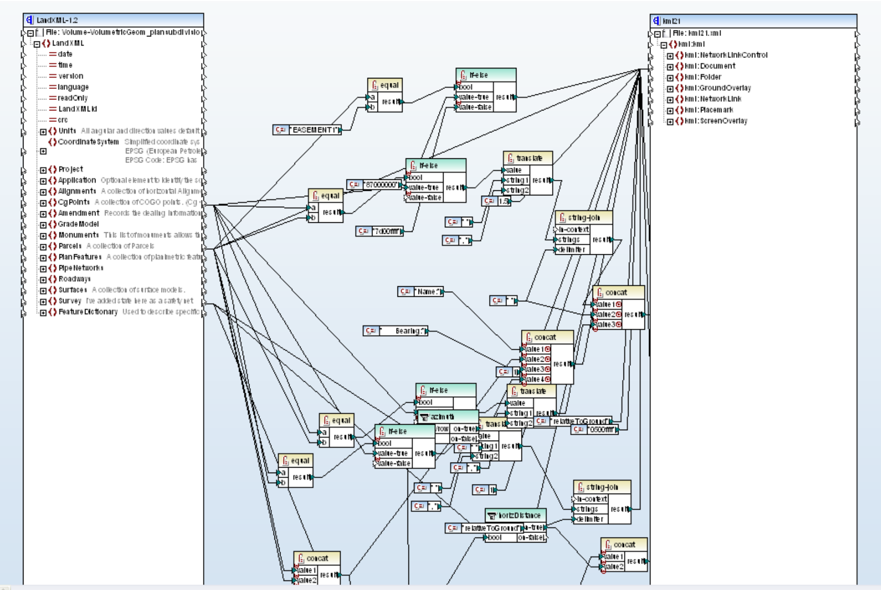


Figure 7. Altova MapForce for mapping the schemas

This XSLT file was utilised in a web-based platform for converting from ePlan/LandXML to KML files. The architectural framework of the system is presented in Figure 8.

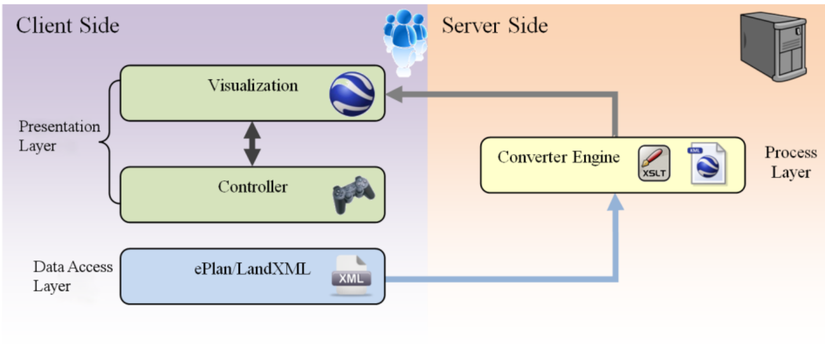


Figure 8. Architectural framework, the interactive visualisation. Arrows indicate the direction of major data flow

Based on Figure 8, in the data layer, an ePlan/LandXML file is uploaded on the server. The ePlan/LandXML file contains all information regarding the rights such as lot, easements and common properties (RRRs). In addition, cadastral attribute data such as bearings and distances exist in this file. Then this file is passed to the next layer. In the process layer, an XSLT file converts the ePlan/LandXML to a KML file. This KML file includes all information from the ePlan/LandXML file. LandXML was designed primarily for data transfer purposes and does not cater for visualisation features (Aien et al., 2011c) such as colour, transparency, and line thickness. Due to the limitation of ePlan/LandXML to support visualisation features, these features are defined and chosen automatically by the prototype system based on the type of the cadastral objects. For example, easements are defined by a specific set of colour, transparency and line thickness to distinguish from other objects (lots and easements). Also objects are labelled in the prototype system to represent attribute information attached to each such as type (lot, easement and common property). Furthermore, bearing and distance observations for each line are attached to it. During this conversion, the coordinate system is also changed. In the ePlan/LandXML file, the coordinates are based on MGA94 which is a UTM projection of the GDA94 datum and GRS80 spheroid. The coordinates in the ePlan/LandXML file are converted to the WGS84 geographic projection to fit in with the Google Earth specification. Finally, in the interaction layer, the output of the previous phase (KML file) is imported to the Google Earth API. Google Earth API is an easy-to-use service for visualising the Earth's surface and can produce a wide range of products. In Figure 9, a snapshot of this prototype system is presented. In this Figure, lots, easement and common property are presented in different colours. By clicking on the edges, additional information such as bearing and distance is displayed.

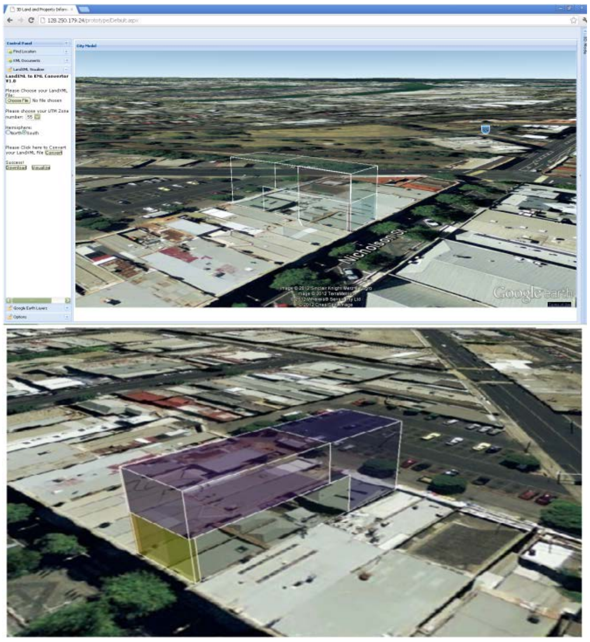


Figure 9. Visualisation of ePlan/LandXML file in a Web-Based prototype system

Developing these prototype systems could help to identify some previously undefined visualisation features and requirements in 3D cadastre and visualisation domains. In developing this prototype system, various technologies were investigated and their advantages and shortcoming were identified. One of the important advantages of this prototype is its ability to bring very simple and understandable views to the users. However, underground visualisation is mentioned as a one of the shortcomings of this system.

6. CONCLUSION

Currently, RRRs are registered and visualised through subdivision plan in Australia. These methods of representation are not efficient and have the following shortcomings:

- Only expert users can understand diagrams and it would be difficult for ordinary people to understand these representations;
- Interactive 3D visualisation is not possible;
- Measurements (area and volume) are not supported;
- Storing, editing and updating is not efficient; and
- Queries and analyses are not supported.

Due to these shortcomings and availability of 3D technologies in visualisation, the ePlan data model was investigated to find a method for storing 3D RRRs in LandXML files. Furthermore, a web-based prototype system was designed and developed to represent 3D ePlan/LandXML files. This system enables users to upload 3D ePlan/LandXML files and explore RRRs through the Internet.

Furthermore, from this research comes a need for more precise specification for visualisation. This specification defines how RRRs can be visualised effectively in a 3D cadastral system which is the future plan of this research.

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BIOGRAPHICAL NOTES

Davood Shojaei started his PhD on 3D Cadastral Visualisation in 2010 at the Centre for SDIs and Land Administration at the Department of Infrastructure Engineering, the University of Melbourne. His research aims to develop 3D cadastral visualisation requirements and implement some prototype systems to represent 3D land rights, restrictions and responsibilities in cadastre. He also has a bachelor degree in surveying engineering and master degree in Photogrammetry engineering.

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