PAPER • OPEN ACCESS

3D Strata Visualization in Web Environment – Review

To cite this article: Faraliyana Mohd Hanafi and Muhammad Imzan Hassan 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **767** 012040

3D Strata Visualization in Web Environment – Review

Faraliyana Mohd Hanafi* and Muhammad Imzan Hassan

Dept. of Geoinformatics, Faculty of Built Environment and Surveying,

Universiti Teknologi Malaysia (UTM)

imzan@utm.my

Abstract. Nowadays, rapid population growth has caused a high demand of land and stratified property especially in urban areas (big city). In cadastral system, visualization is considered as a tool for reflecting the real world which is commonly drawn in 2-Dimensional (2D) based plan. However, it only works efficiently for land parcel but not in representing strata property (high rise building). The complexity and overlapping boundaries also need to be considered in portraying 3-Dimensional (3D) model which cannot be achieved using only 2D plan. On top of that, the need of providing a 3D visualization platform has been recognised by many researchers worldwide. There have been numbers of 3D Cadastral system prototype being developed for different country such as Australia, Russia and Indonesia. 3D visualization helps enhanced communication between users, improve decision making, and helps to manage and facilitate land information system. This paper therefore seeks to analyse the problems related to the visualisation for the application of strata and the current approach of 3D visualisation. It is carried out by investigating different techniques and methods used in visualising 3D objects. The outcome of this paper would be the solutions in finding suitable visualization tools to be developed via Web-based visualization applications which are common with end users and easily accessible due to advancements in technology.

1. Introduction

Expanding population growth has caused massive developments and uses of high-rise buildings especially in urban areas (Budisusanto, Aditya & Muryamto, 2013; Hassan, 2017). Thus, it is crucial to be managed properly regarding the burgeoning populations with shifting demographics and distributions that increasing the demands of the land. The use of land may be traded, even though it is physically immovable property as a set of rights (Chong, 2006). Examples of immovable property are land, interest on the property, rights, or interest that may be obtained from land (Section 66, Evidence Act 1967). The concept of Cadastre is usually an up to date land information system focused on the parcel that includes a record of interests of rights, restrictions, and responsibilities (RRR) according to International Federation of Surveyors, FIG (1995) and almost all cadastral data include both legal and physical data (Aien et al., 2012). Physical features involve all visible objects such as walls, roofs, floors, doors, windows, etc. while legal boundaries are intangible and conceptual entities (Shojaei et al., 2013). Property documentation such as strata title are commonly drawn using 2D drawing (floor plan. cross-sections and isometric diagrams). Although this plan is standard practice for professionals, it is difficult for laymen to understand and interpret these drawings (Shojaei et al., 2012). Therefore, 3D Strata Visualization may provide solutions as it portrayed real imaginary of the building that allows much easier interpretation, also improve decision making.

2. 3D Cadastre

3D space, widely known as length, width, and height is the space in which we reside. The Modern Cartesian coordinate system uses two intersecting axes (in x, y) to define an object's location, and therefore it is called two-dimensional. When adding another z-axis (in x, y, z), it provides a sense of the third dimension of space measurement. The third dimension plays an important role in determining the legal status of such land, especially in areas with multilayer use of space, often involves in today's property scenarios. For example, apartments, overhead infrastructure, and utilities, constructions on top of each other, and use of air space, construction over water, or self-supporting structure of a building. This research focusing on Strata application which is part of 3D Cadastre applications. Many scholars have already acknowledged the inclusion of 3D in cadastral structures to strengthen existing practices in land tenure, urban planning, and real estate transactions (Pouliot et al., 2016; Hassan, 2017). However, not so many researches are focusing on the visualization aspect. It is still complex to address the question if 3D visualization can be applied to the cadastre in 3D. For example, the data model utilized (2D, 2.5D, 3D), user requirements and decision-making action, user and 3D system interaction, additional analytical functionality, and the degree of system acceptability and etc. still requires a deeper understanding on features (Pouliot et al., 2016).

2.1. Strata Application

The current strata application, which is part of 3D Cadastre, still relies more on paper-based certified plan (CP), floor plan, and 2D CAD drawing. However, the world is in 3D view, people move, think, and experience in 3D life which in many cases, 2D are not sufficient. Similarly, the motivation and purpose for the creation of a 2D cadastre also apply to the 3D cadastre as well. It ensures 3D parcel protection, preserves owner's rights, and provided valuable financial instruments such as mortgages, collateral, valuation, taxation (Dimopoulou et al., 2018). However, some of their properties and connections to other objects may be lost due to 3D objects depicted in 2D projections as it may create difficulties in understanding, analyzing, and evaluating the real-world objects and real-world solutions (De Vries & Zlatanova, 2004). This shows a reason why strata application requires a better visualization rather than just a 2D plan on PDF. Strata property is represented as a multi-level building, housing units, apartment blocks or offices built jointly within the same development that shares similar facilities. Figure 1 below shows an example of a strata scheme which depicted an information about property development of buildings which are divided into parcels, accessory parcels and common property (JKPTG, 2021).

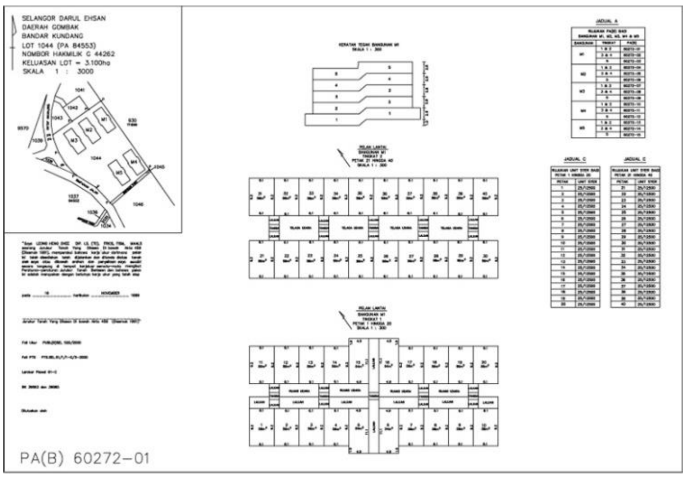

Figure 1. Example of strata scheme in Selangor.

In Malaysia, efforts in upgrading existing cadastral systems are still in the on-going phase. In strata management, most of the information related to RRR is located in an independent system such as '*eTanah*', which requires an authorized person to access. While the spatial information is located on other, independent system called as '*eKadaster*'. According to Hassan et al., (2008), both of the systems work separately. Jia et al., (2004) also mention on the need for spatial data between various districts and different departments to be shared and interoperated. Since the production of up-to-date and accurate (2D or 3D) spatial data is very costly, exchanging and sharing data between different organizations is often the only way to get all relevant information for decision making and end users (De Vries & Zlatanova, 2004). A standardized data model has not yet applied since it is still in the 2D framework. For that reason, a study by Zulkifli et al., (2014) has proposed a Malaysian country profile for 2D and 3D cadastral registration systems using LADM standard to show the link between 2D and 3D strata object. The strata object is being represented in a separate class under spatial unit group class.

According to *Pejabat Pengarah Tanah dan Galian Wilayah Persekutuan (PPTGWP),* there are 3,210 strata schemes in Kuala Lumpur comprising 359,087 strata parcels (Ravindran, 2019). These show a growing number of data and information (big data) if the whole nation comprised which require an efficient integrated system to handle the information. The continuous study by Hanafi & Hassan (2019); Nasorudin et al, (2016) shows that both of the independent systems can be integrated using a unique identifier called Unique Parcel Identifier (UPI) for 2D parcel and Unique Feature Identifier (UFI) for 3D object or of strata parcel.

The current registration system (Malaysia as a case study) shows that it is divided into two sections, which is non-spatial and spatial (Hashim, 2018). These involve a lengthy process that requires a lot of approval and verification from various levels of officers of different management. Besides that, Wahab (2020) also mentioned on the current issues nowadays show a lack of management where the majority of townhouse owners have not yet received strata title for their property. These show some of the management issues by the administrators, as the property owners cannot prove ownership of their property. The use of modern technologies provides tools such as an information system, software and web portal may help in managing strata efficiently. From Hashim (2019) has proposed a 3D strata registration or data entry through a web platform which can help shorten the time taken of data entry (registration), as all of the information will be stored directly to the database as a record for archive.

2.2. Cadastral Visualization

Cadastral visualization generally corresponds to the visualization of ownership boundaries and related descriptive data of measurements such as (length, azimuth, area and ownership) on 2D maps or legal documents such as title, deed or mortgage (Pouliot et al., 2018). According to Lemmen (2010); Williamson et al., (2010), visualization is a basic component of any cadastral system that provide instant boundary clarification, or any kind of property unit that cannot be achieved using textual description. Adding an interactive 3D visualization system with additional third geometric dimension allows user to explore the complexity and depth of 3D situation and overcome issues on traditional 2D techniques (Pouliot et al., 2018). 3D cadastre visualization brings new opportunities but also result in many new challenges and limitation. 3D Visualization of cadastral parcels provide a challenge since cadastre require displaying both physical and legal information. However, portraying something that cannot be seen in real life (legal boundaries) makes the visualization even more challenging (Cemellini et al., 2018; Pouliot et al., 2018). Globally, web technologies have made considerable progress and many web-based applications have been developed to represent spatial data through the World Wide Web (WWW). In developing web applications, the architecture will involve database, web server and client itself. However, most of the applications as mentioned in Section 4 are still in prototype level which requires validation by users before it being used in real world applications. The validation of requirements involved prototype development based on User Requirement Analysis (URA) and gathering expert's feedback using a questionnaire (Shojaei, 2014). For example, a usability testing carried out by potential user to access the developed 3D Cadastre prototype (Cemellini et al., 2018). The implementation of the prototype and the feedback, established the validity and priority of the requirement.

The need for 3D visualization of cadastre data mainly is to have a better representation of the data, to understand the ownership boundaries, the spatial relationship between neighbouring lots, and distinguishing the private and common property (e.g. stratified properties). In 3D cadastral visualization research, both spatial (2D or 3D) and non-spatial (attributes or semantic) data, along with the topological relationship must be considered. To date, there have been some research been made used to support 3D visualization called Cadastral System Prototypes that include web-based and desktop system. In the context of web-based systems, Shojaei et al., (2015) has established a web-based 3D cadastral system with a comprehensive review of functional visualization requirement and the applicability of 3D visualization platform. Aditya et al., (2011) has also experimented on two web map prototypes based on KML with Google Earth and X3D with ArcGIS online, respectively. Google Earth is one of 3D visualization using the desktop version and some researchers used CityEngine (Ribeiro, de Almeida, & Ellul, 2014). Other researchers also experimenting on using WebGL (standard for 3D graphics) on the web that provides a JavaScript interface allowing a fully customized 3D software package to be developed (Evans et al., 2014).

This paper is organized as follows: an introduction on 3D Cadastre and issues on strata application which are explained in Section 1 and 2. Then, a review of existing 3D Visualization approach is provided in Section 3 including data format and common 3D web visualization outlook followed by a discussion on related works regarding to existing 3D web viewer in Section 4. Lastly, Section 5 concludes the paper and gives an insight for the future work.

3. Existing 3D Visualization approach

In this section, various 3D data format and 3D web-based application were reviewed in order to choose a suitable option for 3D Strata Visualization.

3.1. 3D Data Format

It is essential to understand what types of data should be represented in any 3D cadastral application. 3D digital data, 3D database, and 3D visualization systems should be included in a digital 3D cadastre application. Legal and physical data are both included in cadastral details (Aien et al., 2012; Shojaei et al., 2013;2015). There are variety types of data formats can be used to define 3D objects. For example, CityGML -focus on storing 3D digital models of cities and landscape, Industry Foundation Class (IFC) – intended to describe architectural, building, and construction industry data, Keyhole Markup Language (KML) – an XML notation for expressing geographic features and visualization of 2D maps and 3D Earth browsers, it is developed to be used with Google Earth, X3D – XML based format for representing 3D scenes and objects., it is an improved version of the VRML, LandXML – an XML file format for civil engineering design and survey measurement data, Collada – widely used 3D file format defined in XML schema to transport 3D models among 3D applications, glTF – a standard file format that stores 3D model information in JSON format. It is important to choose the formats that best suits the physical and legal objects.

However, each data format has its own limitations. For example, CityGML are rarely used in industry, and LandXML cannot support objects with complex geometry. IFC files is not supported in WebGL and it only comprise physical objects while JSON format does not support various types of geometry i.e. lines and it is limited to some basic 3D models only. XML based format might be the most suitable format to represent physical and legal information as it is represented in a text-based format. In order to link both 3D models and administrative information, unique ID's can be applied.

3.2. Common 3D Geospatial Web based visualization tools

In this section, several web-based solutions are studied and compared to find the suitable option for the development of 3D Strata Viewer.

WebGL is a cross-platform, royalty-free web standard for a low-level 3D graphics API based on OpenGL Embedded System (ES). WebGL can meet user expectation for better graphics and this technology is supported by various web browsers. However, WebGL cannot render huge datasets, because of the limited amount of cache memory that may crash the application (Pereira, 2013; Shojaei et al., 2015)

WebGL Earth is an open source software enabling visualization of maps, satellite imagery and aerial photography on top of a virtual terrain (webglearth.org). It has included some of the features such as free movement in space (rotation, zoom, tilting), it also runs without the use of plugin in web browsers, displaying an existing map (OpenStreetMap, Bing, etc.). The implementations can be done with modern web browser on all computer with recent graphic cards ("WebGL Earth", n.d.).

Cesium JS is an open source JavaScript library for creating world-class 3D globes and maps with the best possible performance, precision, visual quality and ease of use (cesium.com). Developers are allowed to edit and run the code directly in the web browser with the existence of live code editor which is good for facilitating the development phase ("Cesium", n.d.; Cemellini et al., 2018). Cesium is the open platform for software applications designed to unleash the 3D location data. 3D tiles used in Cesium help improve streaming and rendering performance of massive heterogenous datasets to expand on terrain and imagery streaming, 3D tiles will be used to stream 3D content (i.e. buildings, trees, point clouds and vector data) ("Cesium", n.d.).

Google Earth is a computer program, formerly known as Keyhole EarthViewer that renders a 3D representation of Earth based primarily on satellite imagery. It is one of the most popular 3D visualization application used worldwide. Google Earth's imagery is displayed on a digital globe, transitions into different imagery which is 3D imagery, a street view, water and ocean view. However, it does not include underground object, such as tunnels. The Google Earth plugin and its JavaScript API allows embedding Google Earth in web pages. The API also has the ability to load 3D models in KML/KMZ formats (Shojaei et al., 2015).

Web WorldWind is a free, open source virtual globe for web pages developed by NASA WorldWind. It enables web page and application builders to quickly create interactive visualizations of geographic information of an interactive 3D globe or 2D map. Web WorldWind provides an API that enables JavaScript program to control every detail of visualization and interaction. All source code is open source for developers throughout the world. However, it is limited to above ground buildings ("Nasa WorldWind," n.d.).

Bitmanagement Software, BS Contact by Bitmanagement is a stand-alone viewer or embedded in leading web browsers based on DirectX or OpenGL. It suited for 3D vector and spline format i.e. VRML, X3D, COLLADA, KMZ. Since it is a commercial product, user will require a license for the application ("Bitmanagement.com", n.d.).

Skyline offers a lightweight 3D GIS viewer called as TerraExplorer for Web (TE4W) that enables to view and analyze high resolution, and a stunningly realistic 3D content in a web browser without any plugins. The employment of HTML/WebGL standards allows TerraExplorer for Web to provide support for multiple platforms and browsers ("Skyline Software Systems," n.d.).

XNavigator is an interactive online 3D viewer and integrated client for exploring virtual city and landscape models. XNavigator is the first application that support the Web3DService (W3DS) service interface. The software built on Java technology that allows integration in web pages (XNavigator Home, 2011).

iTowns is a web framework written in JavaScript/WebGL for the visualization of 3D geographic data and precise 3D measurements. It is highly extensible and based three.js that handles a variety type of data types. Free sample datasets are available on GitHub (iTowns, n.d.).

OSM Buildings is a free and open source web viewer for 3D buildings. It supports most of the OpenStreetMap tagging schema. The data tiles are based on XYZ tiles. The data format used is GeoJSON with geometry projection EPSG:4326 (WGS84).

Esri City Engine WebViewer is a web application based on WebGL technology for viewing 3D city scenes and other 3D scenes in a browser to do navigating (pan, zoom, change perspective), choosing layers, swipe the scene for different scenarios and search scene content (features, attributes, and metadata) ("ArcGIS", n.d.).

This paper attempt to find solutions on suitable web viewer in the attempt to visually display 3D strata visualization. The viewer must be able to focus on each unit in each floor of a building. From review, every web viewer mentioned above has the ability to represent above ground object. However, some of the viewer are made for 3D city scenes where each building being portrayed as blocks. Shojaei et al., 2013 has compared each different viewer available and the ability to handle each feature stated.

Table 1. Comparison table of different viewer (Shojaei et al., 2013).

	Visualisation solutions					
Visualisation features	WebGL	Google Earth	NASA WW	BS Contact	TerraExplorer	XNavigator
Handling massive data	No	Yes (Network links)	Yes	No	Yes	No
Result of functions and queries	Yes	Yes (only search)	Yes	Yes	Yes	Yes
Underground view	Yes	No	No	Yes	Yes	No
Cross-section view	No	No	No	No	No	No
Measurements (3D)	No	No	No	No	Yes	No
Non-spatial data visualisation	Yes	Yes	Yes	Yes	Yes	Yes
Interactivity	Yes	Yes	Yes	Yes	Yes	Yes
Levels of detail	Yes	Yes	Yes	Yes	Yes	Yes
Symbols	Yes	Yes	Yes	Yes	Yes	Yes
Colour, thickness, line-style	Yes	Yes	Yes	Yes	Yes	Yes
Labelling	Yes	Yes	Yes	Yes	Yes	Yes
Transparency	Yes	Yes	Yes	Yes	Yes	Yes
Tooltips	No	Yes	Yes	No	Yes	Yes
Technical diversity	Weak	Yes	Yes	Yes	Yes	Yes
System integration and interoperability	Yes	Yes	Yes	Yes	Yes	Yes
Usability	Low	High	Medium	Medium	Medium	Low
Platform independence	PC, Mac, Linux, Android	PC, Mac, Linux	Platform Independent (java based)	PC, Mac, Linux, Mobile	Windows	Platform Independent (java based)
Cost	Open-source	Freeware	Open-source	Proprietary	Proprietary	Open-source
Web-based 3D visualisation	Yes	Yes	Yes	Yes	Yes	Yes
Plug-in free	Yes	No	Yes (Java is required)	No (X3DOM is plug-in free)	No	No (Java is required)

Listed below are common function used in a Graphic User Interface (GUI) of a 3D web viewer available currently.

- *Identify tool* – To gain information attached to each strata parcel.
- *3D measurement tool* – To measure distance of the 3D model.
- *Cross-section tool* – To display the interior geometry of a structure.
- *Various views* – The viewer should be efficiently designed in the prototype to display and interact with 3D objects for better navigation. In order to give the user, the most natural type of control over the object, the camera should always face the top of the screen.
- *Search and find tool* – The ability to query, to find and classify strata objects.
- *Move, undo tool* – It is necessary to move an object in some cases i.e. parcel lot from its original position for detailed viewing individually. A tool like this enables any highlighted object in the view to be shifted back to somewhere else A simple undo button will shift the object back to its previous position.
- *Object control* – Provide users with control over object visibility that enable viewing of any variation of physical and legal objects.
- *Representing Administrative Information* – an option to view administrative information.

4. Previous Work

Globally, the issues on 3D cadastre has been investigated in many viewpoints, which includes legal, organizational, and technical. Even so, the research in visualizing the 3D model still require a lot of tools and work. An effective visualization is one of the primary components in realization of a true cadastre in 3D (Pouliot et al., 2018). Historically, 3D applications mostly depend on high-end computer systems and commercial software such as ArcGIS Pro, Cesium Ion, Revit, SketchUp Pro etc. The use of desktop application has been an effective tool for capturing, storing, analyzing and making land information available. However, in most cases, it is still largely inaccessible for the public to access, when and where is needed (Shojaei et al., 2015). Today, with the help of internet act as an online platform helps improving the interoperability in sharing and accessing 3D Cadastre data and challenges. At present time, several 3D visualization applications and cadastral prototype has been developed around the world. For example, a web-based strata registration (Hashim, 2019), a prototype of a 3D Cadastral System (Višnjevac et al., 2019), and development of 3D Digital Cadastre Visualization Prototype (Shojaei et al., 2018).

Displaying a spatial data in a web browser, which act as a distributing platform allows easier data sharing among different types of user. Most developers have variety of programming languages, libraries and framework to perform spatial data visualization. Nevertheless, these can only cover 2D maps and data. When it comes to 3D models, researchers have developed different type of data standards such as CityGML for the purpose of data sharing between different software programs, as well as over the web (Rees, 2019).

A 3D cadastre prototype supported by a web browser has been developed for the Russian Federation to display both 3D Objects and their legal boundaries. The user interaction takes place on the 3D viewer where user need to install a plugin called the BS Contact plug-in from Bitmanagement. Here, the 3D geometry is stored in static X3D files, while the other corresponding attributes related to administrative information stored in XML files. One of the main issues takes place in the development of the prototype is the linking between the 3D objects in the viewer windows (X3D files) and the legal cadastral data (XML files) (Vandysheva et al., 2012).

Besides that, a web-based land information system has also been developed which act as an online land administration for the city of Akure, Nigeria (Babalola & Uyi, 2019). However, it only covers 2D lot parcel with feature information such as Parcel ID, Area, and Address. It also includes a simple analysis such as measuring the distance and lot area. One of the interesting features is the 'Staff login' for Person in Charge (PIC) only which act as a limitation or security in accessing the web portal.

A 3D Cadastre Information System has also been developed by (Budisusanto et al., 2013) that focusing on the stratified property of multi-level apartment in Indonesia. The prototype is called as Sistem Informasi 3 Dimensi (SIK3D) Version 1.0 has functions that mainly support registration and visualization regarding apartment objects and their corresponding ownership rights. LADM basic classes were implemented as the database tables used in the prototype. Here, it is not mention on the linking of the database and the 3D model. However, it is mentioned that the targeted users are land office staff (require login id) to be able to utilize the application.

Višnjevac et al., (2019) has developed a 3D Cadastral System focusing on Database Management System (DBMS) part where NoSQL database is implemented. The prototype uses MongoDB database for storing data and Cesium JavaScript Library is used for 3D Visualization. This design is tested to investigate the possibilities of using a new technical solution for the development of a modern 3D Cadastral System. The cadastral data (i.e. building unit, land parcel, underground shelter) used are prepared as JSON document that was imported into MongoDB. The user interface for 3D Visualization of cadastral data is divided into several sections: map canvas section, control section, textual data section (pop-up). Three different visualization modes are implemented to enable intuitive visualization that is a building unit mode, a floor mode, and a building mode. Up until now, the result of '3D Cadastre Demo' provides ideas required for this research considering the ability it has to view each building unit linked with its legal information which is compatible with strata needs. Hence, it becomes the main reference for the study.

A review made by Pouliot et al., (2018) in a workshop relating to cadastre's user shows that primarily the user groups that will make use of 2D cadastral system i.e. government managers responsible for land administration system maintenance, along with lawyers, notaries and land surveyors. By using 3D visualization appears to contribute and increase the potential of a new cadastre data users such as architects, engineers, real-estate agents, developers (Atazadeh et al., 2017). Different type of users has different requirement restrict the accessibility in viewing and utilizing the data.

National Mapping Agency Malaysia has also come up with a web application called as SmartKadaster Interactive Portal (MySKIP). It is developed to enable public user to mark and describes places on the map. User has the ability to contribute information by generating contents on the web maps, which DSMM called it as collaborative mapping or crowdsourcing. This user-generated contents can be implemented for enhancing DSMM geospatial data and further enhance their maps. Digital City Modelling of the FT Kuala Lumpur and Putrajaya is one of the main products available via MySKIP (Isa, Hua, & Halim, 2015). The 3D datasets produced from airborne or terrestrial laser scanning to fulfill the 3D representation requirement. However, the representation of the 3D viewer requires user to install additional plugin called Terra Skyline Explorer and it only works on browser Internet Explorer 9 or above. The 3D visualization only conveyed the information in building modes with names and does not cover any stratified property unit. The 3D parcel does not link with any ownership data since it is developed by JUPEM, which is an organization that only responsible for spatial data.

All of the above research is related to the visualization of cadastre data on web. However, from the review made, most of the researcher mentioned on the challenges to link legal object and its semantic data. This paper focuses on the issues and working toward in finding the solution to cater the problem.

5. Conclusion and Future Work

The need for 3D visualization of cadastre data mainly is to have a better representation of the data and to understand the ownership boundaries. In this review, some of the available geospatial domain web viewer were studied. There are several solutions, open source and commercially product available today. Common approach of an existing approach may also be applied for the development of strata application. Most of the researcher are applying WebGL as it can meet user expectation and provide better graphics across wide platform via web without the use of plug-in. However, Cesium as the current web viewer also able to provide best performance and it is less complicated to work with as developers are allowed to edit and run live code editor directly in the web browser which is good for facilitating the development phase. A prototype of a '3D Strata Viewer' will be develop to allow user, to view, to query strata information using an interactive viewpoint as an 3D web-based viewer. Based on the considered requirement, Cesium has the ability to view each object along with its attribute which is crucial for the strata application. Three different visualization modes done by previous researcher shows that there are possibilities to visualize 3D strata object via web using Cesium.

The lack of an application for 3D visualization to illustrate ownership boundaries is apparent and the industry is anxious in finding a solution. The prototype can be a good starting point for development of a modern strata application that allows registrations of 3D properties, intuitive interfaces, database solutions, and 3D spatial data visualization techniques to be built.

References

[1] Budisusanto, Y., Aditya, T., & Muryamto, R. (2013). *LADM implementation prototype for 3D cadastre information system of multi-level apartment in Indonesia.* Paper presented at the 5th Land Administration Domain Model Workshop.

[2] Hassan, M. I. (2017). *Integrated Three-Dimensional Cadastre Object Registration Framework Based on Cadastre Data Model*. (Doctoral Dissertation), Universiti Teknologi Malaysia (UTM).

[3] Chong, S. C. (2006). *Towards a 3d Cadastre in Malaysia: An implementation evaluation.*

[4] FIG. (1995). FIG Statement on the Cadastre In FIG Techical Report Publication 11, Federation International des Geometres, Commission 7 (Cadastre and Land Management). Copenhagen, DENMARK.

[5] AIEN, A., Kalantari, M., Rajabifard, A., Williamson, I., & Shojaei, D. (2012). *Developing and testing a 3D cadastral data model: A case study in Australia*.

[6] Shojaei, D., Kalantari, M., Bishop, I. D., Rajabifard, A., & Aien, A. (2013). *Visualization requirements for 3D cadastral systems.* Computers, Environment and Urban Systems, 41, 39-54.

[7] Shojaei, D., Rajabifard, A., Kalantari, M., Bishop, I. D., & Aien, A. (2012). *Development of a 3D ePlan/LandXML visualisation system in Australia.*

[8] Pouliot, J., Wang, C., Hubert, F., Ellul, C., & Rajabifard, A. (2016). *3D Cadastre visualization and dissemination: Most recent progresses and future directions.* Paper presented at the Proceedings of the 5th International FIG Workshop on 3D Cadastres.

[9] Dimopoulou, E., Karki, S., Roić, M., de Almeida, J.-P. D., Griffith-Charles, C., Thompson, R., . . . van OOSTEROM, P. (2018). *Initial registration of 3D parcels. In Best Practices 3D Cadastres: International Federation of Surveyors.*

[10] De Vries, M., & Zlatanova, S. (2004). *Interoperability on the Web: the case of 3D geo-data.* Paper presented at the IADIS International Conference on e-Society.

[11] JKPTG. (2021). *Strata Owner*. Retrieved from https://www.jkptg.gov.my/en/hakmilik-strata.

[12] Hassan, M., Ahmad-Nasruddin, M., Yaakop, I., & Abdul-Rahman, A. (2008). *An integrated 3D cadastre–Malaysia as an example.* The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37(B4), 121-126.

[13] Jia, W., Chen, Y., Gong, J., & Li, A. (2004). *Web service based web feature service.* Paper presented at the Proceedings of the 20th ISPRS Congress.

[14] Zulkifli, N. A., Abdul Rahman, A., Jamil, H., Teng, C. H., Tan, L., Looi, K., . . . Van Oosterom, P. (2014). *Towards Malaysian LADM country profile for 2D and 3D cadastral registration system.* Paper presented at the Proceedings of the 25th FIG Congress: Engaging the challenges, enhancing the relevance, Kuala Lumpur, Malaysia, June 16-21, 2014.

[15] Ravindran, B. M. a. S. (2019). *Old tax, new system with new name. The Star Online*. Retrieved from https://www.thestar.com.my/metro/metro-news/2019/10/29/old-tax-new-system-with-new-name.

[16] Hanafi, F. M., & Hassan, M. I. (2019). *The Integration Of 3d Spatial and Non–Spatial Component for Strata Management.* International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42(4/W16).

[17] Nasorudin, N. N., Hassan, M. I., Zulkifli, N. A., & Rahman, A. A. (2016). *Geospatial Database for Strata Objects Based on Land Administration Domain Model (ladm).* The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 329.

[18] Hashim, M. N., Hassan, M. I., & Rahman, A. A. (2018). *3D Modelling towards Strata Registration.* International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42(4/W9).

[19] Wahab, F. (2020). *Many townhouse owners still waiting for strata titles. The Star Online*. Retrieved from https://www.thestar.com.my/metro/metro-news/2020/01/21/many-townhouse-owners-still-waiting-for-strata-titles.

[20] Hashim, M. N. (2019). *Mobile Indoor Laser Scanning For 3D Strata Registration Purposes based on IndoorGML*. (Master's Degree Dissertation), Universiti Teknologi Malaysia,

[21] Lemmens, M. (2010). Towards Cadastre 2034. GIM International, 24(9).Williamson, I., Enemark, S., Wallace, J., & Rajabifard, A. (2010). *Land administration for sustainable development*: Citeseer.

[22] Cemellini, B., Thompson, R., Van Oosterom, P., & De Vries, M. (2018). *Usability testing of a web-based 3D Cadastral visualization system*. Paper presented at the Proceedings of the 6th International FIG Workshop on 3D Cadastres, Delft, The Netherlands.

[23] Shojaei, D. (2014). *3D cadastral visualisation: understanding users' requirements*.

[24] Shojaei, D., Rajabifard, A., Kalantari, M., Bishop, I. D., & Aien, A. (2015). *Design and development of a web-based 3D cadastral visualisation prototype.* International Journal of Digital Earth, 8(7), 538-557.

[25] Aditya, T., Iswanto, F., Wirawan, A., & Laksono, D. (2011). *3D cadastre web map: prospects and developments.* Paper presented at the Proceedings of the 2nd International Workshop on 3D Cadastres, Delft, The Netherlands.

[26] Ribeiro, A., de Almeida, J.-P., & Ellul, C. (2014). *Exploring CityEngine as a visualisation tool*

for 3D cadastre. Paper presented at the 3D Cadastres 2014-4th International FIG 3D Cadastre Workshop.
[27] Evans, A., Romeo, M., Bahrehmand, A., Agenjo, J., & Blat, J. (2014). *3D graphics on the web: A survey. Computers & graphics, 41*, 43-61.
[28] Pereira, K. J. (2013). *Water Simulation on WebGL and Three. Js.*
[29] WebGL Earth (n.d.). *OpenSource Project: 3D digital globe for web and mobile devices.* Retrieved from https://sites.google.com/site/webglearth/about.
[30] Cesium - *The Platform for 3D Geospatial*. (n.d.). Retrieved from https://cesium.com/.
[31] Nasa World Wind (n.d.). *Web World Wind* . Retrieved from https://worldwind.arc.nasa.gov/web/
[32] Bitmanagement.com (n.d.) Interactive 3D Web. *BS Contact is a realtime and online capable viewer offering full interactivity.* Retrieved from https://www.bitmanagement.com/en/products/interactive-3d-clients/bs-contact
[33] Skyline Software Systems (n.d.). *TerraExplorer for Web lightweight 3D GIS viewer*. Retrieved from https://www.skylinesoft.com/terraexplorer-web.
[34] XNavigator Wiki (n.d.). *About.* Retrieved from http://xnavigator.sourceforge.net/doku.php?id=about.
[35] iTowns. (n.d.). Retrieved from http://www.itowns-project.org/.
[36] About CityEngine Web Viewer—ArcGIS Online Help | Documentation. (n.d.). Retrieved from https://doc.arcgis.com/en/arcgis-online/reference/about-cityengine-web-viewer.htm.
[37] Višnjevac, N., Mihajlović, R., Šoškić, M., Cvijetinović, Ž., & Bajat, B. (2019). *Prototype of the 3D cadastral system based on a NoSQL database and a Javascript visualization application.* ISPRS International Journal of Geo-Information, 8(5), 227.
[38] Rees, E. V. (2019). *Visualizing 3D spatial data in a web browser using Cesium, FME and 3D tiles.* Retrieved from https://www.spar3d.com/blogs/all-over-the-map/visualizing-3d-spatial-data-in-a-web-browser-using-cesium-fme-and-3d-tiles/.
[39] Vandysheva, N., Sapelnikov, S., Van Oosterom, P., De Vries, M., Spiering, B., Wouters, R., . . . Penkov, V. (2012). *The 3D cadastre prototype and pilot in the Russian Federation*. Proceedings FIG Working Week 2012, Territory, environment and cultural heritage, Rome, Italy, May 6-10, 2012.
[40] Babalola, S., & Uyi, I. (2019). *A Web-Based Land Information System, Tool for Online Land Administration in Akure Nigeria.* International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences.
[41] Atazadeh, B., Kalantari, M., Rajabifard, A., & Ho, S. (2017). *Modelling building ownership boundaries within BIM environment: A case study in Victoria, Australia.* Computers, Environment and Urban Systems, 61, 24-38.
[42] Isa, M. B., Hua, T. C., & Halim, N. B. A. (2015). *Smartkadaster: Observing Beyond Traditional Cadastre Capabilities for Malaysia.* The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40, 53.

Acknowledgements
The author express gratitude towards Dr Muhammad Imzan Bin Hassan on the help of supervising and monitoring the journey of the research. Authors also acknowledge the support of 3D GIS Research Lab members in the preparation and development of the research. This research is funded by UTM Research University Grant, (Vot Number: Q.J130000.3552.05G54).