

APPLICATION OF PHOTO-REALISTIC 3D MODEL IN WEB-BASED OPEN SOURCE GIS PLATFORM

Faizal Azmi Setiawan¹ and Jiann-Yeou Rau²

¹Master student, Department of Geomatics
National Cheng Kung University, Tainan 70101, Taiwan, ROC
Email: fzlavr@gmail.com

²Associate Professor, Department of Geomatics
National Cheng Kung University, Tainan 70101, Taiwan, ROC
Email: jiannyeourau@gmail.com

KEY WORDS: 3D Web GIS, JavaScript, Photo-realistic 3D

ABSTRACT:

The advancement of web technology has caused a paradigm shift in the use of the website, especially for 3D contents. Web browsers have become an effective computation platform, as they are able to execute HTML5, JavaScript, WebGL, also OpenGL 3D graphics library that runs directly inside the browsers. With those elements, it allows the user to access in multi-platform such as mobile phone, notebook and PC. 3D Web GIS can give the user 3D visualization through internet. From this feature, it would be very useful if it combined with Photo-realistic 3D model. It can give information about the condition of some areas, buildings, even historical objects. For 3D reconstruction, acquisition of all 2D images in every part of the object are conducted, including UAV images or terrestrial images. Put all the acquired images together and perform structure from-motion by Bentley ContextCapture. After that, all the images interior and exterior orientation parameter will be obtained. Set the map projection output into WGS84. Then, dense point cloud, 3D Mesh, Texture model are created. In this research, CesiumJS will be used as a platform to build 3D Web GIS. It is an open-source JavaScript library for world-class 3D globes and maps. It can create 3D globe and map for static and time-dynamic content, with the best possible performance, precision, visual quality, platform support, and ease of use. It provides *Hierarchical Level of Detail* (HLOD) to adaptively load and refine 3D models. It allows the engine to render low resolution 3D model when they are far from screen and high resolution 3D model when they are near. CesiumJS also can load GIS data such as building information, road line, area segmentation and many others. Thus, it is useful for many 3D GIS applications, such as disaster modelling, heritage object, and 3D city modelling.

1. INTRODUCTION

In the past few years have seen remarkable development in photogrammetry and computer graphic to create 3D model. Photo-realistic 3D model is one of a technique to generate reliable 3D model. There exist various approaches to build photo-realistic 3D models of real objects. Image-based 3D reconstruction has vast literature in computer vision. The common characteristic of these techniques, such as stereo vision, shape from structure, shape from shading, etc., is that models are built only from images, or video sequences (Janko, 2006b). Normally, the procedure for the generation of photo-realistic 3-D model includes four main steps, namely (1) recognition, (2) feature extraction, (3) topology reconstruction with geometric modeling, and (4) photo texture generation (Gruen & Wang, 2001a). Generally, photo-realistic 3D models are used for visualization, interpretation and spatial measurement in many disciplines, such as city, cultural heritage, archaeology and geoscience (Sima, 2013a). There are many methods to acquire 3D model of large area, such as city. Those are using Airborne Laser Scanning or LIDAR data, Aerial Photography and High-resolution Satellite Imagery (Rau, 2013a).

The result of photo-realistic 3D model can be displayed in many applications. The application consists of desktop application, mobile application, and others. Nowadays, the effectiveness of application which can run in any platforms is very important. The user will only need one application to view. As the technology has developed, website comes with the ability to run in multiplatform. Internet and browser are some elements what it needs. Most of people already have an internet also with the browser in their PC and mobile phone. It means they can view and browse something over the internet. That is our major reason to use website application. The development of website

programming language is very promising. It makes the website able to load the 3D object over the internet. There are several studies which use website to display 3D model. They come in many different purposes such as urban precinct assessment system (Trubka, 2016a), assessment and dissemination of solar income (Bremer, 2016), archeology (Galeazzi, 2016a), building information modelling (Niu, 2015a), and open source GIS website (Zavala-Romero, 2014a).

In this research, CesiumJS will be used for displaying 3D object. CesiumJS is an Open-Source Javascript library for displaying 3D object and world maps. It can create 3D globe and map for static and time-dynamic content, with the best possible performance, precision, visual quality, platform support, and ease of use. It provides *Hierarchical Level of Detail* (HLOD) to adaptively load and refine 3D models. It allows the engine to render low resolution 3D model when they are far from screen and high resolution 3D model when they are near.

2. METHODS

The first step to get the 3D model is acquiring some overlap images from the object. To acquire the image, airplane with 5 cameras is used. It captured the vertical and oblique image to get good result of object surface. After all images are acquired, they will be processed in Bentley ContextCapture. Then, Interior orientation and exterior orientation parameter will be acquired after performing structure-from-motion. Next, process it with dense point cloud, 3D Mesh and add texture to 3D model, respectively. Then, the 3D model will be acquired. To be able to load in the CesiumJS environment, the 3D model should be converted into JSON file format. ContextCapture has a feature to make a conversion. The coordinate reference system of 3D model should be changed into WGS84 because it is one of requirement to be able to load inside CesiumJS.

After the conversion is complete, the main website can be start to build. Start with create a homepage of the website with HTML, CSS, Javascript and CesiumJS. The homepage display will directly show the world map and location of 3D model. So, the location of 3D object should be configured first to get right position. Basically, the 3D object will seem to be floating while move the position angle of 3D model. To avoid a floating movement of the 3D model, checking the terrain should be done. The terrain should be flat and 3D model should be above the terrain. CesiumJS has a feature to make surface of the terrain into flat. In order to gain some information from the 3D model, information of GIS would be added inside the website. The information consists of road information, district information, and building information.

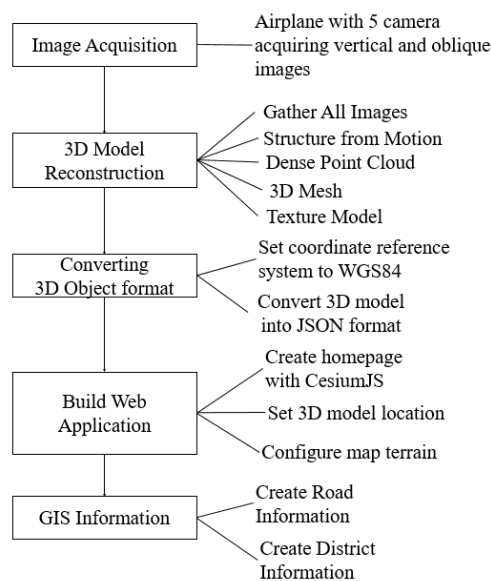


Figure 1. Proposed method to build web application

3. SYSTEM OVERVIEW

The result of rendering and displaying 3D model which is appear in client side must be considered. To promote applications on the Internet, website system must have the capability of fast transmission of geospatial data and powerful performance for rendering 3-D scenes. CesiumJS offers *Hierarchical Level of Detail* (HLOD) to adaptively load and refine 3D models. Doing so allows the engine to render low resolution tiles when they are far from the camera and high resolution tiles when they are near the camera. However, standard methods of displaying HLOD models will load every level of resolution up until the desired resolution is achieved. In recent update, CesiumJS renderer now allow it to skip levels of detail while loading, significantly decreasing load time, network requests, and memory usage. In order to accomplish this, CesiumJS only loads a subset of the tiles when traversing the HLOD tree

based on visual heuristics and applies some clever rendering tricks to accurately blend between multiple levels of detail. By doing this, CesiumJS prioritizes higher resolution tiles.

3.1 Server and Client

In this web application, server and client will be adopted as a mechanism to communicate with user. The presentation tier acts as the client side and the data services tier the server side, which includes the Web Server and Data Manager. In Figure 2, Web Server and Data Manager will become a core of data which is displayed in client side. Apache server will be used to run the web server. The Web Server undertakes web browsing following the Hyper Text Markup Language (HTML) syntax. Hyper Text Transfer Protocol (HTTP) is basically the common language between the Web Server and the Client's browser. Either side can transmit data to the other using the HTTP protocol. When the Client side has received web pages the various data types are parsed by the Client's browser. A web application system, such as the one developed in this study, is installed on the Web Server. It is capable of publishing web pages and transmitting the user's requests from the Client Side to the Server.

Data manager contains a lot of resources which will be displayed into client side. 3D model is a model which is generated from ContextCapture. The 3D model contains a lot of B3DMfiles which are bundled in a single folder. Then, JSON format is served to call that folder in order to load 3D model. Line and polygon are created to gain some information about 3D model. Together with GIS information, the 3D model has some information like road information, district information and building information. HTML, Javascript, and CSS will be used to gather all information from data manager in a web application.

In client side, all the data from data manager will be gathered. It will display 3D model and GIS information into client screen. Chrome and Mozilla Firefox browsers are utilized to assess web data, which are distributed by the web server and transmitted to the clients using HTTP, to perform parsing of HTML, Javascript and CSS codes and display the results to the client. *HLOD* of CesiumJS will work when in the client side when displaying 3D model.

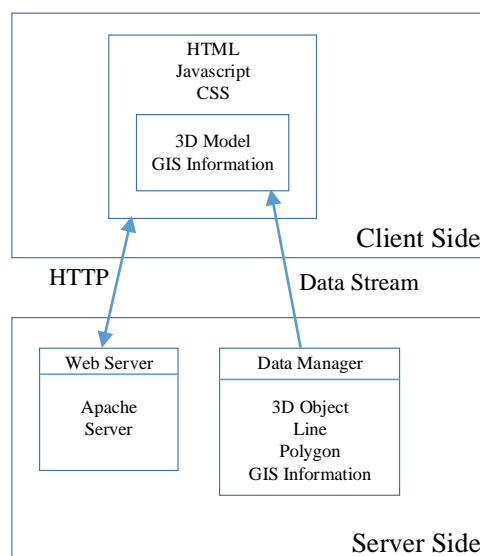


Figure 2. Proposed method to build web application

4. CASE STUDY

Taipei City is the capital town of Taiwan. Taipei City is widely regarded as the political, economic, and cultural center of Taiwan. Pronounced in Mandarin as Táiběi, the city is located in the northern part of the island in a basin between the Yangming Mountains and the Central Mountains. Consisting of 12 distinct districts, each with its own style and charm, Taipei is an amazing modern city with an innumerable amount of historical attractions, numerous acclaimed night markets, shopping districts, as well as cultural amenities like modern coffee houses, and museums. With a population of about 2.6 million residents, its population is eclipsed by New Taipei City (which surrounds Taipei), however Taipei's identity is closely linked with New Taipei as well as its other neighbor Keelung and are regarded as one large metropolitan area with a population in excess of 7 million. The city is characterized by straight roads and public buildings of grand Western architectural styles. The city is built on a square grid configuration. However, these blocks are huge by international standards with 500 m (1,640.42 ft.) sides. The area in between these blocks is infilled with lanes and alleys, which provide access to quieter residential or mixed-use development. Other than a citywide 30 kilometers per hour (19 mph) speed limit, there is little uniform planning within this "hidden" area;

therefore, lanes (perpendicular to streets) and alleys (parallel with street, or conceptually, perpendicular to the lane) spill out from the main thoroughways. These minor roads are not always perpendicular and sometimes cut through the block diagonally. Although development began in the western districts (still considered the cultural heart of the city) of the city due to trade, the eastern districts of the city have become the focus of recent development projects. Many of the western districts, already in decline, have become targets of new urban renewal initiatives.



Figure 3. Geographic location of 3D Model in Taipei City

4.1 3D Model Acquisition

The first thing to generate photo-realistic 3D model is take aerial photos. Overlap pictures are used to get better result of 3D model. In this research, pictures are taken from an airplane with cameras. It captures the object in vertical view. The airplane has a route to capture the surface of building roof, road, vegetation and other things around the target area. In Figure 4, the route has 3 rows of location in taking pictures. Then, 52 images have succeeded to collect. Some images are overlapped with other images. Those overlap images will stitch each other and a continuous image will be acquired. This process was run inside ContextCapture in order to get a photo-realistic 3D model. Then, performing structure-from-motion in order to get interior and exterior orientation parameters. Next, it conducts dense image matching to obtain dense point cloud, perform 3D meshing and texture mapping to 3D model, respectively. Then, the textured 3D model will be obtained like in Figures 5-7.

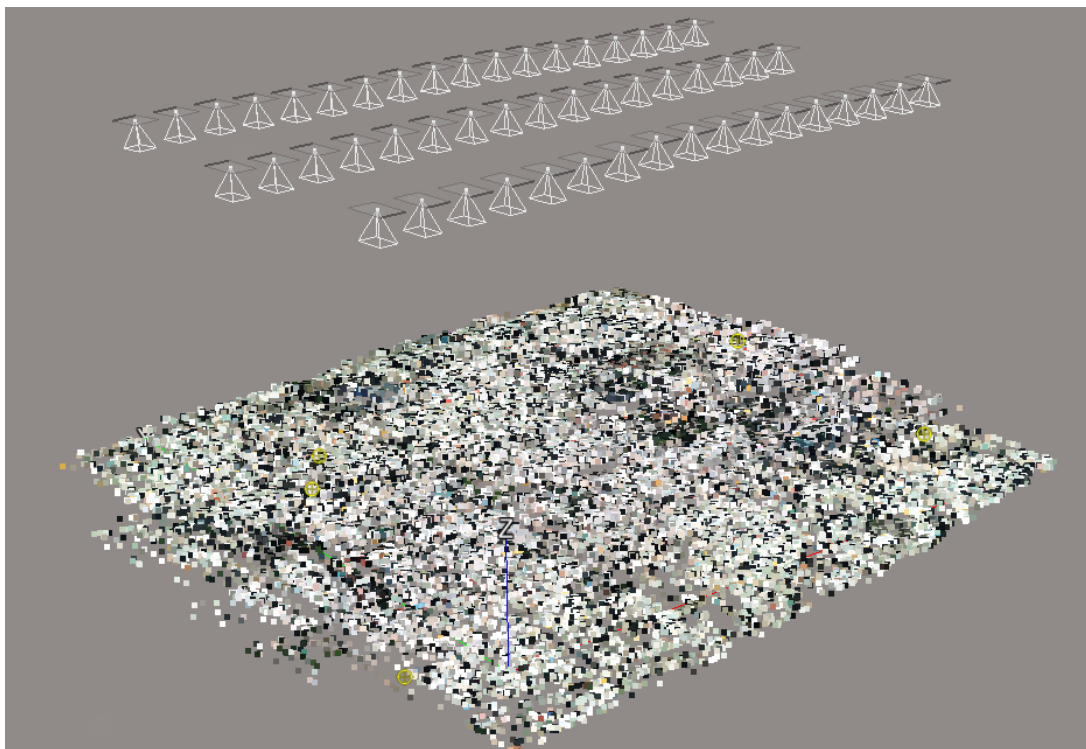


Figure 4. Flight route to capture aerial image

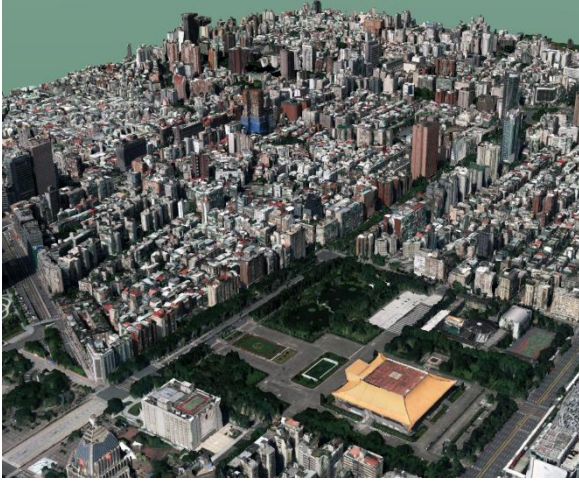


Figure 5. Photo-realistic 3D model result



Figure 6. Photo-realistic 3D model building view



Figure 7. Photo-realistic 3D model landscape view

In Figure 7, the 3D model is not only the building model. The road, tree, and the others which in coverage of airplane capture are generated into 3D model. The historical building, Sun Yat Sen Memorial Hall also included in this 3D model. The popular one, Taipei 101 also captured in this 3D model. However, it is too tall and the used three flight routes couldn't cover the whole Taipei 101 building, thus the whole 3D model can't be reconstructed complete.

5. RESULTS AND DISCUSSION

In this research, there are three stages to accomplish photo-realistic 3D city model in web application. The first stage is the creation of photo-realistic 3D model. This stage has explained in previous section. The second stage focus on website development. This stage is mainly to import the generated 3D model on the website. Then, create a user interface for user interaction and visualization. The third stage focus on developing a GIS information on the 3D model. The information consists of road line, district segmentation, and building information. CesiumJS is able to process all those three stages. HTML, Javascript and CSS are the element that work with CesiumJS to create the website.

5.1 Features in CesiumJS

CesiumJS is an open-source JavaScript library for world-class 3D globes and maps. It is able to create 3D globe and map for static and time-dynamic content, with the best possible performance, precision, visual quality, platform support, community, and ease of use. CesiumJS provide different map sources from Bing Maps, OpenStreet Map, ESRI world street maps and other map providers. It also has a feature to search a specific location by city name. In Figure 8, some map providers are attached on the application. It also has a feature to change the terrain. WGS84 Ellipsoid and STK World Terrain meshes are kinds of terrain type which CesiumJS has offered. WGS84 changes the

terrain into flat. STK World Terrain is a high-resolution worldwide terrain elevation tile-set useful for earth surface visualization and other uses. It continually grows in size and resolution as new sources of high-quality elevation data are found, acquired, and incorporated into the tile-set. CesiumJS also provide a feature for stereo image display. Thus, it can display a 3D visualization with VR cardboard stereo-glasses when it opens in mobile phone.



Figure 8. Map providers in website application

5.2 Roadline Feature

In this website application, roadline feature is added to gain an information regarding photo-realistic 3D model. The file format of roadline feature is Geojson. Basically, a line feature in GIS using Shapefile format. Nowadays, many applications have a feature to convert a Shapefile into Geojson, such as QGIS, ArcGIS and many others. The roadline feature contains information such as road name which can be loaded inside 3D model. Button is created to show and hide the roadline. All roadlines are shown in Figure 9. Every roadline has its name. To make the name of roadline appear, user can click it and the name will show in upper right screen, as shown in Figure 10.



Figure 9. All roadline attach in 3D model



Figure 10. Roadline name

5.3 District Feature

This website application has district feature. Each district is distinguished by a color. The district information is acquired from Taiwan spatial information data. The file format for the district feature is Geojson. It contains polygon entities. Regarding to the area of the generated 3D model, it covers 4 districts. Those are Daan District, Zhongshan District, Songshan District, and Xinyi District. Some variables are added to gain information in district description. Those are *townid*, *towncode*, *countyid*, *countycode* and *description*. In Figure 11, the district segmentation is shown.

The color difference signifies different district. In Figure 12, particular district information is shown after it was clicked. In the description field, information about the district is attached.

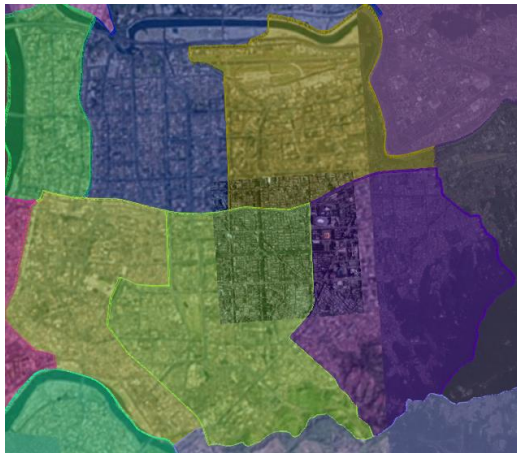


Figure 11. District feature distinguished by color

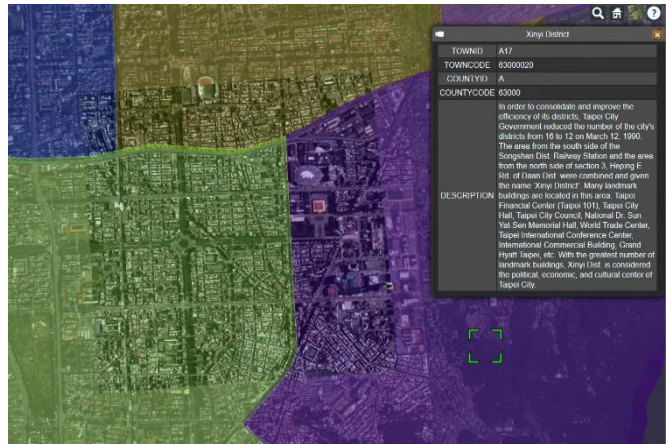


Figure 12. District information

5.4 Building Information Feature

Building information is added in the web application as a feature to attach some information about particular building. The file format of building information feature is also Geojson. Basically, this feature contains polygon which covers the building. It should be processed in this way because the establishment of 3D model is a single mesh model. It means that the photo-realistic 3D model contains only one object, each individual building did not separate into building objects. In Figure 13, the polygon describes building object. When the polygon was clicked, it will show the description of the inquired building. The information contains building ID, address, site area, height and description. On the left corner of information panel, it has a video icon which can move the chosen building to the center of screen directly for better visualization, as shown in Figure 14.

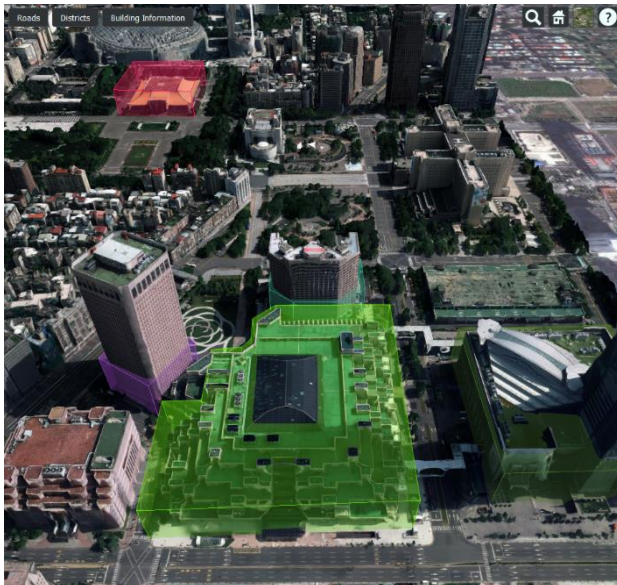


Figure 13. Some buildings area

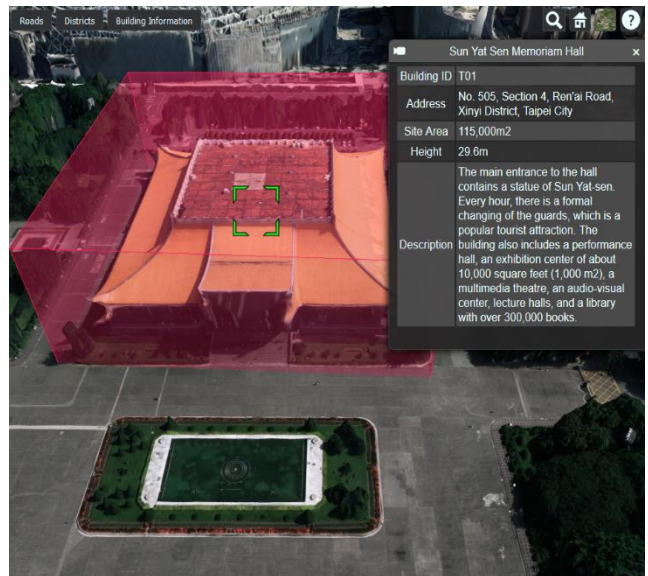


Figure 14. Building information

In other display of building information feature, user also could view a visualization of 3D building which is created from building boundary information data. The data contain some attributes such as roof height, height on the ground at the entrance of the building, and building floor number. This data is a shapefile format. Convert it into geojson format is a compulsory for loading data purpose in CesiumJS. Technically, this data contains some polygons of the building. With those polygons, the 3D building can be created automatically based on the height information. Then, user can select the 3D building to show the information inside.



Figure 15. Building boundary data

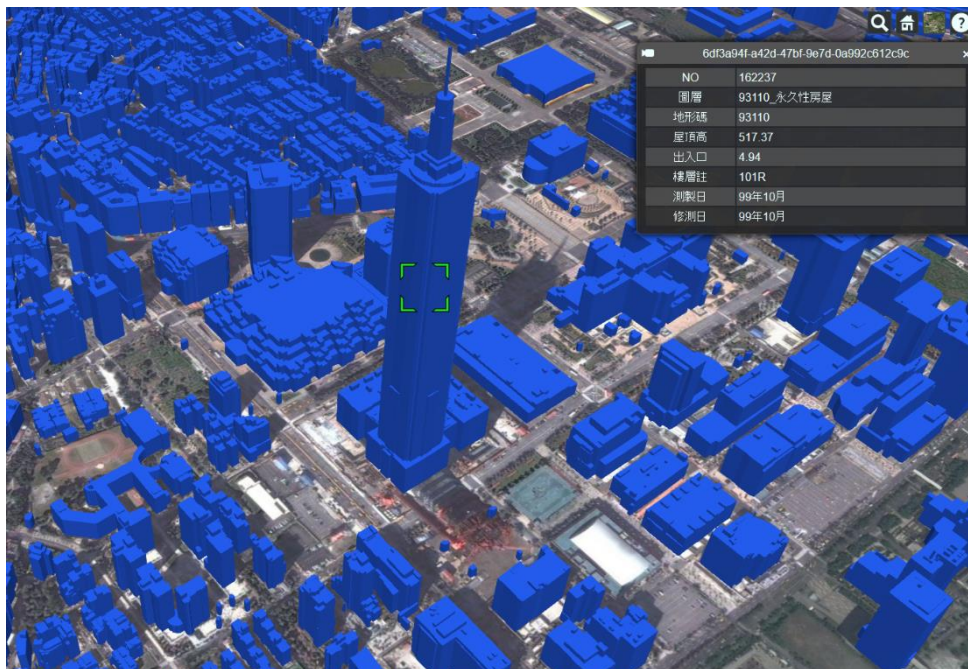


Figure 16. 3D building generated from building boundary data

In figure 15, the original building boundary data have many polygons. Each of polygon has some attributes which contain information about building. In figure 16, 3D building is successfully created from building boundary data. It also can display the information about attribute of the building. But, some of buildings don't have building boundary data as it displays on map. This issue is caused by establishment time difference between building boundary data and map information. The time difference is around 2 years. Thus, it might be a new building has built after building boundary data is created.

6. CONCLUSION

In this study, a strategy to build website application with open source GIS platform is proposed which can load a photo-realistic 3D model and attach some GIS information. The test site for this study is in Taipei city. This study also examines the applicability of a wide area and large scale city model with photo-realism operating on a web-based 3D GIS platform. Based on our experiment, CesiumJS is able to offer a 3D visualization through website browser to load a photo-realistic 3D model with the information attached in it. The file format of photo-realistic 3D model is JSON. This JSON will be called inside the Javascript line of code. The swiftness of loading a 3D model is efficient, due to HLOD was applied. To load this high quality and large area photo-realistic 3D model, it spends 50 seconds at the first time. After that, the browsing speed will become faster.

This website application provides GIS information such as road line, district segmentation area, and building information. All this GIS information have same file format which can be loaded in website. The file format is Geojson. In fact, Geojson is an open standard format designed for representing simple geographical features, along with their non-spatial attributes, based on JavaScript Object Notation. Thus, the easiness of sharing the GIS information will make a CesiumJS a familiar platform around spatial information developers.

Applying the developed web-based for photo realistic 3D model in Taipei City is only one of many possible applications. Multiple benefits could be introduced, if a photo-realistic city model can be integrated simultaneously with various applications on a Web-based 3-D GIS platform, such as disaster modelling, heritage buildings, and many others. The system may become a useful geospatial platform for GPS navigation applications by both government and the general company.

7. ACKNOWLEDGEMENT

The authors would like to thank the Taipei City Government for providing the large scale digital topographic map, digital terrain model and other geospatial information. The authors would also like to appreciate Sinotech Engineering Consultants Ltd. for providing the aerial photo and CesiumJS Community for their technical support.

8. REFERENCES

- Janko, Z., 2006b. Photorealistic 3D Models of Real-World Objects. PhD Thesis, Computer and Automation Research Institute, Hungary.
- Gruen, A., & Wang, X., 2001a. News from CyberCity-modeler. Automatic Extraction of Man-Made Objects, pp. 93–101.
- Rau, J.-Y., Cheng, C.-K., 2013a. A cost-effective strategy for multi-scale photo-realistic building modeling and web-based 3-D GIS applications in real estate. *Computers, Environment and Urban Systems*, 38, pp. 35-44.
- Trubka, R., 2016a. A web-based 3D visualization and assessment system for urban precinct scenario modelling. *ISPRS Journal of Photogrammetry and Remote Sensing*, 117, pp. 175-186.
- Bremer, M., 2016a. A new multi-scale 3D-GIS-approach for the assessment and dissemination of solar income of digital city models. *Computers, Environment and Urban Systems*, 57, pp. 144-154.
- Galeazzi, F., 2016a. Web-based visualization for 3D data in archaeology: The ADS 3D viewer. *Journal of Archaeological Science: Reports*, 9, pp. 1–11.
- Niu, S., 2015a. A BIM-GIS Integrated Web-based Visualization System for Low Energy Building Design. *Procedia Engineering*, 121, pp. 2184 – 2192.
- Zavala-Romero, O., 2014a. An open source Java web application to build self-contained web GIS sites. *Environmental Modelling & Software*, 62, pp. 210-220.
- Sima, A.A., 2013a. Computer-aided image geometry analysis and subset selection for optimizing texture quality in photorealistic models. *Computers & Geosciences*, 52, pp. 281–291