A Framework for Interactive Online 3D Visualization of Electric Information

Yan Li, Hong Zhang*, QianQian Zhang
Southwest Branch of State Grid Corporation of China, No. 299, shuxiu West Road, Wuhou District, Chengdu City, Sichuan Province, China

*hongzhanggrid@126.com

Abstract. To manage the electric network effectively, 3D visualization framework is necessary to reveal the complexity of power grid system. In this paper, an interactive online 3D visualization framework is proposed to visualize the electric network related information from power station to the static data of the system. We applied Cesium, an open source platform for 3D visualization based on WebGL supported browsers. Meanwhile, multiple Level of Detail (LoD) structure of power grid facility is generated to improve the speed of 3D model loading and rendering. The experimental results indicate that the proposed framework can integrate and dynamic visualize power grid information from multiple sources. The multiple LoD structure can reduce the model loading time by 76% and increase the FPS over 50% according to the tests on sample data.

Keywords: Electric information, 3D visualization, Interactive, Level of details, Cesium.

1. Introduction

Power grid is critical for our daily life, and it is essential to maintain the stable operation of the power grid system. Therefore, many kinds of sensors are installed to monitor the electric network from different aspects. For example, the cameras can be used to monitor the swings of power lines and the intrusion to the distribution networks. Temperature and humidity sensors are applied to gather the environment of the power line towers. These data from the sensors additional with the information from the power grid itself have become increasingly difficult to management. Therefore, it is necessary to develop an interactive 3D visualization framework so that the data from different sources about the electric system can be integrated and analyzed visually.

Existing visualization frameworks in electric management systems are mainly based on tables and 2D maps. Along with the development of different types of sensors, 3D visualization is becoming increasingly necessary. Especially the 3D Geoinformation system that can integrate the geography data and electric network information should be applied in the power grid management system. In this paper, we study the different data types in the electric management system and create 3D models for the typical power grid equipment structures. A Cesium based online 3D platform is applied to implement the main framework with GIS information such as maps and satellite images. Then, the visual variables such as color, transparency, size and etc. are used to represent the system running information from the power grid (temperature, humidity, wind and so on). Besides, a multiple LoD structure of 3D models is generated to increase the loading and rendering speed of the framework.
Finally, the proposed framework can interact with user and dynamically visualize the changing of historic records and real time information. We also implement a demo system to show the capacity of the proposed framework. The rest of the paper is structured as follows. Section 2 introduces the related work. Section 3 describes suggested framework in detail. The system implementation and experimental results are given in Section 4. Section 5 concludes the whole paper.

2. Related work
Overbye and Weber [1] emphasized a concept of using word-sized graphics called sparklines to show the time-varying data in the power grid system. Hidalgo and Cano [2] summarized the visual data representation in smart grid system and they suggested that visualization plays a key role in facilitating the challenging tasks of monitoring, analyzing, and responding to the events in the smart grid. Ruiz et al. [3] proposed a case study of visualization of energy consumption not only for the export users but also easy to use for the non-export users based on a web based platform. These studies shown that visualization for power grid system and its operation information is necessary to improve its management.

Galeazzi et al. [4] studied the web-based resource for the management and analysis of archaeological data. They developed a 3D viewer using WebGL technology. Wang [5] proposed a 3D visualization framework for virtual package design and representation. Figueiras et al. [6] applied the particle-based 3D visualization technology to represent the 3D quantum wave function dynamics. They used the VTK library to implement the 3D rendering. Zhi et al. [7] implemented a 3D dynamic visualization method of an urban drainage model, and they promoted a shift in analysis from 2D to the combination of 2D and 3D. Nishanbaev [8] described a methodology and a web repository to integrate maps, 3D models, and geospatial data such as geolocation. It can be utilized for long-term archiving and visualization of geo-located 3D digital cultural heritage models on the Web.

Schilling et al. [9] proposed an online 3D visualization platform based on glTF to integrate information for city models. They applied Cesium.js, an open source virtual globe as a platform for embedding custom 3D assets. Kulawiak and Kulawiak [10] indicated that the combination of Cesium and 3D Tiles constitute a promising set of open standards for dissemination and visualization of LiDAR data in a web environment. Chen et al. [11] studied how to use 3D Tiles to visualize the complex Building Information Model or BIM. Gan et al. [12] proposed a method of organizing and visualizing the Digital Surface Model combined with fine building model on the virtual globe based on WebGL and 3D Tiles. Their research shown that 3DTiles can effectively solve the multi-level organization and scheduling of the hybrid models and enhance the visualization effect. Mao and Li [13] applied the Cesium and 3D Tiles structure to energy consumption visualization. They implemented the multiple LoD structure of energy use and created the dynamic animation in Cesium platform with CZML. These studies show that Cesium can integrate and visualize the multiple LoD data from different sources, which is essential for the electric network management.

3. Methodology

3.1. 3D Visualization Framework
The information from the power grid system is diversity in sources and formats. Therefore, we have to develop a strategy to convert the data into visual variables such as color, size, shape and etc. for the non-photorealistic 3D visualization. Along with the development of Internet of Things or IoT technology, increasing number of sensors have been installed into the power grid system. Besides the operation data about the power grid itself such as voltage and electric current, environment information such as temperature, humidity, lightness, and video surveillance are integrated into the system. Traditional 2D visualization cannot integrate all these new datasets from the IoT systems, and 3D based visualization is necessary for the electric management platform. In this paper, we proposed an effective visual variable mapping algorithms to visualize the multiple sourced datasets of electric system as shown in Fig. 1.
First of all, aiming at the visual variables of geometry, texture and distribution, we use 3D model
generalization algorithm, which mainly includes simplification, enhancement, selection and fusion, to
build the visual variable database. Specifically, for the geometric model, including CSG (constructive
solid geometry), zooming, position and other visual variables, the visualization effects and the
Corresponding implementation complexity under different rendering strategies such as volume
rendering, face rendering, line rendering and point rendering are tested respectively, so as to define the
rendering scene; at the same time, the multi-level geometric prototype library is established by means
of CSG typification, geometric model simplification and other means; real The fusion visualization of
visual variables of multiple level of detail geometric elements is presented. For texture elements, we
build multi-level of detail texture database, define multi-level resolution texture image, texture type,
and realize the dynamic generation of texture data, so as to reduce the transmission of texture data. For
the distributed visual variables, it is proposed to subdivide them in terms of parameters, segmentation
accuracy, types, etc.

Next, the fusion mapping of multi-element visual variables driven by 3D electric visualization is
realized. Based on the requirements of diversified 3D electric visualization, this paper analyzes the
interaction between different visual variables, especially the coupling mechanism between different
levels of detail visual variables, so as to realize the fusion visualization of multi levels of detail visual
variables. As shown in Figure 2, the composition and characteristics of visual variables are analyzed,
and a multi-dimensional spatial coordinate system of visual variables is established. In this coordinate
system, the 3D electric visualization requirements are located, and the corresponding visual variable
parameter database is generated. Based on the mapping relationship between visual variables and
multi-level of detail 3D model, the experiment will analyze and determine the requirements of visual
variable elements and the accuracy requirements of specific visual variables in different levels of
detail.

3.2. 3D electric multi detail hierarchy based on 3DTiles
3D tiles is an OGC standard. It is a new specification defined by AGI (analytical graphics, Inc.) on the
basis of gltf format in March 2016. It is used for visualization and sharing of heterogeneous 3D
data. 3D tiles technology renders 3D model data in block and hierarchical form, which
reduces the burden of browser. It is an excellent open source data specification, mainly used in the
cesium platform.

In 3D tiles, a tile set is a tile set that usually organizes 3D model data with a tree spatial data
structure. Each tile has a minimum bounding box that completely encloses all its contents, and the
contents of all the child tiles are completely contained in the bounding box of the parent tile. A tile
index one or a group of 3D features, such as building 3D model data, green vegetation point cloud data, and some vector data points, polylines, etc.

Urban 3D model data is mainly stored in the binary format of gltf, with. B3dm as the file suffix. The b3dm file can store a table batch table that describes the attribute information of the model. Each model in the batch table corresponds to a unique batchid, which is used to identify the attributes of each model. At the same time, the batch table usually contains metadata, which can be used to visualize the declaration style. For example, the batch table contains a series of height values of building model data. When we use 3D tiles for visualization, we can render the model into different colors according to the height values.

In this paper, 3D power grid is divided into three levels: network, station and equipment. The main features of the system are as follows: 1. It supports large-scale data integration visualization at the city/area level. Because of the tile structure, the urban area can be divided, and the information of the area can be displayed dynamically based on the user's viewpoint, so that the 3D electric data of the city can be quickly and uniformly viewed. Two Multi level of detail 3D model geometry and semantic information binding. By building a multi-level of detail structure with the theme of network, station and equipment, the 3D electric semantic information can be bound to the corresponding geometry structure according to the relationship of ownership. For example, for the station, there are data such as height, building unit, frame structure, plot ratio, shared proportion, and etc., while the layer includes the layer High, channel, fire-fighting equipment, water supply and drainage, strong and weak electricity and other information; equipment includes property ownership, utility, transaction transfer, input/output and other information. 3. To associate dynamic semantic data, considering the dynamic characteristics of electric data, it is necessary to decouple the information of dynamic changes from the 3D model itself, so as to improve the flexibility of the system. 3DTiles can associate with database information through 3D model ID, and directly set model style based on related information and visual variable mapping method, so as to realize the dynamic visualization of data.

3.3. 3D electric data interactive visualization
On the basis of 3DTiles, through model semantic information, this paper designs an interactive visualization framework of 3D electric information, as shown in Fig. 2.

![Dynamic Interactive Visualization Framework for Electric Network](image)

Object selection view. In 3DTiles, 3D model object ID can be set, and the corresponding 3D electric object can be directly selected by ID matching, and the electric information can be displayed by non-photorealistic visualization mapping. In this paper, a fast display method for electric data visualization is designed. By coloring the electric object and transparently processing its surrounding building model, the information of the target object right and its surrounding area is integrated and displayed. In addition, this paper also uses the model information window function supported by
cesium system to realize the interactive display of 3D electric information and its related introduction, and to support users to query and retrieve the target object.

Semantic dynamic rendering. After the visual object is determined, the semantic information is rendered by setting different visual variable mapping functions. 3DTiles supports conditional rendering of model data, and realizes different rendering styles by setting visual conditional parameters. In this paper, two modes are used to complete semantic rendering: function definition and direct mapping. In the method of function definition, the conversion function between semantic value and visual variable (mainly color and transparency) is established to directly convert semantics to corresponding visual variable and realize visualization; in the way of direct mapping, a series of semantic value color / transparency mapping pairs are defined to directly convert semantic data to visual variable. Compared with the two methods, the function method is concise and fast, but it needs to find the corresponding conversion function; while the semantic mapping method is more direct and can be defined quickly, but needs to define a large amount of data, which is suitable for the situation of less semantic types of the model.

External information integration. Due to the limitation of 3DTiles model generation, it is difficult to directly integrate external data such as dynamic information (such as real-time voltage of the electric equipment) into the model. Therefore, for the display of external information, we can first generate corresponding visual data based on external data, such as color, transparency, etc., and then display it through the ID of 3D electric object through direct mapping method. In addition, the dynamic rendering of 3DTiles greatly improves the visualization efficiency of the model, and can support the animation rendering of historical dynamic data and real-time data. By repeatedly refreshing the rendering mode of the electric object in a certain period of time, we can show the dynamic changes of the relevant information of the electric object. For example, binding the temperature of the electric equipment with color can show the rise of historical information and the temperature distribution of the equipment in different time.

4. Visualization Results

4.1. System implementation
3D Tiles data generation. The existing 3D property data is mainly stored in general 3D model files such as obj or COLLADA, which can only be viewed separately, so it is difficult to achieve rapid and unified integration and dynamic rendering. To do this, we need to first convert the existing 3D model to 3DTiles data. At present, there are many open source programs that can directly convert a variety of 3D models to 3DTiles data format. In this paper, obj23dtiles tool is used to complete the conversion from obj 3D model.

After 3DTiles data is imported into the Cesium framework, the visualization effect of 3D electric data can be directly seen. 3DTiles supports dynamic rendering strategy by defining different rendering conditions or directly defining the color and transparency of the model through ID. In this paper, the user interaction framework provided by cesium is used to realize the interface setting of different visualization strategies and their input parameters. Users can directly select the non-photorealistic visualization effect and set the key parameters, so as to generate a variety of rendering results that can reflect the specific attributes of the 3D electric data.

The demo system is developed on WIN10 operation system based on cesium.js library. Nodejs network service system and python3.5 compiler are needed. To view the system content, a browser supporting WebGL is necessary. At present, the mainstream browsing including chrome and Firefox can realize direct browsing. The demo system running on an inter (R) i7-6700hq CPU@2.60GHz 2.59hz, 16GB RAM, 64 bit computer.

4.2. Electric information visualization
The overall visualization results is given in Fig. 3(a). We can see that different type of information about the electric network can be integrated in Cesium and supply a GIS based management system. Fig. 3(b). Show the user interface for 3D visualization setting and styling.

![Electric information visualization](image1)

![User interface](image2)

**Fig. 3** Electric information visualization results

Fig. 4 gives an example of 3D electric model with the image data from video surveillance system. These results indicate that the proposed 3D visualization framework can effectively integrate the electric information and supplies a GIS based interface for the users.

![3D object visualization](image3)

**Fig. 4** 3D object visualization results

We test the loading time of model and rendering speed of FPS (Frame per Second) of the proposed framework by comparing the 3D models in 3DTiles format and not. The results are given in Table 1. According to the test results in different models, we can see that the proposed multiple LoD framework can improve the FPS by 50% and reduce the loading time by 76%.

| Methods            | FPS | Loading Time (ms) |
|--------------------|-----|-------------------|
| Non-3DTiles model  | 18  | 5871              |
5. Conclusions
3D visualization of the electric network is necessary for efficiency management of the power grid system. It can integrate data in multiple formats and from different sources, and support the interactive querying of the complex electric data. The Cesium platform can provide a GIS based 3D visualization framework for the electric information. Also the 3DTiles structure can effectively increase the rendering speed and reduce the loading time according to the experiment results.

References
[1] Thomas O and James W 2015 Smart Grid Wide-Area Transmission System Visualization Engineering 1 4 pp 466-474
[2] Sanchez-Hidalgo M and Cano M 2018 A survey on visual data representation for smart grids control and monitoring Sustainable Energy, Grids and Networks 16 pp 351-369
[3] L R, M P, Molina S and Yike G 2020 A case study on understanding energy consumption through prediction and visualization (VIMOEN) Journal of Building Engineering 30 101315
[4] Fabrizio G, Marco C, Matteo D, Michael C, Julian R and Roberto S 2016 Web-based visualization for 3D data in archaeology: The ADS 3D viewer Journal of Archaeological Science 9 pp 1-11
[5] Zhiqiang W 2017 Virtual Package Design and Realization Based on 3D Visualization Technology Procedia Engineering 174 pp 1336-1339
[6] Edgar F, David O, Angel P and Humberto M 2019 QMBlender: Particle-based visualization of 3D quantum wave function dynamics Journal of Computational Science 35 pp 44-56
[7] Guozheng Z, Zhenliang L, Wenchong T, Xin W and Juxiang C, A 3D dynamic visualization method coupled with an urban drainage model Journal of Hydrology 577
[8] Ikrom N 2020 A web repository for geo-located 3D digital cultural heritage models, Digital Applications in Archaeology and Cultural Heritage 16
[9] Arne S, Jannes B and Claus N 2016 Using glTF for streaming CityGML 3D City Models Proc. of the 21st Conf. on Web3D Technology pp. 109–116
[10] Kulawiak M and Kulawiak M 2017 Application of Web-GIS for Dissemination and 3D Visualization of Large-Volume LiDAR Data Lecture Notes in Geoinformation and Cartography
[11] Chen Y, Shooraj E, Rajabifard A and Sabri S 2018 From IFC to 3D Tiles: An Integrated Open-Source Solution for Visualising BIMs on Cesium ISPRS Int. J. Geo-Inf. 7 393
[12] Linlu G, Jun L and Ning J 2017 Hybrid organization and visualization of the DSM combined with 3D building model 2nd International Conference on Image, Vision and Computing (Chengdu, China) pp. 566-571
[13] Bo M, Yifang B and Laumert B 2020 Dynamic Online 3D Visualization Framework for Real-Time Energy Simulation Based on 3D Tiles ISPRS Int. J. Geo-Inf. 9 166