Research and application of 3D GIS in the visualization and information management of power grid construction projects

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Abstract. The research direction and application scope of transmission line 3D visualization aided design system include design data retrieval of transmission line project, preliminary path selection, feasibility study, and preliminary design. Actively explore the in-depth application of line 3D construction drawing design and digital transfer. Based on the relevant work experience of the author engaged in the application of GIS technology for many years, and taking the application of 3D GIS technology in power grid planning and design as the research object, this paper designs and implements a 3D GIS visualization system for power grid planning and design, decomposes the system function with a case, and analyzes the operation flow of the system in detail, which is believed to be beneficial to colleagues engaged in related work.

Keywords: 3DGIS, Power grid planning and design; Visualization system; Workflow.

1. Introduction

With the rapid development of computer technology, Geographic Information system has been more and more widely used in the whole power industry. Introducing GIS into the distribution management system (DMS), and combining it with power consumption MIS, load management, and SCADA subsystems to provide a set of simple, rapid, and convenient distribution network operation management system for managers at all levels has become an effective means for modern power enterprises to improve the management level and work efficiency. However, at present, the GIS system based on two-dimensional coordinates is widely used in power systems, and its spatial representation and analysis ability are very limited. The transmission line is an artificial structure located in geographical space, which has a long-distance, complex geographical condition through the region, and crosses with many power lines and communication lines, and usually passes through residential areas, parks, and other special areas.

The location of transmission lines and their towers is closely related to the geo-spatial location, especially the hierarchical information in the vertical direction is particularly important, which makes the two-dimensional geographic information system can not meet the needs of its management. In recent years, with the development of computer graphics and the improvement of computer hardware performance, three-dimensional representation technology is becoming more and more perfect. Through these technologies, we can construct three-dimensional surface models and all kinds of
equipment models that are more close to reality, and make the GIS system develop from two-dimensional to three-dimensional. [1]

The international development of GIS began in the 1960s and originated in North America. The first GIS in the world was proposed and established by surveyor R. F. Tominson in 1963 by the Canadian Land investigation Bureau to deal with a large number of land survey data. After the 1970s, due to the rapid development of computer software and hardware, especially the use of large-capacity storage function disk, it provides a powerful technical means for the input, storage, retrieval, and output of geospatial data, which makes GIS develop rapidly in the direction of practicality. The 1980s is the great development stage of the popularization and application of GIS. Due to the popularity and rapid development of the new generation of high-performance computers, GIS is also gradually becoming mature. [2]

The software and hardware investment of GIS has been greatly reduced and its capability has been significantly improved. it has entered multi-disciplinary fields, developed from a single and simple decentralized system to a multi-functional integrated information system shared by users, and began to develop to the power industry.

The application of power grid GIS has experienced the stage of CAD+ database and traditional GIS application and entered the stage of AM/FM/GIS application in the early 1990s. The establishment of power grid GIS, characterized by digital power grid and cooperative work environment has become an indispensable tool for power enterprises in developed countries to reorganize production and operation business processes and improve the scientific management level of power grid operators to enhance their competitiveness (reduce production costs and improve service level).

2. Construction Scheme of three-dimensional Digitalization of Power Grid

2.1. Scheme architecture

The application architecture of a 3D digital platform for power grid engineering can be divided into six levels and two systems. they are the infrastructure layer, data management layer, data access layer, application service layer, application layer, user layer, information standard system, and information security protection system. Among them, the data access layer, application service layer, application layer, and user layer are separated to facilitate the expansion of the system.

![Three-dimensional digital architecture diagram of the power grid](image1)

*Figure 1. Three-dimensional digital architecture diagram of the power grid*
Big data, cloud computing, Internet of things, visualization, 3D digitization, and other technical means are mainly used to realize the transfer and reception, archiving and storage, centralized management, 3D visualization display, data sharing service application of the design results of power transmission and transformation project, effectively promote the construction of data management system of power transmission and transformation project, and support the whole life cycle management of the company's power transmission and transformation project data. The server side is responsible for the storage and release of power grid engineering design data, and the client-side is in the form of web pages. As shown in Figure 1. [3]

2.2. Overall function
The main functional modules of the 3D digital platform for power grid engineering are divided as follows: data upload tool, handover progress management, power grid handover project management, geospatial data and handover management, engineering design achievement handover and management, power grid engineering 3D digital browsing, 3D digital achievement sharing service, 3D digital platform configuration management and so on.

3. Key Technology and Implementation

3.1. Integrated basic Information platform of 3D Geographic Information system Technology
Using the basic geographic image DOM and digital elevation model DEM, needed by the remote sensing data acquisition platform, through the image data processing work such as correction, registration, mosaic, and fusion of the remote sensing image, the spatial data pyramid is constructed based on the spatial quadtree principle, and an efficient index mechanism is established to store, manage and publish in the form of tile file.

3.2. Hierarchical power grid construction
Based on the rich geographic information data, the required power equipment models such as substation, tower, insulator string, foundation, spacer rod, shock hammer, and so on are stored uniformly; secondly, the hierarchical power grid details are organized and stored in the loop according to the business logic relationship, and the unreasonable data are preliminarily detected and modified, and then the power engine drive is used to construct the results of the three-dimensional power grid. After the completion of the construction of the power grid results, it is necessary to further optimize the results, including dynamic wire index creation and LOD optimization. [4]

3.3. Dynamic wire creation
To ensure the efficiency of loading and rendering of power grid results, a variety of technologies and algorithms are adopted for wire creation and rendering and strive to achieve a degree consistent with reality. It includes the following points:

Catenary algorithm: In the transmission line, due to the influence of wire rigidity, the wires between adjacent towers will sag to a certain extent, forming an arc; at the same time, the selection of sag formula is also related to the error of wire stress and the error of wire spacing between crossover objects.

Taking OC as the research object, balance by force:

\[ T_0 = T \cos \theta \]
\[ \mu s = T \sin \theta \]
\[ \tan \theta = \frac{\mu s}{T_0} \rightarrow \frac{dy}{dx} = \frac{s}{a} \rightarrow s = a \frac{dy}{dx} \]

Get the differential arc length formula:
\[
\frac{ds}{dx} = \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\tag{4}
\]

Bezier curve interpolation algorithm: to ensure the fluency of wire radians and rendering effect. P0 is the starting point of the line segment, P1 is the adjustment point of the middle adjustment curve shape, and P2 is the endpoint. t represents the whole process, and t gradually changes from 0 to 1, and all the position coordinates of P on the actual curve can be obtained.

\[
P = (1-t)^2 P_0 + 2t(1-t)P_1 + t^2 P_2\tag{5}
\]

\[
P_x = (1-t)^2 P_{x0} + 2t(1-t)P_{x1} + t^2 P_{x2}\tag{6}
\]

\[
P_y = (1-t)^2 P_{y0} + 2t(1-t)P_{y1} + t^2 P_{y2}\tag{7}
\]

4. The present situation and summary of the pilot project

Centralized management to realize the integration and sharing of design results. Through digital, three-dimensional visualization form of effective management, storage and release of power grid engineering three-dimensional design results, to promote the application of three-dimensional design results in the whole process of power transmission and transformation project construction, better service for project evaluation, infrastructure construction, production management, and control. [5]

![Figure 2. Transfer flow chart](image)

(1) Establish unified digital standards and specifications for power grid engineering;
(2) Define the work plan of 3D digital transfer, but the original scheme based on 2D GIS is not clear;
(3) Realize 3D digital expression of design results;
(4) Assist design inspection and construction site investigation based on corridor 3D digital sand table, and further effectively improve the visualization and accuracy of engineering design and evaluation. [6]
5. GIS-based model development

5.1. The selection of the GIS system.
The construction of a 3D visual-aided design system for transmission lines is a process with a large investment and a long time, which requires platform suppliers to provide long-term support and maintenance to users' application systems. In addition, because the content of the system is very complicated and the technology involves a wide range of areas, GIS products with a large number of users should be adopted to ensure technical support, product stability, and product upgrading.

5.2. GIS data
The shapes of natural features and human features on the earth's surface are different, complex, and closely related. After abstraction and simplification, the earth's surface features can be expressed by the following four types of data. The main contents of this paper are as follows: (1) as the most common core data form of most GIS, digital line data (DLG): DLG uses abstract graphics to express geospatial entities, which is very suitable for computer expression. (2) Image data: image data include remote sensing images and aerial images. Because the image data source is rich, the production efficiency is high, and the natural phenomena of the surface are recorded intuitively and in detail, so the image data plays a more and more important role in the modern GIS. (3) Digital elevation model ((DEM): DEM) has been collected as special spatial data in GIS, and the accuracy of DEM has gradually become the standard to measure a geographic information system. (4) Attribute data: the spatial query and spatial analysis of GIS can not be separated from the support of attribute data. It is precise because GIS stores graphics and attributes data that GIS is rich in content and widely used.

The software development model of the transmission line 3D visualization aided design system adopts the three-level architecture mode: supporting the basic GIS software which adopts open data structure and industrial standard; on this basis, the component secondary development professional operation platform is adopted; on the professional operation platform, all kinds of advanced applications are developed again. The schematic diagram of GIS development is shown in Figure 3.

![Figure 3. 3D GIS construction feedback system design](image-url)
6. Conclusion

Build a Three-Dimensional digital platform for power grid engineering, and use big data, cloud computing, Internet of Things, mobile and visualization technology to carry out three-dimensional digital unified centralized management of the design and construction of power grid engineering at different stages and different professional design results to achieve design results.

Integrate and share, create a three-dimensional digital power grid, promote business integration, assist digital design, effectively manage the three-dimensional design results of power grid projects through digital and three-dimensional visualization, and better serve a multi-level response, risk warning, statistical analysis, etc., and improve The comprehensive handling capacity for the safe operation of elevators has played a positive role in the construction of safe cities and smart cities.

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