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Research on Construction Planning for Bridge in Mountainous Area Based on GIS/BIM Virtual Construction Technology

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Abstract. It is difficult to plan the construction of super large bridge in mountainous area by traditional methods due to the complex geological conditions and narrow sites there. This paper proposed a new construction method of virtual construction platform for the construction planning of super large bridge in mountainous area applied in engineering based on BIM/GIS virtual construction technology. Based on the visual representation of BIM model and taking the GIS graphics engine as a carrier, this method combines the temporary building, the main structure and the geographical environment for virtual presentation. An integrated platform of model, data and rendering is formed for the realization virtual planning, virtual construction, digital twin, data supervision and other functions. Taking the pre-construction planning of a grand suspension bridge in the complex mountainous area of southwest China as an example, this virtual construction technology is used to realize the goal of the intelligent application in three aspects, namely, 3D planning of temporary construction site, intelligent control of access road and virtual preview of construction progress.

Keywords. Bridge, construction planning, virtual construction, BIM technology, GIS technology, digital twin, engineering application

1. Introduction

Virtual Construction (VC) originally refers to the use of computer technology to digitally simulate the construction process of construction projects. The virtual construction technology was limited by the level of computer software and hardware at the primary stage, where virtual construction couldn't match with the environment but to be roughly compared, since graphics and models were usually simplified and the environment and terrain in the site was restored badly in the simulation [1]. With the rapid development of the new generation of intelligent technology, the building information model (BIM) technology, 3D IVR technology and graphics engine are constantly changing, and the concept and technology of virtual construction are becoming more and more perfect. Based on the new generation of intelligent technology, BIM related modeling software

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can be applied to efficiently and finely build 3D models of construction projects, and 3D IVR technology can be combined to build geographic environment models. Integrating matching and simulation in graphics engine can highly restore the construction situation in the site and realize visual verification, optimization and improvement of the construction scheme [2, 3]. In the field of building construction, due to the small size and high repeatability of the model, the whole manufacturing process and the building construction process can be accurately simulated by using virtual construction technology. Compared with buildings, super large bridge structures are more complex, and many environmental factors and application scenarios need to be connected, so it is difficult to realize virtual construction, but virtual construction also has prominent effects. Yan et al. [4] developed the BIM management system for bridge construction in order to improve the construction and management level of Shanghai-Suzhou-Nantong Yangtze River Bridge, and preliminarily studied the information functions such as visual disclosure, drawing management, construction planning, 3D construction log, etc., which made a useful exploration in BIM research and application of long-span bridge in the whole life cycle. Liu et al. [5] put forward a BIM-based construction schedule optimization model, taking an expressway girder bridge as an example, to realize the information management of on-site construction schedule and dynamic simulation of construction.

At present, there are few studies and applications related to the construction planning of super large bridge in complex mountainous area. Traditional bridge construction planning methods rely on drawings and words cannot reflect the overall planning, and it is difficult to present the site layout and construction plan in a 3D and dynamic way. Given these concerns, this paper proposed a construction method of virtual construction platform for super large bridge construction planning in mountains area based on the 3D visual virtual construction of BIM technology, combined with the geographic information system (GIS) engine, and made reasonable construction planning, so as to improve the construction efficiency of super large bridge in mountain environment and save costs.

2. Virtual Construction Platform for Bridge in Complex Mountainous Area

The virtual construction platform is based on the visual expression of BIM model, and the graphics engine is used as the carrier. The temporary planning, main structure and geographical environment are combined for virtual presentation, which intuitively reflects the layout planning of the whole bridge construction process and the relationship between main structure and geographical environment. At the same time, the platform can also monitor data and access progress data in the construction according to the construction characteristics, and realize the digital twins in some functions through the unified integration of the virtual construction platform [6]. Therefore, the virtual construction platform needs to build the models of bridges, temporary planning facilities, equipment and geographical environment, select the graphics engine as the carrier and connect with the database to form an integrated platform of model, data and rendering. The virtual platform architecture is shown in Figure 1.

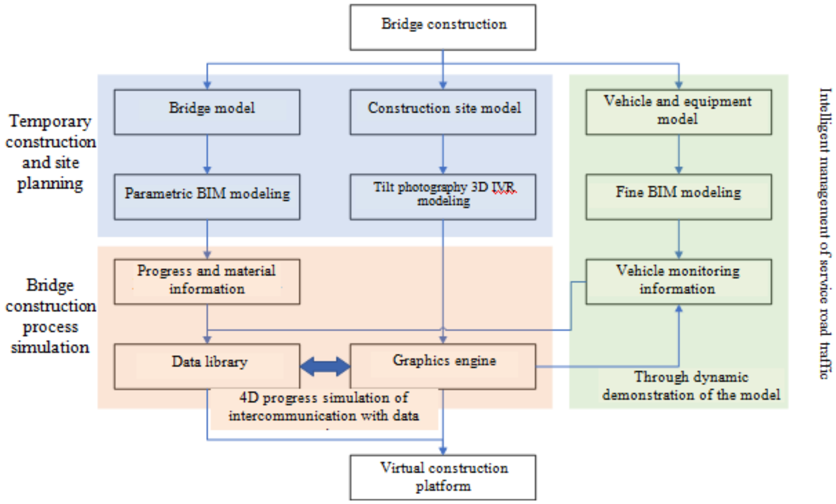


Figure 1. Functional architecture diagram of virtual construction platform.

One of the cores of virtual construction platform is the application of graphics engine. According to the architecture characteristics of virtual construction platform, this paper comprehensively analyzes the development cost, operation efficiency and presentation forms of various graphic engines such as UE4, Unity 3D, GIS, etc., and decides to use GIS engine with high open source and better combination with 3D IVR model as the carrier. GIS engine is widely used in surveying and mapping industry, which can integrate geographic information, support B/S architecture, and convert BIM model into IFC, 3Dtails and other formats for integration. Besides, the GIS engine can read the data and refresh the model in real time, and display the vehicle position and monitor data in real time on the web page. Compared with other relatively closed C/S engines, it can meet the needs of virtual construction.

Ceisum engine, as an open-source GIS engine, is not a customized product. It supports JavaScript development and B/S (Web-side) encapsulation, and can customize functions according to actual needs to meet the application requirements of virtual construction interactive scenes. Therefore, Ceisum engine is selected as the graphic engine of virtual bridge construction platform in mountainous areas, and digital elevation model (DEM) data is loaded into Ceisum engine to present terrain model. Because the model presents the whole region, the accuracy can only be controlled within 5 m. In order to meet the precise positioning requirements of the project, the 3D IVR model processed by unmanned aerial vehicle (UAV) is docked with the digital elevation model according to latitude and longitude, so as to greatly improve the accuracy of the geographic model in the construction area, which can increase from 5 m to 5 cm. Based on Ceisum, the data can be called to check through the BIM model, and the parameter data in the BIM model co-relates to the background database with Engineering Breakdown Structure (EBS) as the link, through which any model component can be clicked to view the related data [7, 8].

3. Engineering Application

Taking a grand suspension bridge in a mountainous area of southwest China as an example, the special function research and development and pilot application of virtual construction platform are carried out. The construction site of the bridge is narrow, and the existing roads are narrow and steep. The site selection, road management and construction period planning are more difficult than those in plain areas. Therefore, according to the actual needs of the project, the research and development of three aspects, namely, 3D planning of the site, intelligent control of access roads and virtual preview of construction progress, are carried out on the virtual construction platform.

3.1. 3D Planning of Temporary Construction Site

Firstly, in order to improve the accuracy of the virtual construction platform construction scene, a 3D IVR terrain model is established. Aerial survey of the ground of the construction site at a constant speed is carried out by using unmanned aerial vehicle, and image information of different shooting angles and corresponding pos data are collected through multiple aerial surveys as the material for building the model; Computing the collected photos, and forming a 3D model of the photographed object by fitting photos through different shooting angles; Deepening the design of the 3D model, such as flattening the areas on both sides of the road, repairing the water surface, filtering floating objects, etc.; The 3D IVR model is docked to the geographic coordinates of the virtual construction platform GIS engine through latitude and longitude coordinates, and the layout of IVR terrain in the engine is completed (Figure 2).

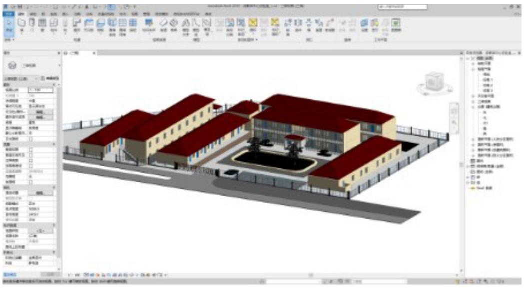
Figure 2. Example of 3D IVR terrain model.

Then, the combination of 3D IVR terrain model is used to realize the accurate positioning of the temporary construction and building planning. The 3D IVR model is imported into the platform, and the temporary planning model is placed on the corresponding coordinate points of the 3D IVR terrain model by inputting the coordinates. The placement process of the model can be matched with the terrain in the three spatial dimensions of X, Y and Z, and the model can be rotated, translated and flipped by the mouse. Besides, the location relationship can be planned according to the functional characteristics and transportation requirements of each temporary planning, through which any two models are on the platform are clicked to automatically display and calculate the road distance. The road planning is shown in Figure 3a. Based on the virtual construction platform, the overall layout effect of the temporary building planning is evaluated by functions such as roaming, and the unreasonable layout of the planning could be adjusted in time. By adjusting the position of the temporary building on the 3D IVR model (Figure 3b), the reasonable planning and efficient operation of roads and temporary buildings can be guaranteed to the maximum extent.

(a) Road planning (b) Decentralized temporary planning

Figure 3. Road and temporary construction planning based on 3D IVR model.

Finally, based on the virtual construction platform, the internal functional zones and landscape planning of the temporary construction are presented. The deepened model can be directly called in the virtual construction platform to adjust the size, position and quantity of structural models in the temporary building in real time, so as to realize landscape planning and functional design of the temporary construction. The appearance and layout are viewed by model visualization, and the functional zones and planning inside the model are also viewed by roaming function (Figure 4).



(a) Temporary building exterior model

(b) Temporary building internal scene

Figure 4. Temporary exterior and internal scene model.

The temporary building planning based on the platform supports to view the environmental situation of the whole construction site and the existing road route before the project starts, and the model can be imported by coordinates to select the site, and the functional zones and landscape effect can be planned by refined BIM model to show the effect during the completion and application of the temporary building planning.

3.2. Intelligent Control of Service Road

Existing roads in complex mountainous areas are all civil zigzag roads with narrow roads, small turning radius and limited transportation capacity. Materials such as concrete, steel bars and slags need to be transported by large-tonnage vehicles. Therefore, in order to ensure the transportation safety of large vehicles, it is necessary to monitor and manage the transportation situation of sidewalks.

Through the platform, combined with on-site intelligent monitoring equipment and video recognition algorithm of artificial intelligence, to realize planning of transportation routes and digital twin management of sidewalks. First of all, the virtual construction platform is used to realize the transportation planning. By selecting the starting and the ending point in the platform, the platform can independently plan the transportation route according to the road conditions and other information, and output the route length, estimated transportation time. Secondly, based on the visualization function of virtual construction platform, the digital twin management of service road is realized by combining with sensing equipment [9]. By setting intelligent identification gates and combining with GPS sensors, mobile phone positioning and other functions, the status of vehicles entering the service road can be identified and tracked, and the received data such as vehicle type, license plate number, speed and current position can be fed back to the platform for real-time presentation through the Internet of Things technology (Figure 5). In combination with the platform, the traffic lights and other equipment on site can be remotely controlled to ensure the smoothness and safety of the service road.

Based on the real-time update of GIS engine, the virtual platform can accurately locate vehicles, and realize intelligent planning of transportation routes and digital twinning management of sidewalks in 3D scenes. The two applications complement each other, that is, by improving the transportation utilization rate and management efficiency of roads, the double handling is effectively reduced, and the safety supervision is improved while the management cost is reduced.

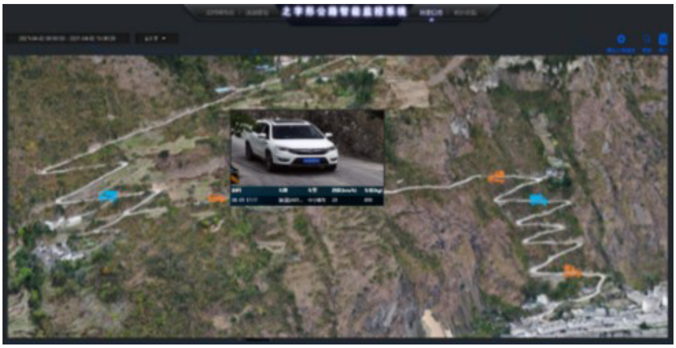


Figure 5. Example diagram of virtual construction platform driving digital twin management.

3.3. Virtual Preview of Construction Schedule

It is difficult to formulate the construction schedule of super large bridge in complex mountain environment, and it is necessary to comprehensively consider the environmental site, climatic conditions, technological methods and other factors. Therefore, BIM 4D technology is combined with virtual construction platform to realize virtual preview of the whole construction process [10]. Based on the traditional spatial 3D model, BIM 4D technology adds the time dimension to endow the model with the schedule attribute, and carries out dynamic simulation in the virtual construction platform with terrain scenes. Firstly, BIM models of temporary planning and main structure are established, and all components are decomposed and coded according to EBS (engineering breakdown structure). Then, the database is established, and the docking of model components and database is realized by EBS coding. Finally, the schedule plan of the EBS decomposed component is made, which is related to the component. The 3D model is driven by the construction schedule information, so that it can change the state of display, disappearance and transformation according to certain rules in the time dimension, thus simulating the construction process (Figure 6).

Figure 6. 4D construction simulation based on virtual construction platform.

Based on the platform, BIM 4D dynamic simulation technology can preview the construction process in advance, find out the construction difficulties and optimize the schedule. Through virtual preview, could reasonably and scientifically formulate the construction plan, accurately control the construction schedule, optimize and integrate the construction resources, manage and control the construction schedule, resources and quality of the whole project in a unified way, and achieve the goals of reducing cost. With the continuous advancement of the project, BIM model in virtual construction platform and data in database will be enriched continuously, and a set of deliverable model results will be formed after completion.

4. Conclusion

The construction environment of super large bridge in mountainous areas is complex. In order to carry out reasonable construction planning, a virtual construction platform based on functional application is built based on BIM combined with 3D IVR technology and embedded GIS graphics engine. Taking a grand suspension bridge project as an example, the functional research and development is carried out aiming at the 3D planning of temporary construction site, intelligent control of access roads and virtual preview of construction progress, which achieves the effects of optimizing scheme planning, verifies the feasibility and advancement of this technology in the construction planning of super large bridge in complex mountainous areas. The engineering application shows that the visual, interactive and simulative functions of the virtual construction platform can solve the problems of low coordination of planning and non-intuitive expression of scheme in traditional bridge construction, realize the application of optimizing temporary site planning, improving site management level, assisting in decision-making construction plan and so on, and help the bridge industry to move towards the direction of intelligence and digitalization.

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