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Research on the Feasibility of Solving Problems in Construction of Sponge City Based on GIS, VR and BIM Combined Technology

Chongzheng Zhao [a, *], Lin Lv [b]

Taiyuan University of Technology, Taiyuan, China

[*,a] Corresponding author e-mail: cz.zhao@foxmail.com

[b] lvlindeyouxianga@163.com

Abstract. The sponge city theory has played an extremely important role in urban planning and construction, comprehensive management of rain and flood, and development of green ecological cities. However, the reconstruction of the pipelines in the sponge city is complex, and the transformation process has big conflicts, low efficiency, and poor linkage among departments, which indirectly increases unnecessary costs and construction time. This article is devoted to the deep analysis of the problems in the construction of Sponge City, combining GIS (geographic information system), VR (virtual reality) and BIM (building information model) technologies, and exploring whether these technologies can solve the problem of design, construction and management of sponge cities. This technology can realize early detection of design (construction) problems and large-area linkage management and reduce construction costs while improving the construction and management efficiency of Sponge City.

1. Introduction

In recent years, there are many cases [1] for the construction of sponge cities based on BIM, GIS, and VR technologies, but they are limited to the application of a single software. Each software has its own advantages, and a single software cannot complete the goal of the macro design of the sponge city. This paper integrates the advantages of the three technologies into a single platform and explores the feasibility of combining the three technologies. Afterwards, the author conducted a case study on the feasibility of the combined technology to solve the problems of the construction of the sponge city, so as to save the working time of the design and construction personnel and maximize the benefits.

2. The problems in the construction of sponge city

2.1. Some scholars have over-emphasized the development of new materials in the construction of sponge cities and the application of new technologies, while ignoring the integration of multiple sectors in the process of sponge city design (construction).
There are already many studies on the preparation and properties of various materials required for the construction of sponge cities in domestic and foreign reference. For example, Yail, J im et al. [2] made

a lot of explanations on the performance and application of water-infiltrated concrete as a sponge after blending different materials. Scholars Chunqi Lian et al. [3] have done a lot of research on the main mechanical properties of pervious concrete materials in sponge city construction. However, we rarely find examples and applications of planning, construction, water supply and drainage, hydrology, electricity, etc. in the promotion of sponge city construction [4-6].

In each stage of the traditional sponge city engineering design, each department will have certain contradictions. This contradiction is that the designers of various specialties did not have sufficient conditions to communicate before, and this eventually led to problems. For example, since the parties only have their own construction drawings, when the water supply and drainage engineer has completed the pipeline layout and arrived at the construction site, they will find that when the pipelines are arranged, there are rocks, power lines, etc., which hinder the laying of the pipeline. This causes rework consequence.

2.2. The complexity of the sponge city management process requires a unified platform to solve it.

At present, there is no mature cross-department communication platform in the world to achieve advanced risk prediction, cross-sector collaboration, surface runoff simulation, and storm water management science in sponge city management.

When Danjie Wu [7] and others from Northwest University conducted a practical study on the construction of a sponge city, they proposed the existence of "multiple regulations" in the existing urban management. However, the construction of the Sponge City emphasizes the overall layout and comprehensive deployment. This requires us to break the barriers of multiple departments and multiple systems. Through the overall arrangement of various departments such as water, roads, pipelines, and green areas, and through the use of modern advanced BIM technology, we can integrate and share the fields of management departments to achieve organic unity.

3. Overview of GIS, VR and BIM Combining Techniques

3.1. The concept of BIM and its development trend

The building information model (BIM) was first proposed by Eastman et al. [8] in the 1870s and has had a huge impact on the civil engineering industry. BIM has features such as visualization, coordination, simulation, optimization, and information integrity. BIM is the direct application of digital technology in the management of the entire life cycle of construction engineering. BIM can solve the problems of model and information shared in the project construction, design, construction, operation and maintenance of buildings, and BIM can provide the engineering designers, technicians, managers and owners with the required information at any second [9].

At present, the development of BIM is moving in the direction of intelligent operation and maintenance. BIM includes in-depth, macro-management and refined management of basic technologies and related standards, integration of information management and information applications, tool integration for dynamic detection and real-time evaluation, intelligent building, ecological building construction, etc.

3.2. The concept of GIS and the relationship between BIM & GIS - the combination of macro and micro

Geographic Information System (GIS) was first born in the 1960s. Its core is to use computers to process, analyze, and manage geographical information with spatial attributes. The application form of GIS technology in municipal construction has been transformed from the initial purely visual application to a complex application of multiple analysis such as set analysis, simulation, and prediction. The function of GIS technology has also been upgraded to the dynamic detection and analysis of multi-period geographical information. For spongy city management, BIM is more biased towards microcosmic, and GIS is biased towards macroscopic. Both of these integrations are applied to space management and can exert better results. In the construction and management of a sponge city, BIM provides detailed

information on the properties of the gallery or building. The GIS provides geographical information for A range of pipe corridors or buildings. GIS provides BIM with large-area data integration. In practical applications, this realizes the information exchange and dynamic update of various departments in the sponge city, and controls both the macro and micro levels of the construction of the entire sponge city.

3.3. The concept of VR and the relationship between VR & BIM - the combination of virtual and reality

Virtual Reality (VR) is a three-dimensional virtual world created by computer simulation. The two major features of VR technology are immersive and interactive. The immersive type mainly provides user's simulation about sight, hearing, touch and other senses through the VR device, so that the user feels kind of immersive. The interaction is controlled by the VR device to control the movement of the scene object, so that the things in the three-dimensional space can be observed without restriction.

BIM technology focuses on model building and information storage for integrated pipe galleries or buildings, providing virtual reality with exactly the same model as the actual project. BIM&VR technology translates traditional 2D CAD design solutions into intuitive 3D visualization models, which helps construction, design and operating units to communicate on the same platform. This enables them to clearly express the construction concept and discover defects in design (construction) programs in a timely manner, and to reduce waste of resources [10].

4. Research on the Feasibility of BGV Technology* to Solve the Problems in Sponge City Construction* GIS, VR and BIM Combined Technology

4.1. The feasibility of the integration of the three technologies

The key components of BGV technology in large-area linkage management include BG (BIM and GIS) model fusion, BV (BIM and VR) model fusion, and front-end control system.

BG model fusion: BIM adopted by BGV technology uses Autodesk's Revit software, which provides an open graphics system. After modeling in Revit software, the generated IFC file [11] can be imported into secondary development software, such as ArcGIS software, Skyline platform. Afterwards, the properties of each element in the model are set in the secondary development software. At this point, the BG model is interconverted and completed.

BV model fusion: There are many BIM&VR software platforms, such as the most commonly used software (Arch2012, Sketchup8.0, and UC-WIN-ROAD), for quickly transferring building information model data into VR systems.

Front-end control system: The general form of the front-end control system is the application software that the user can directly use to corresponding functions, such as web pages, computer application software, and mobile application software. As long as the front-end control system connects the previous BG model application code and BV model application code to the database and designs the graphical interface, the user can complete the large-area linkage management in the corresponding application software.

Based on the mature model interoperability and integration results, it is already possible to implement a software system that combines BIM, VR, and GIS technologies. This system can control the phases of design, construction, operation and maintenance management. Taking the pipeline system and architectural model data as the core, the BIM as the information carrier, the GIS technology as the information integration, and the VR as the system of simulation, it will meet the application and management needs of different stages.

4.2. The advantages of BGV technology in the construction of sponge city

First of all, during the current construction of a sponge city, some cities do not recognize the diversity of the sponge city construction and are limited to low-impact development and blindly carry out the construction of "green infrastructure" without paying attention to match the existing "Grey Infrastructure". Some cities lack comprehensive consideration of water resources and water

environment problems they face, and it is difficult to control the essence of ecological restoration. The design plan is fragmented. If it stays on fragmented projects, it will be trapped in the "engineering only" theory. Secondly, the construction of a sponge city is a systematic project involving drainage, afforestation, urban construction, and transportation. It requires comprehensive thinking, design and construction. Thirdly, under the existing administrative system, different ecological elements belong to different departments, resulting in the partition of the sponge city construction management system. Each department considers its own goals, and it is difficult for the departments to coordinate with each other. During the actual project promotion, the government has multiple gates. The phenomenon of pushing and wrangling occurs from time to time, and it is impossible to build a rigorous and efficient coordinated rainwater management system.

Through the use of BGV as a model, the storm water management system will be constructed in a sponge-city city to achieve full-life circulation, which will lead to refinement, simulation, and intelligent design, construction, and operation and maintenance management. The advantages of BGV technology are reflected in:

1) Through BIM's pipeline synthesis and collision inspection, the contradiction between pipelines and structures is discovered more comprehensively and early.

2) Using BIM can realize complex graphic design, cross-section design, vertical design, cross-well design, appendage design and so on.

3) Improve the level of construction management. Through VR simulation, it is possible to step into the interior of a green facility or pipe gallery and immersivity view all construction and pipeline attributes so that problems can be identified in advance, thereby improving the accuracy and efficiency of design and construction.

4) Achieve intelligent operation and maintenance management. By designing the BIM model and supplementing and correcting it during the construction phase, it is used to form the data model foundation for the operation and maintenance management phase. This can ensure the consistency between the model and the real sponge city design and can connect the model to the IoT system to achieve smart operation and maintenance management of sponge city corridors, green buildings, and rainwater reuse systems.

5) GIS technology can achieve big data model synthesis. It can synthesize independent models such as roads, bridges, greenery, pipe galleries, and buildings into complete sponge city big data system.

6) Based on this technology, the Web platform can realize real-time analysis and capture video, pictures, and other data in Sponge City. In addition, the collected information can be automatically classified and clustered, and the collected data can be trended to simulate the rain and flood resistance of the sponge city in advance.

5. Application Cases of GIS, VR and BIM Combination Technology

5.1. Case I: Using Visualization, Coordination, Simulation, and Expansion of BGV Technology to Reduce Costs and Increase Efficiency

Make full use of the visualization and coordination of BGV technology and coordinate the parties to analyze the problems that may be encountered in advance of construction and plan for the construction technology and process in the construction of the sponge city. It is also possible to use BIM's collision detection and design optimization functions to avoid rework during obstacles in the construction process, thereby improving efficiency while saving construction time and costs.

The use of BGV technology in the five-dimensional (cost dimension) function can automatically calculate the amount to save budgeting specialists time, and through the three-dimensional model to control the project cost more accurately. Theoretically, it can improve work efficiency while avoiding human error [12].

The BGV technology developed based on cloud computing can transfer processes that require a large amount of work to the cloud. This can not only improve the computational efficiency, but also allow the user to view the project files and obtain the BIM function through the mobile terminal in real time at the

construction site, free from the environmental restrictions of using BIM. In addition, incremental synchronization can be used to improve the efficiency of construction file transfer. For example, if the design unit only modifies a certain attribute in the model, only the incremental synchronization technology is used to transmit the modified part to the cloud. This saves a lot of time compared to sending the entire model file to the construction contractor.

5.2. Case II: Combining 3D Visualization to Realize Large-area Linkage Management

Under the large area pipe network system, the 3D visualization space management system using BGV technology can link all pipe networks within a certain area. If a fault occurs in a large area, the system can be used for large-scale management and different types of Pipes can be differentiated by the system. This solution improves the management efficiency of managers for complex pipelines.

Based on the GIS platform for municipal and sponge construction projects, a unified smart water management platform will be set up to unify the city's pipe network system, pressure detection system, water quality detection system, water plant production management system, and wastewater plant production management system. Its production and operation data are collected and analyzed in real time. At the same time, it will vectorize its geographic information data. In this way, the engineering environment can be visually displayed and the environment analysis simulation can be realized, which is beneficial to the management personnel's decision-making [13].
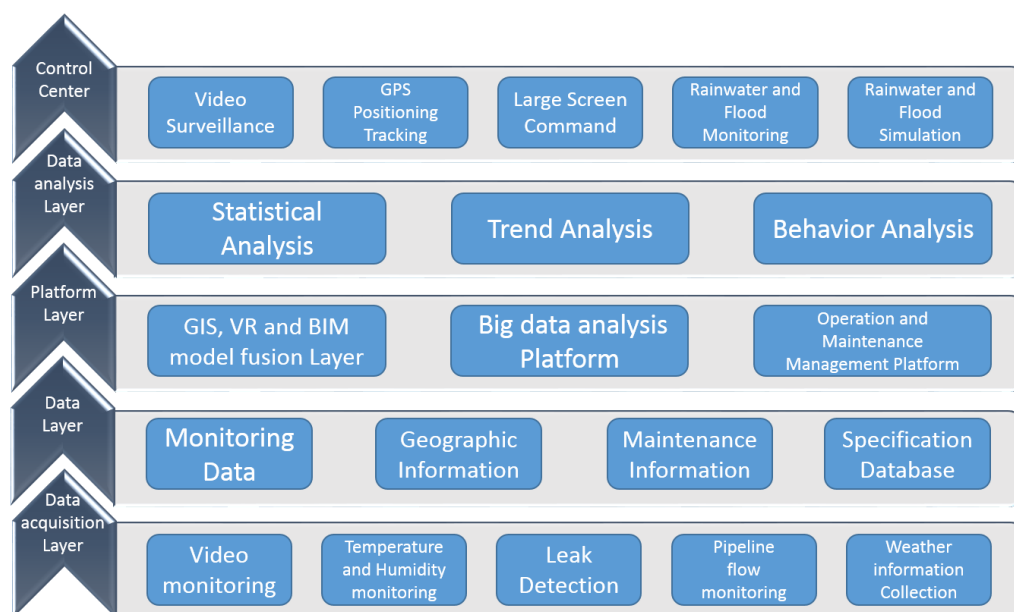
Figure 1. Architecture of BGV Technology in Operation and Maintenance System Operation.

6. Conclusion

The combination technology of GIS, VR and BIM proposed in this paper solves the problems such as fragmentation of design planning, lack of management system, and difficulty of coordination among related departments in the construction of sponge cities. In the process of design and construction, technologies based on GIS, VR, and BIM are combined to make use of visualization, coordination, simulation, and expansion to enable multi-sector real-time collaboration, early detection of design (construction) problems, and realization of later-stage large areas governance. However, the combined technology proposed in this paper has not been extensively applied and case-by-case in the construction of the current sponge city, and large-scale pilot projects are still needed.

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