Design and application of BIM based digital sand table for construction management

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Abstract. This paper explores the design and application of BIM based digital sand table for construction management. Aiming at the demands and features of construction management plan for bridge and tunnel engineering, the key functional features of digital sand table should include three-dimensional GIS, model navigation, virtual simulation, information layers, and data exchange, etc. That involving the technology of 3D visualization and 4D virtual simulation of BIM, breakdown structure of BIM model and project data, multi-dimensional information layers, and multi-source data acquisition and interaction. Totally, the digital sand table is a visual and virtual engineering information integrated terminal, under the unified data standard system. Also, the applications shall contain visual constructing scheme, virtual constructing schedule, and monitoring of construction, etc. Finally, the applicability of several basic software to the digital sand table is analyzed.

1. Introduction
With the rapid development of the BIM, internet, and cloud computing technology for information, the digital sand table is a rich vitality of management idea, which is an indispensable tool for the modern project management during the whole life period of engineering [1]. Through the integration of three-dimensional GIS, information models, engineering project data, the BIM technology based digital sand table may provide data support and services to make decisions for the project management.

2. Concept Design
The BIM technology based digital sand table should conform to the two basic principles, which consider as a whole and systematic project management for engineering. Compared with traditional visual software systems, which focus on the three-dimensional browsing and roaming of objects [2], the BIM technology based digital sand table should focus on the virtual simulation, integration and internet applications of data. Thus, its key functional features should include three-dimensional GIS, model navigation, virtual simulation, information layers, and data exchange, etc.

2.1. 3d GIS
Engineering construction is a kind of activity which is closely combined with topographic features and restricts each other. Therefore, three-dimensional GIS is the primary characteristic of digital sand table. For spatial analysis was established based on three-dimensional GIS technology, the three-dimensional model for terrain, meets the needs of the overall situation and macroscopic expression in engineering construction, and satisfy the engineering project and coordination analysis of both the ecological environment [3]. In the figure 1, it shows the three-dimensional model for terrain, which takes the route of real modeling. Firstly, obtain the hi-res pictures by Unmanned Aerial Vehicle (UAV) using the way
of vertical or oblique photography \[4\]. Then the three-dimensional model for terrain was generated rapidly by the picture processing software of Context Capture, carrying with the digital elevation and real texture feature.

![Figure 1. Three-dimensional model of terrain.](image)

2.2. Model navigation
The concept of model navigation is the key feature of digital sand table, which is conducive to manage engineering models systematically. The engineering construction model is divided into two parts: the permanent structure model and the temporary structure model, and the model fineness of the component level should be reached during the construction phase \[5\]. For engineering management during the whole life period based on BIM technology, the classification and coding of model components should follow a unified model breakdown structure (MBS).

For the management of models, constituting with a huge number of model components, the digital sand table shall adopt the concept of model breakdown structure (MBS) to decompose model, and set coding for each component. Then it's easy to retrieve model components, and make information exchange, which is the most important for model management. In the figure 2, it shows the effect of accurate searching and precise positioning for each model component, using MBS code among thousands of components of a bridge model, which is 55 kilometers. The highlighting component is the only object that being searched. What's more, the 3d models shall be blended in GIS, which may provide geographic data services, such as location and spatial analysis. As shown in the figure 1.

![Figure 2. Model navigation by the fineness of component.](image)

2.3. Virtual simulation
Virtual simulation is the key feature of the system, which may enhance the cognition of engineering construction. The visual simulating technology mainly includes two aspects, namely, the virtual time inference (Time-liner) and the motion simulation (Animator) \[6\]. The former is used for the 4D expression of the engineering construction process. The latter is used to reflect the dynamic logic relation of the engineering scheme and the engineering method \[7\]. In addition, the digital sand table should support the immersive experience effect by virtual reality (VR) technology \[8\]. In the figure 3, it shows the virtual simulation of bulwark building, which contains the constructing sequence, working plane, timing plan, and machinery operating, etc.
2.4. Information layers
The concept of information layer is the core of digital sand table, which means the most function of digital sand table should be driven by data. In view of the huge amount of data during the construction phase, the digital sand table shall adopt the mode of structure entity model associating multi-dimensional information for management, and each dimensional information shall be organized by layers.

The multi-dimensional information layers contain bill of quantities, working plan, process documents, management of organization and so on. Considering the data breakdown structure, we may call that all as QBS, WBS, DBS, OBS, etc. What’s more, the process documents may decompose into technical documents, log documents, quality documents, security monitoring documents, mechanics calculation documents, etc. So as to make the information classification and coding.

By establishing the mapping relation between MBS encoding and project information encoding, which includes the QBS, WBS, DBS, OBS, etc. The digital sand table shall provide interconnected data services for project management, which surround the 3d model of engineering entity object.

2.5. Data exchange
Considering the digital sand table as an engineering information integrated terminal, it should support multi-source data acquisition \([9]\), interaction, which mainly includes 3d GIS, BIM model, bill of quantities, working plan, process documents, management of organization and so on. Moreover, the digital sand table shall make data exchange between other professional software, systems by the way of data services. Such as P6, Project, security monitoring system, project management system, etc. All above, the data exchange by means of data service or file transfer, it must comply with the unified data standard system of MBS, QBS, WBS, DBS, OBS, etc.

3. Applications

3.1. Visual constructing scheme
The simulation of constructing scheme mainly includes that determine working process, choose working machines, working methods and related technical measures, etc. Therefore, the digital sand table should support the logical definition of working process, the motion simulation of working machines and methods for visual constructing scheme, which using 3d model to deliberate, optimize the scheme interactively and comprehensively. Moreover, the digital sand table shall establish index system of quantitative evaluation for schemes, such as the specific degree and level of technical advancement, cost, time limit, environmental friendliness, etc.

The main applications include the simulation of special and comprehensive schemes, such as site layout planning, temporary structures design (E.g. template and bracket), key and complex nodes constructing, transporting and hoisting, earth excavation, etc. In the figure 4, it shows the site layout model of tunnel entrance with 3d GIS, which make the scheme of site layout planning optimal in a narrow space.
3.2. **Virtual constructing schedule**

The virtual constructing schedule mainly includes the determination of constructing sequence, the division of constructing section and working plane, the formulation of the timing plan, the planning of personnel, materials, machinery and other resources, and the related organizing measures.

Through the 3d visual and 4d virtual simulating environment of digital sand table, the virtual constructing process may be realized, by the way of founding 3d models of the unit engineering and partial engineering division and associating the work planning data. Then it’s easy to analyze the rationality of working sequence, working section, working face and working organization in a visual way. So as to analyze the feasibility of working time and resource plan. What’s more, it may show the construction planning, milestone and visual schedule of project, combining with GIS.

Moreover, the digital sand table should support multi-objective optimizing analysis, such as the shortest time limit, the lowest cost, the lowest impact of environment, and the highest level of security, to support the compare of different constructing schedules. In the figure 5, it shows the application of virtual constructing schedule for a bridge, which is 55 kilometers. The highlighting model components represent the actual finished status, and the gray components represent the actual unfinished status in site.

3.3. **Monitoring of construction**

For engineering construction, there are many work management systems, such as builder’s diary, test batch, mixing station, laboratory and security monitoring, etc. and the integrated information system of project management. How to use the digital sand table to integrate effective work data, and to realize data planning and interconnecting management, and to assist making project decision, which is the important factor influencing the vitality of digital sand table.

As a typical case of application, the professional work data of engineering management integrating by digital sand table, which may come true as following methods. Firstly, defining the classification and coding of monitoring points. Then establishing the mapping relationship between the coding and MBS. Finally, creating the data service pack and sending to the digital sand table from the monitoring professional system. Through the digital sand table, which may display the dynamic monitoring data,
and make the post-processing to identify the risk, warn reminding and release, etc. As shown in the figure 6. And there is an example for the application of bridge model rotating driven by monitoring data.

![Figure 6. Application of bridge model rotating driven by monitoring data.](image)

4. Analysis of foundational software

Presently, the BIM technology based on software environment is not very mature, and it is still in the stage of conceptual design, system demand and development. According to the concept design requirements of digital sand table, the applicability between several foundational software was analyzed, that the results were shown in table 1.

| Index of evaluation | Synchro | Delmia | Infra-Works | Micro-Station | 3D-GIS platform |
|---------------------|---------|--------|-------------|---------------|----------------|
| Having a mature environment of 3D-GIS | ○ | ○ | ● | ○ | ● |
| Having a mature environment of BIM | ● | ● | ● | ● | ○ |
| The BIM model was integrated with 3D-GIS effectively | ○ | ○ | ● | ○ | ● |
| Having a powerful environment of virtual simulation | ● | ● | ○ | ○ | ○ |
| Supporting the secondary development of engineering management by customers | ○ | ● |
| Supporting multi-customer collaborative application | ● | ○ | ● | ○ | ● |

Table note: ● suitable; ○ lesser suitable.

It's worth noting that Synchro is a mature 4D software, which has a strong function of the virtual constructing schedule, and supports the data exchange with planning software of P6 or Project, etc. The DELMIA has a powerful and stable environment of acting simulation, which supports the self-defined workflows by users, and fits well with the design requirements of virtual constructing schedule. The InfraWorks has a complete simulating scenario with a generator of 3d digital terrain model, which is very suitable for engineering planning and preliminary design. The MicroStation is a design platform that supports two and three-dimensional models. At last, the 3D-GIS platform have good scene effect, which may integrate BIM model more open, and support the secondary development by customers.

5. Conclusion

This paper explores the design and application of BIM technology based digital sand table for construction management. Its key functional features should include 3d GIS, model management, virtual simulation, information layers, and data exchange, etc. This paper studies several engineering applications of the digital sand table, such as the visual constructing scheme, virtual constructing...
schedule, and the monitoring of constructing security, etc. Also, the applicability of several basic software to the digital sand table is analyzed.

In conclusion, the BIM based digital sand table concept of integration, interconnection and sharing management should be open and multi-source for data. As results, under the unified data environment, the BIM technology based digital sand table may be created as a whole and systematic product, which meets the requirements of engineering construction management.

References
[1] YIN Yan. Research on the application of BIM technology in large public project management [D]. Shandong University, 2015.
[2] LONG Teng. Research of visual construction technology in variable cross-section bridge based on BIM [D]. Wuhan University of Science and Technology, 2015
[3] NIU Zuo-peng, LI Guo-jie, LIU Li. Technology of multi-source waterway engineering measurement data integration based on BIM [J]. Port & Waterway Engineering, 2018, 539(2):142-145.
[4] LI Fei, LIU Yu-heng, YANG Cheng, etc. Technology research and application of construction site layout based on BIM [J]. Journal of Information Technology in Civil Engineering and Architecture, 2017, 9(1):60-64.
[5] ZHAI Shi-hong, JI Fu-quan, WANG Xiao-xiao, etc. Research on standards of building information modeling of mining railway tunnel [J]. Railway Standard Design, 2016, 60(1):107-110.
[6] WANG Xue-qing, ZHANG Kang-zhao, XIE Yin. 4D simulation of real-time construction based on BIM [J]. Journal of Guangxi University: Nat Sci Ed, 2012, 37(4): 814-819.
[7] JI Fan-rong, QU Di, SHANG Fang-jian. Study on visualization of construction schedule management under BIM scenarios [J]. Construction Economy, 2014, 35(10):40-43.
[8] JIANG AI-ming, HUANG Su. Application of BIM virtual construction technology in project management [J]. Construction Technology, 2014, 43(15):86-89.
[9] XU Xia-yan. Research on BIM heterogeneous data integration and management for the construction phase [D]. Southeast University, 2016.