INTERACTIVE VIRTUAL SAND TABLE

A theoretical review on its application towards Urban Planning

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Abstract. The sand table is a tool of expression of urban planning.With the development of computer science and technology,virtual reality technology is playing an important role in many aspects of urban planning and design,as well as,the virtual sand table.This article analyzes the limitations of the current urban planning sand table from designers‘ and other participants’ perspectives. It analyses the advantages of applying interactive technology in a sand table for urban planning and proposes using such interactive technology in the future. This paper will also investigate three aspects of interactions: human-computer interaction technology, collaborative interaction technology, remote visual interaction technology. The application of interactive technology on the virtual sand table, on the one hand, can carry out a multi-angle forward-looking analysis of the problems of urban construction and improve the efficiency of planning and approval, and development; on the other hand, it can increase public participation in urban planning and design.

Keywords. Interactive technology; urban planning; urban planning sand table; electronic sand table.

1. Introduction

Urban planning refers to design and direct the harmonious development of Spaces to meet social and economic needs.The focus of the design process is to fully consider the public interest and balance various contradictions□Li□2020□. In traditional urban planning and design, a physically scaled sand table model is usually made first (Li, 2013). As a result of the time-consuming model-making process and laborious modification, the cost of having such a model is very high yet it has considerable limitations with information that is not very accurate. In recent years, remote sensing and telemetry technology (Cai, 2013), 3D modeling technology (Li & Jia, 2018), and computer graphics (Yu & Zhang, 2007) have been gradually introduced into the research methods and means of urban planning, providing improved technical means for design planning and development.

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Urban planning model as the final form of expression, can systematically express the planning and layout of the city.With the comprehensive application of computer technology,urban planning uses geographic information systems (GIS) and other infrastructure platforms to combine urban information resources uses three-dimensional (3D) visualized technology(Liu, 2020) and urban digital twin(Dembski et al, 2020) to assist design. But this tools are still presented through a screen.It is not as easy for users to adapt to the new interactive mode even though it allows users to control the model more flexibly. Users still prefer the traditional interaction method of the sand table where they can intuitively interact with the model to better understand urban planning and design. The arrival of VR offers an opportunity to restore that connection.

VR is a comprehensive technology that combines several technical achievements, using computer technology and the latest sensing devices to simulate a brand new environment (Liu & Zhang, 2018). It enables the observer to walk in it arbitrarily, making him feel like he was in the scene. As a new attempt,the use of Interactive Virtual Sand Table to assist design.It can express timely and accurate feedback on the work and put forward comments.And designers of urban planning can use computer technology to make changes in seconds to meet the needs of observers.

This paper analyses virtual reality technology's interaction capability and compares it with urban planning and design needs. It explores the theory and possibility of an Interactive Virtual Sand Table (IVST), discusses its potential to makes up for the relatively unintuitive interaction of the current urban planning sand table, and analyses how IVST could improve the urban design process.

2. Background

Research into virtual reality human-computer interaction (HCI) has been going on for years to see how humans interact with computers and digital technologies, from interface visualization to functional control, from keyboards and mouse to touch screens to tracking sensors. Although virtual reality hardware is still considered a "computer," the interaction is very different. Because users are immersed in a virtual world environment, interaction has gone beyond the traditional scrolling of a mouse. However, all of these interactions and communication can only work well when the experience is intuitive and enjoyable. It is necessary to understand the development of VR and Virtual Sand Table before exploring the interaction modes in-depth for the research direction of IVST.

2.1. VIRTUAL REALITY TECHNOLOGY

VR integrates computer graphics, image processing, and pattern recognition, intelligent technology, sensing technology, voice and sound technology, and many other sciences (Lo, 2020). It changes the digital information processed by computers into multidimensional information with various forms of expression that people can interact with. As a comprehensive high and new technology in graphics and images, the advantages of VR technology provide possibilities for the construction of new and more efficient interaction of urban planning and design.

In the 1993 World Electronic Annual Conference, many scholars proposed the "3I" feature for virtual reality technology. It expresses three key elements of the virtual reality system, namely, Immersion, Interactivity, and Imagination.These "3I" features inform how virtual reality technology is rising to a new height. It is distinguished from the simple traditional two-dimensional picture and three-dimensional modeling,forming a new media art form. Using VR in urban planning can also have these immersive aesthetic characteristics bringing people closer to the digital content for their imagination. But they have a different need in how the content is interacted with for its information.

Further development of digital technologies and immersive interaction technologies, such as virtual reality (VR), augmented reality (AR), and emerging mixed reality (MR), provide opportunities to better understand the design of cities and urban planning. In addition to the mixed visual effect of the virtual and reality, virtual technologies also provide the means to realize real-time interaction between users and the virtual model, providing the necessary conditions for the generation and development of IVST.

2.2. USING SAND TABLE FOR URBAN PLANNING

In Urban Planning there are four important issues: it is for and about people; the valueand importance of the "place"; operates in the "real" world; and the importance of design as a process. It is about building a scenario for urban evolution,imagining the conditions of transformation and proposing a process capable of incorporating new experiences in the human-environment relationship.

The traditional physical sand table is a model made of sand and other materials according to a certain proportion of the topographic map, field terrain, or aerial map. It has the characteristics of a strong three-dimensional sense, allowing multiple users to feel directly from any angle and have certain physical interactions at the same time. The interaction method is through direct contact with the physical model, moving them around with props since the size is usually quite big.Although the interaction is very limited, it is in line with people's physiological and psychological habits which enable efficient communication.

With computer hardware and software and virtual reality technology, the electronic sand table has replaced the physical sand table for many application fields. An electronic sand table (Li & Han, 2010) has a three-dimensional, dynamic, and interactive realistic environment simulated and displayed in digital display equipment. They can cover geographic information, graphics, and images of the urban environment, and some form of human-computer interaction. The electronic sand table improves the disadvantages of the limited interactive mode of the physical sand table.

VR provides an opportunity for more interaction to be added to urban planning electronic sand tables. Instead of just a touch screen and infrared remote control for users to complete some simple interactive operations to the electronic sand table, VR enables much richer interaction with sand table content. VR's immersive-ness will let the users feel like the virtual sand table model is in front of them. Using the controller, which usually comes will a "laser pointer," allows accurate interaction

by pinpointing the sand table's specific part to work with. However, observation has shown that the fact that the immersive environment is so "real," users tend to reach out to "grab" the virtual objects, only to realize they will still have to use the button operation mode of the controller, which makes the visitors lose the sense of manual interaction naturally. It is necessary to look into other interactive technology that can be integrated into the virtual sand table to develop IVST.

3. Interactive technology for urban planning sand table

The sand table represents the art of urban planning in the form of physical miniaturization. The aim is to represent both the spatial structure and the combination of urban components clearly and expressing the process of urban planning.In addition,the relationship between the different stakeholders in the planning process can be enhanced with the development of virtual technology (THOMPSON et al. 2006).The future of the application of IVST in urban planning mainly has the following three directions: human-computer interaction,collaborative interaction, remote interaction.

3.1. HUMAN-COMPUTER INTERACTION

Human-computer interaction (Diao, 2020) is a process in which the system responds to the interactive information received. The electronic sand table mainly uses a touch screen, infrared remote control, and other technologies to control the sand table; it does not conform to human interaction habits, resulting in a low interaction rate. The display of electronic sand table is rich and colorful multimedia, mainly realized using audio-electronic integration and multimedia interpretation, which lacks immersion (Tan et al., 2007). To improve the communication efficiency between designers, virtual reality technology is introduced into the electronic sand table. The virtual electronic sand table can realize seamless interaction and natural communication between single or multiple people. Still, the research done on the organizational structure and system operation mode of the electronic sand table by relevant researchers is quite limited and did not relate much to VR. The current electronic sand table is still a distance away to satisfy the necessary interaction for urban planning purposes (Figure 1).

To improve user engagement and motivation, it is proposed that urban planning sand table should implement interactions, using simple, intuitive, and natural gestures, the line of sight, and voice to interact directly with the sand table. Using natural gestures instead of the mouse and keyboard to complete some functions in the virtual environment so that the HCI in IVST does not need other intermediary media. Users can define proper gestures to control the operation of the virtual contents more naturally. In the past, during the scheme's discussion, the designer could only create or destroy virtual buildings on the sand table using mouse and keyboard operation. The introduction of such HCI to the virtual sand table allows users to change the sand table's content through gestures in real-time to explore various urban planning and design schemes.

The development of interactive gadgets has gradually developed to interaction through wearable devices allowing more natural ways of interaction such as body

movement, hand gesture, and voice. The interactive interface has also developed from the difficult-to-understand professional text to the easy-to-understand graphical interactive interface. For example, users can adjust the spacing of buildings for daylight, the height of excessively high building objects in a certain area, the position and size of roads, etc. In the process of planning, the sand table can demonstrate some more complex, novel and cool, and more fluid urban acoustic environment system, light environment system, and wind environment system. This enables the general public to really participate in the presentation process, improve their sense of involvement.

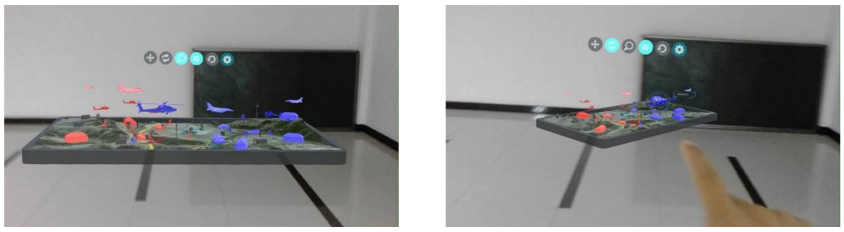

Figure 1. Human-computer interaction(Yao, 2018).

3.2. COLLABORATIVE INTERACTION

Collaborative interaction (Wang, 2018) is the communication between different professions, and different digital contents that usually comes from different software. It is necessary for them to be closely coordinated for effective design and research and development. The main advantage is that the key designer and other stakeholders can simultaneously discuss within the same digital model. The information can be operated interactively, and any problems can be pointed out collaboratively. The improved model can be organized and communicated again in a timely and convenient manner.

Urban planning involves land use planning, environmental planning, rail transit planning, and so on, and at the same time takes into account landscape, architecture, municipal and other disciplines. Urban planning involves the intersection of multiple disciplines and requires the coordination of multiple elements. It is difficult for planners themselves to make correct decisions timely based on their individual experience. Therefore, numeral professions are needed to provide effective information collaboratively and assist planners to make decisions quickly. In this case, horizontal and vertical communication needs to be emphasized. For example, on the one hand, information sharing among various professions and departments to put forward design requirements; on the other hand, planners need to design in accordance with the planning guidelines and standards, visually see the design constraints using the virtual sand table.

For professionals to collaborate in the design, local collaboration enables multiple designers to overlay and synchronize professional information in the sand table through scene sharing. Local collaboration also allows multiple designers to manipulate, mark, browse, and so on the virtual buildings in the sand table. In other

words, any changes made by one person operating the sand table are synchronized in real-time to the other person's view. For example, planners mark urban plot functions in sand tables, and architects can see and change building types simultaneously to achieve the function of multi-person collaborative planning design.

The traditional idea of urban planning is people-oriented, but this idea is not fully reflected in the implementation of urban planning assessment. Urban planning will have a disadvantage if it lacks the necessary bottom-up subjectivity. Due to the lack of communication between planners and citizens, urban planning has become a one-way, dominant, and rational planning. In addition, the quality of the evaluation results depends on the subjective assumptions of experts and scholars. For example, the content of the evaluation is not public, which makes it difficult for the public to participate in the evaluation and even harder to know the quality of the evaluation results. Therefore, it is necessary to provide a simple and quick way for the public to participate in the urban planning assessment and for the planners to receive the feedback of the assessment content in time (Figure 2).

For the public to participate in the assessment, the sand table enables the local coordination with intuitive feedback of many people simultaneously. The planners can then report the main problems to the government agencies through public information feedback. For example, the public prefers to see more parks, squares, and other public places in the city. The public will mark the information on the sand table, and the planner will adjust the urban planning and design after seeing the marks and understanding the public intention. On the one hand, local collaboration builds a bridge of communication between the public and planners and their governments. On the other hand, collaborative interaction improves the operability, scientificity, and fairness of urban planning and urban planning implementation by enhancing public participation.

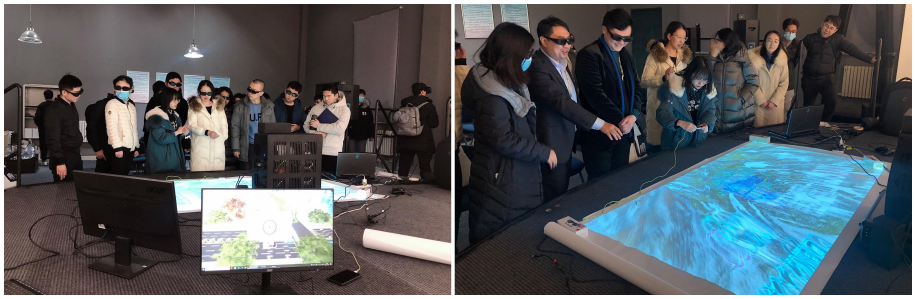

Figure 2. Collaborative interaction .

3.3. REMOTE INTERACTION

Remote visualization collaborative interaction (Bao, 2014) brings together geographically scattered experts and working groups in various fields to interactively carry out research or design of a project and complete a specific project with the support of information technology. Remote visual interaction

emphasizes that designers, decision-makers, and stakeholders from different locations to participate in the design, decision making, and evaluation in a unified and coordinated environment.With the current pandemic situation, it can be seen from these advantages that a long-distance visualization is an efficient form of communication and exchange of views, enabling people to communicate "face to face" because they have to work from home.

Urban planning and design require the extensive participation and collaboration of experts in various fields. Because different people are located in different regions, it is necessary to depend on the network platform for collaborative communication to reduce carbon footprint. However, different people use different platforms and there is no same standard, which makes the way of collaboration somewhat limited. In addition, the model used for discussion between the stakeholders needs to be guaranteed to ensure the consistency of the information.

For professionals to interact in different places, remote designers are projected locally in VR in the form of virtual avatars. Designers can jointly manipulate the 3D model on the same display environment to display the 3D model's different details. They can communicate with each other through "face-to-face" dialogue and record the problems found through the 3D model at the common annotation layer. All parties' collaborative work can be accomplished without the need for personnel travel and without the disruption caused by waiting for documents to arrive. (Figure 3).

Urban planning advocates open design, and the public as a third party should have the capability to provide feedback to the design scheme. But there is no straightforward way for the public in different areas to participate in the design, and the process usually takes quite a bit of time. As a result, the public has no strong enthusiasm to participate in the planning process. Usually, only a small number of persons or interest groups will be represented by the general policy implementation assessment results. The evaluation results of implementing the general plan should combine the expert opinions with the public feedback to infiltrate the public enthusiasm into the evaluation process of the implementation of the general plan.

To enable the public to react to the design schemes, remote visualization enables the public to conveniently participate in all urban planning stages and conduct scientific and fair supervision and evaluation on the implementation effect of planning. The public can directly see the designer's design and renovation of the city and give their opinions on the design scheme through a "face-to-face" dialogue. Virtual sand tables can clearly translate specialized language into a form that the public can understand to provide feedback.

Figure 3. Remote visualization collaborative interaction(Yao, 2018).

4. Discussion

By examining the various interaction needs of urban planning above, this paper proposes integrating the three interaction needs into IVST. The application of IVST can improve the efficiency of the planner of the collaborative design (Shi, 2019), and the visual feedback for planning can also help the planners after by absorbing the opinions of the public feedback to adjust the design (Yao, 2019).

IVST is a tabletop virtual display in which the virtual content is projected on any horizontal surfaces and can be viewed with 3D effects simply with specific glasses. They are a tool that will greatly aid the field of urban planning and urban construction. It is open source and can connect with different professional software to carry out information superposition so that urban managers can carry out traffic dredges, emergency management, and other management of the city, and become the display window of the smart city. The reasons why IVST is more suitable for urban planning are as follows:

- Unlike a traditional electronic sand table or virtual sand table, IVST does not require interaction with a mouse, keyboard, or wearable devices. IVST can interact through the body, gesture, voice. The users do not need to wear heavy headsets and just put on a pair of specific glasses, just like in a 3D cinema. This allows the general public to participate in urban planning and design and provide feedback in an interactive manner consistent with their habits.
- Unlike VR immersive interactions, which lose the sense of isolation from the real environment, IVST has a fixed viewing perspective, and planners will design from a global perspective. Planners meet operational requirements by quickly placing, moving, zooming, rotating, marking information, and browsing. It is not easy for the general public to even rotate the model. Therefore, IVST's fixed perspective duplicates the traditional physical sand table and simply makes it virtual and interactive.
- IVST is more intuitive in displaying information. The professional information from various stakeholders in urban planning can be presented intuitively at the same time. Also, multiple people can view and communicate simultaneously, and the marked information can appear in everyone's vision, satisfying the integration of professional information in urban planning.
- Different from the traditional physical sand table, suggestions can only be recorded on the side and revised back to the paper file. Users can directly add text comments, draw red lines and circles, and sign within the IVST. These marks can also be viewed with the original document at any time, such as the

change content, date, modifier, etc.

- The cost will be reduced compared with the physical sand table. IVST can appear in three-dimensional form on any plane, which can not only meet the design needs, but also reduce the threshold of use.

Although there is a great potential for IVST to be applied in urban planning, there are still some deficiencies that need further research and development:

- Technical aspects: the scope of planning area is too wide, and the demand for 3D model data is too large, which makes the workload of 3D modeling and data processing too heavy.
- Software and hardware: The 3d modeling software in the current market is mainly good at building 3D models, while there are few suitable products and software for building a large number of existing 3D urban landscape models. In addition, the virtual interactive sand table is very demanding for the hardware and software environment of the computer.
- Interaction gadgets: The connection between the interaction and the content is still not perfect. There is still a short lag time, which causes the interaction to feel unnatural.
- Standard system: Standardization has become a major bottleneck restricting the construction of digital projects such as "digital city". Due to the lack of unified standards for project-related data management, it is difficult to realize the update, data sharing and exchange between virtual reality systems established under different circumstances.

The shortcomings of the above four aspects limit the use of IVST in urban planning. Simultaneously, due to the limitations of equipment, planners have become more difficult in the design process. In other words, how to reduce the cost of working in a virtual interactive sand table is a key issue. Also, interacting with users in the same virtual space is another technical problem that needs to be solved.

5. Conclusion

This paper summarizes the application direction of IVST in future urban planning and illustrates how IVST can help professionals and non-professionals better participate in urban planning and design. The feature of IVST is very suitable for solving the problem that urban planning needs cannot be met. Users can interact using the body, gesture, and voice to place, move, scale, rotate, mark information, and browse the sand table to achieve the collaborative design. The next step of this research will be to explore richer, more intuitive interactions within the current technologies' constraints by improving the way the virtual content is generated and how they can be interacted based on its information. With the development of IVST, there are more opportunities for both professionals and non-professionals to participate effectively and immersion in the design process, making the urban design more possible. A comprehensive consideration of the city's problems will lead the city in a better direction.

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