Application of Cloud-based Virtual Reality Integrated Automatic Presentation Script for Understanding Urban Design Concepts

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Dissertation

Application of Cloud-based Virtual Reality Integrated Automatic Presentation Script for Understanding Urban Design Concepts

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Abstract

This PhD research targets to provide a new method that combined a useful presentation technology (APS) with an effective communication platform (Cloud-based VR), as a broader participation platform to create a common virtual scene for improving users' urban design concepts understanding in consensus process. We attempted to build a Cloud-based VR platform to proposing urban design concepts, and created APS for auxiliary guiding users to understand the design concepts, so that they can evaluating and deliberating design concepts through the Internet.

The research starts from VR presentation using 3D laser scanning technology for historic building mapping and modeling, as a new method to obtain data source for APS. We took Shang Shu Di, a Ming Dynasty building which is an officially protected heritage site of China as a case study, and compared the mapping results of detailed components with the traditional method. Aimed at the technical problems of the huge amount of data generated in the application process and the software defects of Cyclone, we presented two solutions which are "reasonable data collection and processing" and "construction of historic building components database".

Then, we seek to find a solution for the problem of how to improve users' urban design concepts understanding through available communication media and useful presentation technology (VR integrated APS). This research recruited 60 participants to view the script video (the running result of APS) or/and freely navigate in the virtual environment of Tatsumi region in Tokyo Bay Zone of Japan. By analyzing the data of subjective feedbacks, the research examined how APS affect participants' cognition and evaluation of Sustainable Taches and Reactivate Space (STARS, the design concepts). Moreover, qualitative interview was developed to further understand participants' design concepts understanding, and validated whether VR integrated APS can improve users' urban design concepts understanding.

After that, in order to provide a broader participation way for users to understand design concepts, this PhD research applied the Cloud-based VR platform in a design report meeting of One Foundation Disaster Prevention Park project. We built a Cloud-based VR platform to proposing design concepts, and created APS for auxiliary guiding users to understand the concepts of urban design and deliberate the design alternatives through the Internet.

Keywords: Automatic Presentation Script (APS), Urban Design Concepts, Understanding, Virtual Environment, Online Discussion, Cloud-based VR, Sustainable Urban Design, Quantitative and Qualitative method.

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Chapter 1 : Introduction

This Chapter will set the stage for the remainder parts of this dissertation. First, I will describe how I arrived at this research topic from the dilemma in understanding urban design concepts and the technical efforts. Second, I will outline the objectives of this dissertation. Third, I will review previous research on the importance of urban design concepts and communication medias from the perspective of urban planning and design. Finally, I will introduce the method of this PhD research, and close with a brief preview of the chapters of this dissertation.

1.1 Research Background

Urban design concepts are designed to serve as the design visions for what the city might become in the future, they provide the overall objectives of urban design and the solutions in dealing with urban issues (such as spatial organization, transportation, built environment), as well as lead the way for design decisions (Roberts and Greed, 2014). However, it is difficult for users to understand urban design concepts or even misunderstanding, due to a lack of user interaction and clear information exchange between users and designers during the top-down planning process (McTague & Jakubowski, 2013). The findings echo the recent experiences in Western countries that emphasize the needs of interaction, negotiation and available communication media in the urban planning and design process (Luo, X.L. et al., 2008; Liu, L. A. et al., 2012).

On the other hand, computer advances in recent decades have contributed to the emergence of graphic and multimedia technologies, and their outcomes as an available communication media which make massive changes to the way we experience, as well as to the sustainable development process, and to the way professionals collaborate and involve the public (Jutraz, A. & Zupancic, T., 2015). For instance, 2D plans (mainly including sketch, map, CAD, GIS) and multimedia (mainly including text message, sound, video, and animation) always been used for designers to express urban design concepts and exchange information with their users. However, it is commonly acknowledged that only users with professional skills can clearly understand 2D plans. Multimedia, such as video, can help users understand urban design concepts easily, but fixed route often restricts their vision when they want to further evaluate the design concepts.

3D visualizations attempt to improve the above disadvantages. VR is one of the innovations that can provide a virtual environment for user interaction, while 3D modeling seems to bear the brunt of this innovation. 3D modeling used to be considered as an effective method to express urban design concepts (WG II, 2004). However, traditional 3D modeling is time-consuming, as manual data collecting and mapping are required for each component as well as for the whole scene, and there were measured omissions and mistakes which affect users' cognition and evaluation of the design concepts (Chen & Truc, 2008). Moreover, it is difficult for users to clearly understand the design concepts even though they can interact with the virtual environment without any auxiliary guidance. Furthermore, face-to-face discussion (fixed schedule and venue) usually is required for users to discuss urban design concepts with their designers.

As the Internet is becoming popular, VR similarly integrate with Web technology is regarded as good ways to replace face-to-face discussion that allow wide participate to design concepts discussion. For example, Virtual Reality Modeling Language (VRML) often been used as an online visualization tool to create a sharing virtual environment for conveying design concepts and decision making through the Internet (Shen, Z., & Kawakami, M., 2010). However, the inefficient programming interface always discourages these designers without computer programming skills; and most online VR platforms have the limitations of data compression and network bandwidth in currently that the Clients (users' computers) need to download the virtual environment and models from the Sever.

As mentioned above, these have consequently increased the needs of data collection and available communication media as well as broader participation ways for improving users' urban design concepts understanding. Automatic presentation script (APS) is a presentation technology which can combine different kinds of communication medias (including 2D plans, multimedia and 3D visualization) to express urban design concepts more clearly; and cloud-based virtual reality (Cloud-based VR) platform can provide synchronous transmission and interactive services for large amounts of data, such as video, 3D model and virtual scene. The integration of Cloud-based VR with APS will shed light on the future use as an efficient method that users can better understand urban design concepts as well as evaluate design concepts, especially in today's increasingly prominent social contradictions and highly competitive world.

1.2 Research Objectives

Based on the problems above, this dissertation has some objectives to give the solution, there are:

1. Propose a new method to obtain 3D data for mapping and modeling as a data source for APS, and verify the advantage of 3D laser scanning technology in data collection.
2. Improve users' understanding of urban design concepts through using VR integrated APS, and examine it effect on users' cognition and evaluation of urban design concepts.
3. Provide a broader participation way for users to understand urban design concepts in consensus process through using Cloud-based VR integrated APS.

1.3 Literature Review

1.3.1 The Importance of Urban Design Concepts

Urban design concept which is outlines design ideas for the future development of key areas in a city (Wallace Roberts & Todd, 1991). It is not intended to be a complete, nor a static image of an ideal "future" for the city. Rather, it is an attempt to visualize certain aspects of future development that are considered essential to the continued success and improvement of the urban environment.

As noted by Moughtin (2003), an urban design concept strongly associated with sustainable development is the idea of mixed land use. Generating design ideas for solving problems of urban structure is fundamental to urban design, and generating concepts is an act of the imagination. Design concepts are the basic of the creative process; without them the process of urban design degenerates into a sterile activity (Cuesta, R., et al., 2012).

Consequently, urban design concepts play an important role in the process of urban planning and design (Kua, 2012; Sundaram, 2013; Minatani, 2010), and the innovation of design concept conjunction with technology will provide new direction for dealing with design issues. For instance, Chen and Zhu (2012) emphases innovation of design concept and technology, they carries out beneficial attempts on harmony with the environment, view effect of the appearance, optimized structure, systematizes, economical efficiency, etc., and acquired good effect. Their design concept and technical measures provide lesson and reference for the future bridge design of passenger dedicated line.

A clear understanding of what the design concepts means are important for users. Because of any theoretical or empirical work in which design is a construct, a clear definition will help ensure construct validity. Furthermore, a clear understanding of the meaning of design concepts will facilitate developing measures of design-related constructs, such as design project success (Ralph and Wand, 2009).

1.3.2 Communication Medias in Urban Planning and Design

In the process of urban planning and design, one of the challenges for planners or designers is to communicate with their users, and convey the design concepts to them (Ding S. N., 2008). Thus, communication media plays an important role due to it will directly determine the users' understanding level for the urban design concepts. Even with the broad variety of communication media available today (e.g. sketches, CAD, GIS, videos, 3D models, point clouds, VR, express meaningful visual information through using different types of communication media usually be neglected that effect on the communication process (Hasebrink and Domeyer, 2012).

Typically, planning supports always use 2D plans (such as Sketch, CAD, GIS) to present design concepts and communicate ideas (Kibria, M. S., 2008). However, users usually have trouble to understand CAD and GIS document files which can lead to discontentment with the end result, and technical training, and specialized software are usually a prerequisite to interpret those (Joseph R. and Perera U., 2013; Wu et al., 2010). Sketches are often favored by designers as a method to present initial design concepts in a more fluid style for communication, on the other hand, comparatively little is known about the pact on viewers of designers' design concepts (Bates-Brkljac N. et al., 2009).

Additionally, some 3D modeling tools such as 3DS Max, SketchUp, Maya allow designs to create accurate and reality models which are the representations of an urban environment with a three-dimensional geometry of common urban objects and structures, with buildings as the most prominent feature. However, the outcomes of manual data collecting and mapping also will affect users' understanding level as mentioned in the previous section; and the way to experience the city in these models is usually restricted to a “bird’s eye view” which makes the assessment of implications of new developments at a human scale almost impossible; and currently, many modeling software are not flexible tools to demonstrate the effects of new developments in the urban fabric (Horne, M. et al., 2007; Biljecki, F. et al., 2015).

What is more, the combination of multimedia and multimodal facilities such as text, graph and image and the Internet can be employed to express urban design concepts that likely to evoke users’ cognitions and reaction (Brockmeier, 2010; Felasari and Peng, 2012). Such approaches can construct regional “stories” of possible futures, informed by collated historical narratives, so as to better forecast evolutionary effects on an urban environment (Foth, M. et al., 2007; Banai, R., 2010). However, viewed and fixed route, which restricts percept of the environment and thus to an extent predetermines feedback. As in serial vision, the field of vision is too narrow to truly represent and capture what human eyes can see (Carmona M. et al., 2003).

Over and above, new forms of communication media emerged in recent years. For example, Google Maps and Google Earth can be used by professional users and lay persons without intense training (Phan and Choo, 2010); and VR also is recognized as an effective communication media that provide opportunities to advance communication among different users, to convey urban design concepts, and to reduce the time in consensus process significantly (Abdelhameed, W., 2012; Yang, X. et al., 2015). However, convey a clear design concepts to users is impossible simply by using VR; many methods of presenting virtual environments can be prohibitively expensive or require specialist equipment and programming (Conniff A. et al., 2010), as well as the integration of additional objects representing vegetation and street regions (Haala N. et al., 2005). Moreover, even the users can freely navigation (means interaction) in the virtual environment; it is difficult for them to clearly understand the designer’s intentions without any auxiliary guidance (Zhang, et al., 2015).

In consequence, there is a need for techniques which can combine the advantages of different types of communication medias to assist in systematic express urban design concepts more clearly, and guide users purposefully walkthrough in the virtual environment to further understand urban design concepts.

1.4 Research Method and Thesis Structure

To address the deficiencies above, this PhD research presents a new way that combined a useful presentation technology (APS) with an effective communication platform (Cloud-based VR), as a broader participation platform to create a common virtual scene for improving users' urban design concepts understanding level. Through this platform, users can be able to communicate more effectively about the issues in reaching a consensus in urban design concepts in consensus process.

The research starts from the VR presentation using 3D laser scanning technology for historic buildings mapping and modeling, as a new method to obtain data source for APS. In this research, we will take Shang Shu Di, a Ming Dynasty building which is an officially protected heritage site of China as a case study, and compare the mapping results of detailed components with the traditional method. Aimed at the technical problems of the huge amount of data generated in the application process and the software defects of Cyclone, we will attempt to present solutions.

Then, we seek to find a solution for the problem of how to improve users' urban design concepts understanding through available communication media and useful presentation technology (VR integrated APS). This research recruited 60 participants (half of the participants who have the professional background of Architecture, Urban Planning, or Landscape Architecture) to view the script video (the running result of APS) or/and freely navigate in the virtual environment of Tatsumi region in Tokyo Bay Zone of Japan. By analyzing the data of subjective feedbacks, the research will examine how APS affect participants' cognition and evaluation of Sustainable Taches and Reactivate Space (STARS, the design concepts). Moreover, qualitative interview is developed to further understand participants' design concepts understanding, and validate whether VR integrated APS can improve users' urban design concepts understanding.

After that, in order to provide a broader participation way for users to understand design concepts, this PhD research applied the Cloud-based VR platform in a design report meeting of One Foundation Disaster Prevention Park project. We built a Cloud-based VR platform to proposing design concepts, and create APS for auxiliary guiding users to understand the concepts of urban design and deliberate the design alternatives through the Internet.

The whole research is organized into 5 Chapters. We started from Chapter 1 for Introduction and following it we will introduce the importance of urban design concepts and communication medias from the perspective of urban planning and design; Chapter 2 about the VR presentation using 3D laser scanning technology for historic buildings mapping and modeling, as a new method to obtain data source for APS; Chapter 3 targeted on using VR integrated APS to improving urban design concepts understanding, we will take Tatsumi region in Tokyo Bay Zone of Japan as a case study; Chapter 4 about Cloud-based VR integrated APS for improving urban design concepts understanding in consensus process; Last, we make a conclusion on this PhD research in Chapter 5.

Chapter 2 : Virtual Reality Presentation Using 3D Laser Scanning Technology

This Chapter aims to research on the VR presentation using 3D laser scanning technology in historic buildings mapping and modeling, as a new method to obtain data source for APS. We took Shang Shu Di, a Ming Dynasty building which is an officially protected heritage site of China in Taining County of Fujian Province, as a case study, and compared the mapping results of detailed components with the traditional method. Aimed at the technical problems of the huge amount of data generated in the application process and the software defects of Cyclone, we presented two solutions which are "reasonable data collection and processing" and "construction of historic building components database".

2.1 Introduction

As stated by Kim (2004), any 3D visualization method typically involves three main construction steps: data collection, 3D modeling, and presentation. Moreover, reconstructing buildings and scenes in a realistic fashion is a popular topic in Virtual Reality (VR) projects, whereas in recent years the main focus of research concentrated on 3D reconstruction based on mapping and modeling (Abmayr, T. et al., 2004). Thus, data collection is necessary for building a replica of the physical object, such as topography, building heights and dimensions.

The traditional tools for data collection of the historic buildings are ruler, tape measures, benchmarks and so on. However, interpretation of records is done by the human eyes and most of the measuring is of "a part taken from the whole", that is, a small component is deduced from the whole is based on assumptions of similarity (Zang, C., 2006). Such data collection results in a considerable extent being dependent on personal experience and temporary judgment, which cannot accurately depict specific components, especially in shaped and complex components with detailed spatial characteristics. Hence, advanced data collection tools and technologies are needed that enablers for effective e-planning in the built and human environment (Arayici, Y. et al., 2005). 3D laser scanning technology is a fast, accurate, and cost-efficient method of gathering three-dimensional data for use in mapping and 3D modeling (Pucci, B. et al., 2009). Compared with traditional data collection methods, laser scanning technology has particular superiority as follows (Cheng, X. J. and Jin, W., 2006):

- is a sort of untouched measure system;
- gains the 3D coordinates, reflecting intensity etc. on object surface;
- rapidity of data acquisition, great quantity of data and high accuracy;
- works in all kinds of environments;
- extensive application.

As a new technique for quickly getting three-dimensional information, 3D laser scanning technology has been widely used in many fields, including urban planning and design. For example, in order to refurbish and extend a conference center which only incomplete records of the original building existed to meet modern requirements, Saal, K. (2010) using 3D laser scanning technology to capture the existing features of the old conference hall and its surroundings, then using the acquired data to architectural consultants for their designs and for virtual “tours”. Bloomberg, M. R. et al. (2012) also using 3D laser scanning technology to rapidly capture existing conditions of a building (interiors and exteriors) and natural environments (landscape), and incorporating it back into the BIM as existing conditions.

Added to this, Huo, X. et al. (2013) described the process of applying of modern digital heritage recording and investigation technology (3D laser scanning technology) in the preservation of Wenming historical and cultural blocks in Kunming of China and argues that 3D laser scanning technology is capable of producing a complete and efficient workflow, as well as providing fundamental technical support for heritage preservation work. Armesto-González et al. (2010) presented a methodology to combine the technology of the terrestrial laser scanner with the techniques of digital image processing to study damage on stony materials that constitute historical buildings.

Moreover, Lim, E. H. (2012) proposed an application that using scanning data for 3D urban modeling, and solved some of the existing challenges in 3D urban modeling, such as time-consuming and large amount of data. Besides, Mahdjoubi et al. (2013) established the case and rationale for the adoption of BIM and laser scanning technologies in the real-estate services sector.

Beyond that, Holopainen et al. (2013) used airborne (ALS), terrestrial (TLS) and mobile laser-scanning (MLS) methods in urban forest (trees) mapping and monitoring.

Jia-Chong et al. (2007) used 3D laser scanning and a global positioning system (GPS) to acquire landslide data and to compute earthwork volume. Over and above, in order to statistics on street-side car parks, e.g. occupancy rates, parked vehicle types, parking durations, and provide important urban street information for urban planning and policy making, Xiao, W. et al. (2016) designed a complete system for car park monitoring, including vehicle recognition, localization, classification and change detection, from the 3D laser scanning point clouds. The point clouds are firstly classified as ground, building façade, and street objects which are then segmented using state-of-the-art methods. Their research results shown that the vehicle recognition, classification and change detection accuracies are 95.9%, 86.0% and 98.7%, respectively.

In consequence, this research will take Shang Shu Di, a Ming Dynasty building which is an officially protected heritage site of China in Taining County of Fujian Province, as a case study, and study the application of 3D laser scanning technology in historic buildings mapping and modeling. Then validate the advantages of 3D laser scanning technology in data collection for mapping through a comparison with traditional methods in detailed components mapping. Finally, two solutions for the huge amount of data generated in the process of the application of 3D laser scanning technology will be studied and presented.

2.2 Virtual Reality based on 3D Laser Scanning Technology

3D modeling is the important contents in Virtual Reality (VR) presentation. So the accurate and realistic 3D models play a key role in the creation of immersion virtual scenes. In order to successfully achieve this virtual representation, the real world scenario and other significant objects must be realistically designed, with accurate geometry and detailed textures (Caracena, T. M. et al., 2014). However, it is a significant deficiency that the creation of 3D models currently based on image and traditional data collection methods, which result in time-consuming and inaccurate modeling task (LI, H. et al., 2007). The appearance of 3D laser scanner has the capable of improving the above deficiency. In many fields, 3D laser scanners are widely used to acquire 3D point clouds of physical objects in real world (Danhof, M. et al, 2015).

The 3D laser scanner targets physical objects to be scanned and the laser beam is directed over the object in a closely spaced grid of points. First, the scanner emits a laser beam to the surface of the physical object for each measuring point $P(x, y, z)$, then the laser beam will reflect back to the scanner, and the 3D laser scanner will measure the flight time of laser beam, which is the time of the laser travel from the scanner to the physical object and back to the scanner. Since the speed of light is a constant ($c = 3\times10^{8} m/s$), thus the scanner can calculate the distance S, which is from the surface of the physical object to the 3D laser scanner:

Equation 2-1 S

$$S = \frac{1}{2}\times c\times t$$

Suppose α is the angle between the laser beam and the vertical direction, and β is the angle between the laser beam and the horizontal direction, as illustrated in *Figure 2-1*. Thus, the 3D spatial coordinates of $P(x, y, z)$ are:

Equation 2-2 x

$$x = S\times\cos\alpha\times\sin\beta$$

Equation 2-3 y

$$y = S\times\cos\alpha\times\cos\beta$$

Equation 2-4 z

$$z = S\times\sin\alpha$$

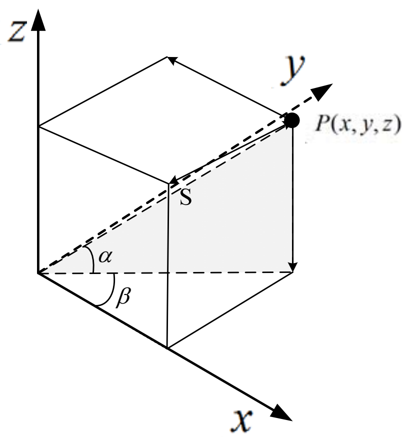


Figure 2-1 3D spatial coordinates of measuring point $P(x, y, z)$

As a result, the "point clouds" (or cloud of points), which consists of thousands of points in a 3D space that are a dimensionally accurate representation of the existing object, is one of the data sources that can be used to show 3D representation of the physical objects, as well as for mapping and modeling (Arayici, Y., 2007; RUSU, R. B. et al., 2008). *Figure 2-2*, illustrates the flow chart of virtual reality presentation based on 3D laser scanning technology.

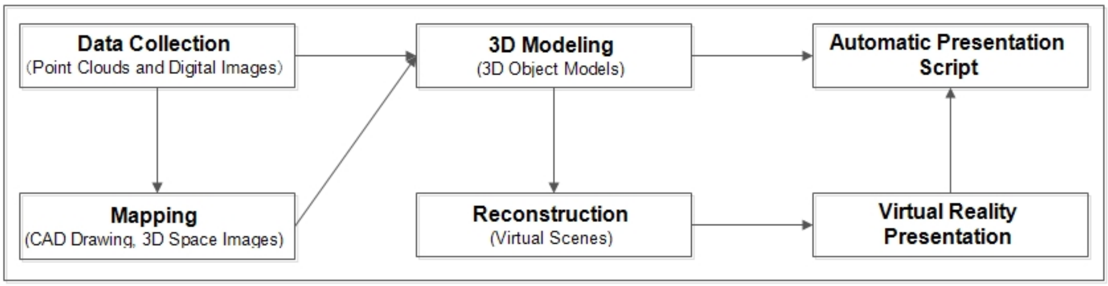


Figure 2-2 The flow chart of virtual reality presentation based on 3D laser scanning technology

3D modeling refers to the process of creating a 3D replica based on the mapping results, as supplemental to the traditional form of urban design representation (such as 2D plans, sketches, CAD), 3D Modeling play an important role in Urban Planning and Design (Velazco, E., 2012). Buildings, landscapes (including plants and trees) and city facilities models are considered as the most important objects for the creation of virtual environments (Eran, S. et al., 2005). VR presentation step involves intuitively displaying 3D model and reconstruction results to the users. The user interface and the type of information delivered through the presentation can vary dramatically.

The development of 3D laser scanning technology will enhance the virtual representation capability of VR presentation and lay a good foundation. Thus, in the application of VR presentation based on 3D laser scanning technology has an extremely important significance.

2.3 3D Laser Scanning Technology for Historic Building Mapping and Modeling

In this Chapter, we used a 3D laser scanner “Scanstation C10” (It is a terrestrial laser scanner), which was produced by Leica Company, to collecting point clouds of Shang Shu Di (It is a historic preservation project for the local government). The scanner has many merits, such as high accuracy, works in all kinds of environments, is multidimensional, has easy operation and so on, so it has the strong superiority of being able to rapidly obtain 3D data for creating 3D models (Fan, Y. et al., 2012). The application of 3D laser scanning technology in historic building mapping and modeling is mainly composed of data collection outdoors and data processing indoors.

Figure 2-3, below, illustrates the flow chart of 3D laser scanning technology for historic building mapping and modeling.

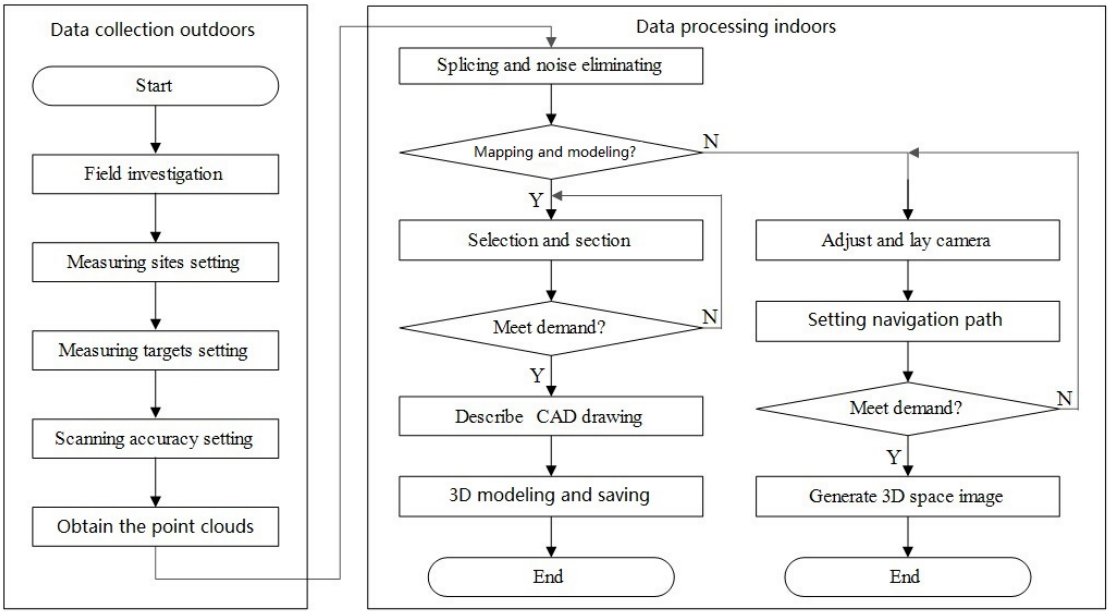


Figure 2-3 The flow chart of 3D laser scanning technology for historic building mapping and modeling

2.3.1 *Data Collection Outdoors*

Data collection outdoors mainly includes field investigation, setting of measuring sites, targets and scanning accuracy, and obtaining the point clouds. For most historic buildings, they have larger and more complex angles, so to avoid excluding sections due to an excess of point clouds, it is reasonable setting multiple measuring sites and measurement targets through multi-station, multi-directional scanning.

Figure 2-4 illustrates 16 measuring sites and 8 measuring targets which have been set in the data collection outdoors. In order to have multiple stations scanning different coordinates of points within the cloud together into the same coordinate system, and to obtain the complete surface information of the object shape, a reasonable target arrangement is particularly important. The basic methods or principles are: Firstly, three targets, which are not in the same straight line, should be placed between every two stations. Secondly, the position of the measurement target should follow the principle of "Service for the next station", which means setting the target in a coordinated location where it can be scanned as much as possible by multiple scanners in order to reduce the number of targets and any resulting error of point clouds during multiple site splicing processing. Thirdly, setting up should avoid omitting set targets.

Scanning accuracy settings directly affect the final results of the data collection, thus for group buildings' positioning measurement, or a single-building's integral measurement, medium or low-resolution scanning is commonly used. However, for specific detail components of historic buildings, such as specific plaques, fonts or painting patterns, which require high or ultra-high resolution scanning. Adjustments for degrees of exposure must be made according to the environment and weather conditions. The degree of exposure needs to be increased when the point clouds occurs in a dark area, or decreased in a bright area.

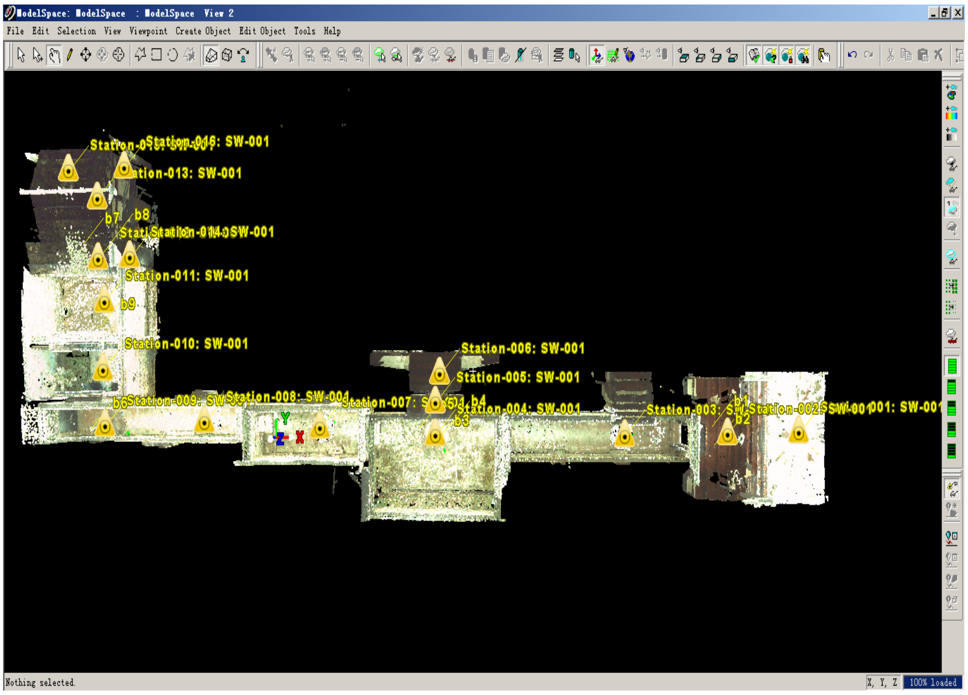


Figure 2-4 The measuring sites and measuring targets

2.3.2 *Data Processing Indoors*

Data processing indoors mainly includes splicing and noise eliminating for the point clouds selection and section, the creation of CAD drawing, 3D modeling, the generation of 3D space image, data storage and extraction for later use. Splicing primarily used the method of "group positioning system", to position single-buildings and the detail components into the historic building's settlement group, namely multiple stations' point clouds, were spliced into the same coordinate system in order to obtain the target entity's complete spatial data. Noise elimination is conducted to remove the invalid point clouds, reducing the overhead of computer data processing, and to improve the ability of computer data processing. The noises of this project is relatively obvious, so it is easy to segment the point clouds through naked eye judgment, then delete directly by a human-computer method to eliminate the noises.

Due to the impact of the scanning mode to obtain the point clouds, and the initialization of the instrument, the cloud model that has been acquired has no accurate coordinate axis. Therefore, it is necessary to determine the coordinates using Cyclone software first, to unify the point clouds, and to optimize the cloud model, then to put the cloud model into AutoCAD to slice the plane, vertical face and profile using the Cloudworx plug-in. Finally, the plane drawing, vertical face drawing and profile drawing is described according to the section feature and point clouds in AutoCAD. *Figure 2-5*, *2-6* and *2-7* illustrate the drawing of the section from the point clouds.

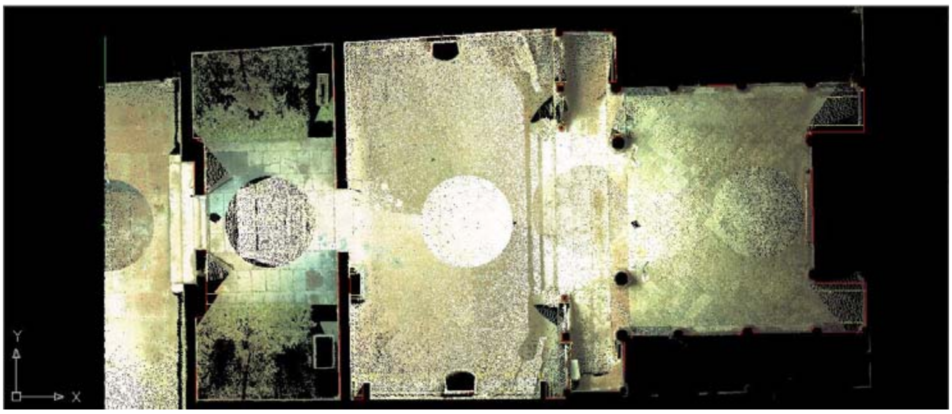


Figure 2-5 The drawing of the entrance plane section from the point clouds

Figure 2-6 The drawing of the entrance vertical face section from the point clouds

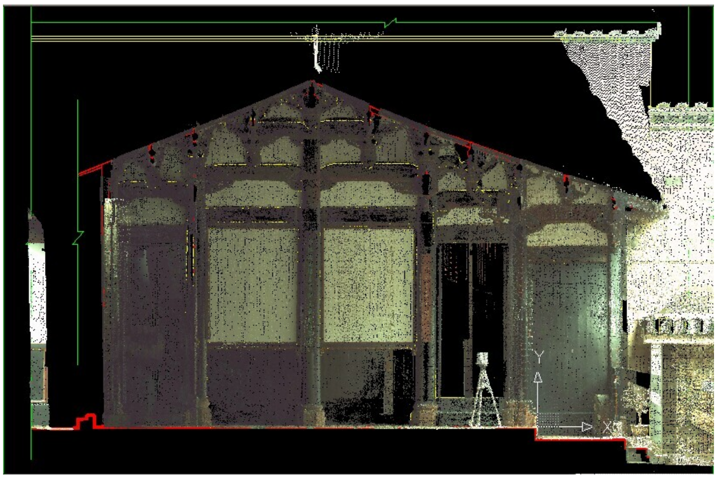


Figure 2-7 The drawing of the entrance profile section from the point clouds

Figure 2-8, *2-9* and *2-10* illustrate the plane drawing, vertical face drawing and profile drawing of the entrance utilizing the hidden point clouds.

Figure 2-8 The plane drawing of the entrance

Figure 2-9 The vertical face drawing of the entrance

Figure 2-10 The profile drawing of the entrance

There are two methods for 3D modeling: the first one is to fitting patches on the physical object's true surface using their point clouds; the second one is to create a 3D replica based on the mapping results (CAD drawings). If the modeling of the big surfaces made from small patches, because of the fitting problems some error can arise. The patches have to be edited by manual to solve this problem, and the 3D editing possibility of software makes that easier (Demir, N., 2004). In addition, many potential users used CAD drawings to realize 3D modeling because it can create an accurate 3D replica (Gaidyte, R. 2010). In order to create accurate and realistic 3D models, we choose the later one for 3D modeling using the mapping results via SketchUp software, and the modeling result can be used as a data source for APS. *Figure 2-11* illustrates the 3D modeling of one historic building in Shang Shu Di project.

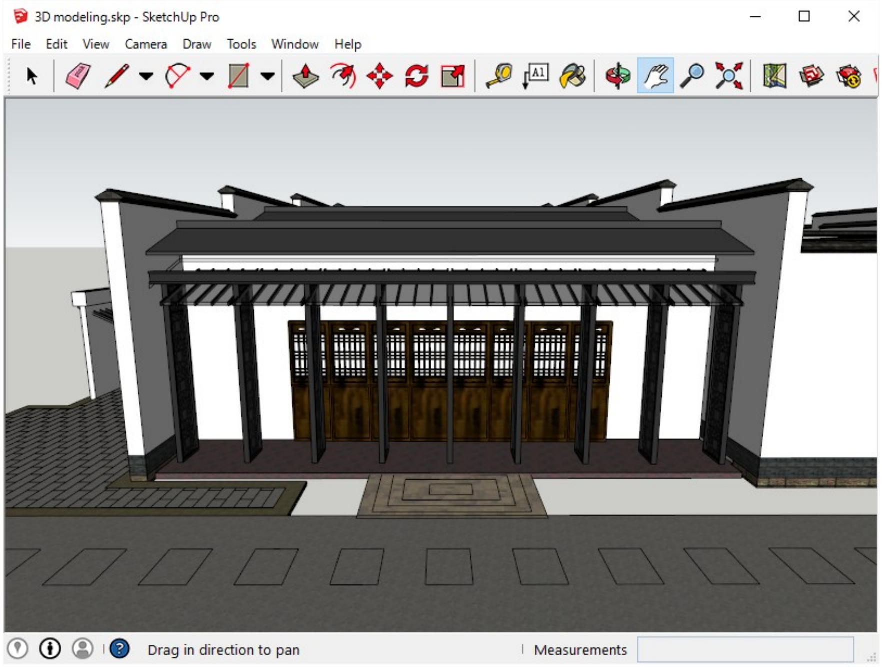


Figure 2-11 3D modeling of historic building (one building in Shang Shu Di project)

The collected data (point clouds with digital images) can also be used in Virtual Reality (VR) presentation, we constructed a 3D space image to show the mapping results and realistic virtual scenes. This was enabled by fitting the point clouds with the digital images captured from the built-in camera, and setting the navigation path. *Figure 2-12* illustrates the 3D space image of Shang Shu Di.

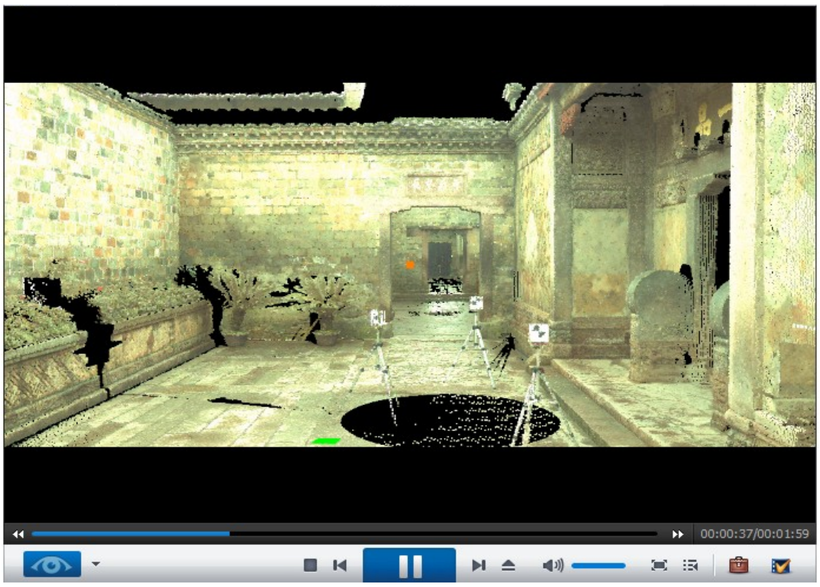


Figure 2-12 3D space image of Shang Shu Di

2.4 Comparison of 3D Laser Scanning Technology with Traditional Method in Detailed Components Mapping

The detailed components of historic buildings and their decoration are important contents in mapping and modeling. The traditional method is to orthographically shoot the various parts of the components and decorations of historic buildings, and to record their sizes by manually mapping them. Surveyors are required to climb scaffolding, prostrate or squat, and there are measured omissions, mistakes and other issues to be taken into consideration. The application of 3D laser scanning technology can overcome these disadvantages of the traditional method.

To begin with, focus can be placed on the detailed components that need to be mapped, using an appropriate resolution to scan and collect data. In order to decrease the volume of the point clouds, it is necessary to adjust the vision angle according to the physical objects which need mapping, then to use a "partial selection method" to extract the desired point clouds accurately. *Figure 2-13* illustrates the extracted point clouds of the Dougong beams above the Gold Pillar.

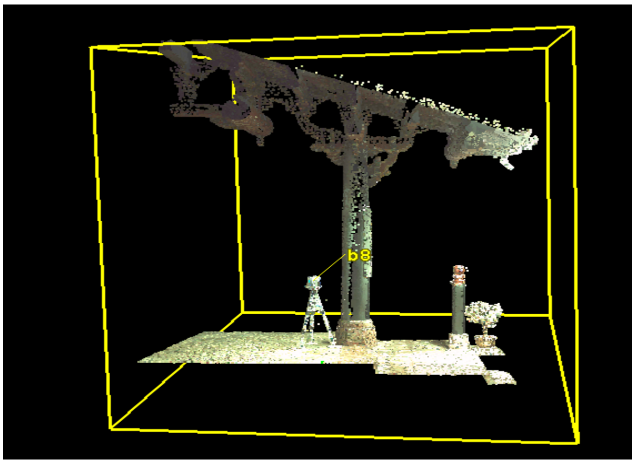


Figure 2-13 Extracted point clouds of the Dougong beams above Gold Pillar

Secondly, the point clouds are unified to reduce their density, then imported into AutoCAD to slice their profile using the Cloudworx plug-in, the profile drawing is then described according to the section feature and point clouds in AutoCAD. *Figure 2-14* illustrates the drawing of the Dougong beams above the Gold Pillar using the point clouds.

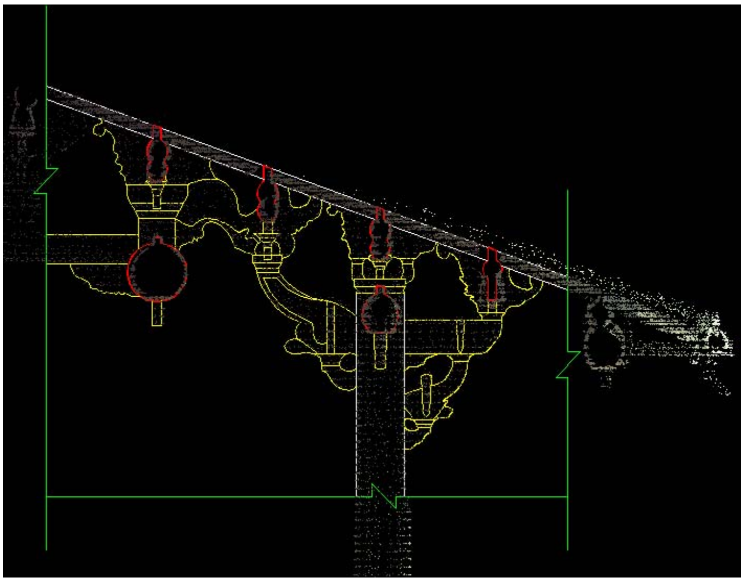


Figure 2-14 The drawing of the Dougong beams above the Gold Pillar using the point clouds

Finally, the hidden point clouds were used to obtain the profile drawing of the Dougong beams above the Gold Pillar, as *Figure 2-15* illustrates. The accuracy of the mapping drawing has improved significantly compared with the original manual mapping drawing. *Figure 2-16* and *Table 2-1* illustrate the mapping results of the 3D laser scanning technology compared with the traditional method.

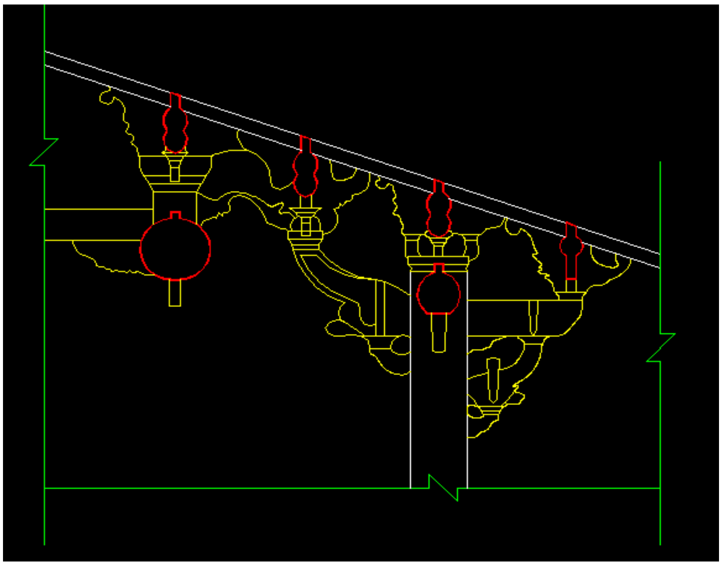


Figure 2-15 The profile drawing of the Dougong beams above the Gold Pillar

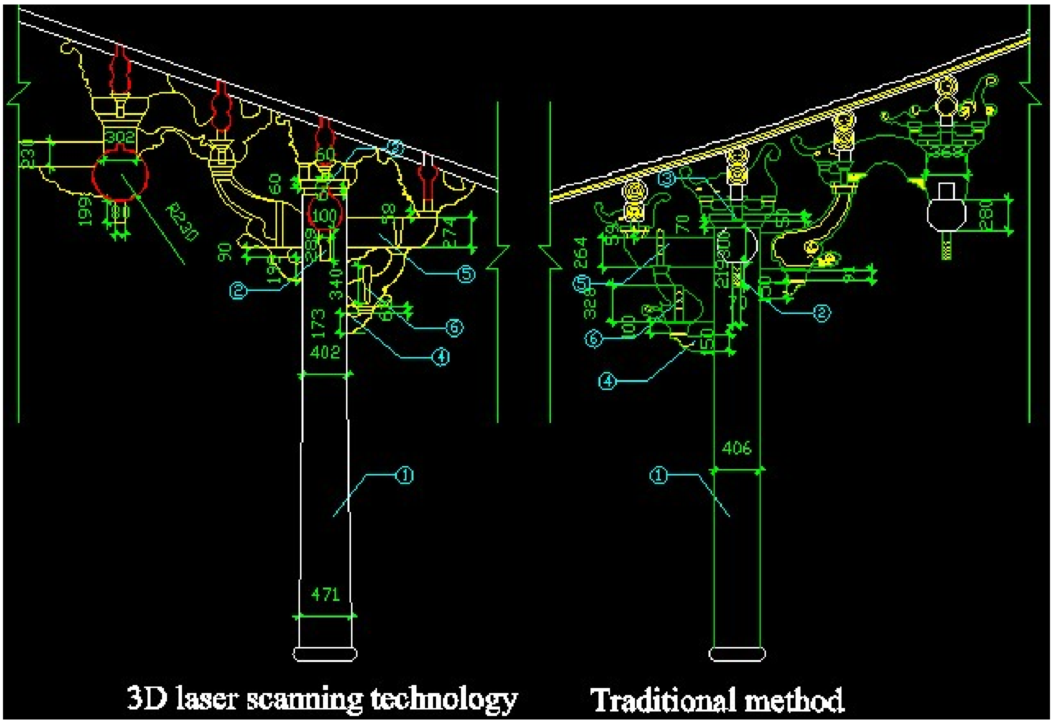


Figure 2-16 Comparison of mapping results of 3D laser scanning technology and traditional method in detailed components

Table 2-17 Comparison results of the two methods corresponding to Figure 2-16

Key points.	Traditional mapping method	3D laser scanning technology	The comparison results (The problems of the traditional method)
①The diameters of the Gold Pillar	The same diameters from top to bottom, 406mm	Small top and big bottom, the diameter is 471mm at 300mm, and 406mm at 2400mm from the bottom.	The traditional method often misunderstands the diameter of the Gold Pillar. So there are measurement omissions.
②The high-aspect ratio of intermediate Dougong.	Width is 70mm and height is 219mm. So the ratio is 3.13.	Width is 100mm and height is 289mm. So the ratio is 2.89.	The ratio of the traditional method is higher than the 3D laser scanning technology, so there is a measurement error.
③Tablet Square	Absent	Present	There are measurement mistakes or omissions.
④Trunk Gong	150mm	173mm	There is a measurement error.
⑤Er Pi Gong	264 mm	274 mm	There is a measurement error.
⑥Hua Ya Zi	328 mm	340 mm	There is a measurement error.

2.5 Solutions for the Huge Amount of Data

Due to the sizes of historic buildings, the complexity of detailed components, the number of sites and the accuracy of scanning, a huge amount of data will be generated during the process of application of 3D laser scanning technology. *Figure 2-17* illustrates the spacing and data of one site's data volume of point clouds at different scanning resolutions. When the scanning resolution is fine, ultra-high, the amount of data from panorama scanning reaches 7.78Gigabytes. This affects not only the processing speed of the computer, but also the data processing later period, CAD graphics conversion and the efficiency of data extraction. Therefore, reasonable data collection and processing, as well as the construction of a historic building components database are two important solutions for the problem of the huge amount of data.

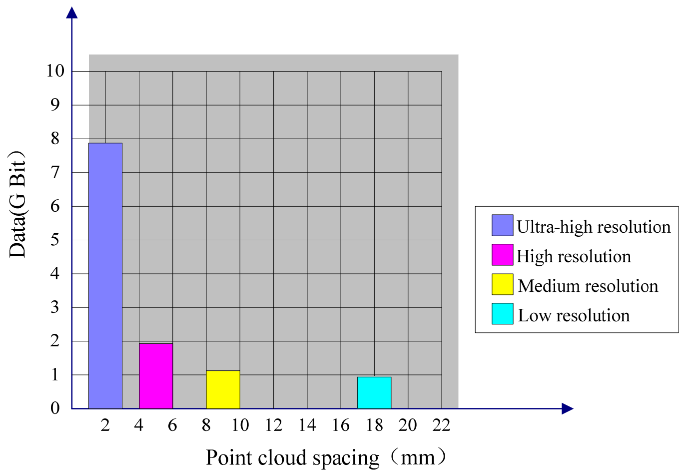


Figure 2-18 The spacing and data of one site's data point cloud at different scanning resolutions

2.5.1 *Reasonable Data Collection and Processing*

Reasonable data collection and processing needs to be done in two stages: First, setting a reasonable scanning accuracy and vision angle when in the data collection stage. Second, noise elimination and saving the data as *.Ptx or *.Pts format files in the data processing stage. The scanning accuracy and vision angle should be set according to different mapping objects, as shown in *Table 2-2*.

Table 2-19 Scanning accuracy and vision angle in different mapping objects

Mapping objects	Scanning accuracy	Scanning vision angle	The distances between two clouds of points within 100 meters.	Data size
Group buildings	Low resolution	panoramic scanning	20mm	0.98GB
Single-building	Medium resolution	panoramic scanning	10mm	1.16GB
Detailed components (such as Dougong, beams, windows, doors.)	High resolution	partial scanning	5mm	1.99GB of panoramic scanning.
Graphic patterns	Ultra-high resolution	partial scanning	2mm	7.78GB of panoramic scanning.

Noises generally comes from two sources: one is the passing vehicles or pedestrians while the 3D laser scanner is in working. *Figure 2-18* illustrates the noises caused by the passing vehicles and pedestrians; another is some invalid point clouds, for example, some modern buildings appear that are adjacent to the historic buildings, or there are some debris of the historic buildings, etc. The invalid data not only affects the accuracy of mapping results, but also takes up storage and system resources, as well as affecting the ability of computer processing. Therefore, for the obvious noises, just using the "Fence Mode" marquee method is sufficient, while for complex noises, it is necessary to separate the noises area from the point clouds, then combine with the "Fence Mode" marquee method to eliminate the noises. *Figure 2-19* illustrates the point clouds after noise elimination.

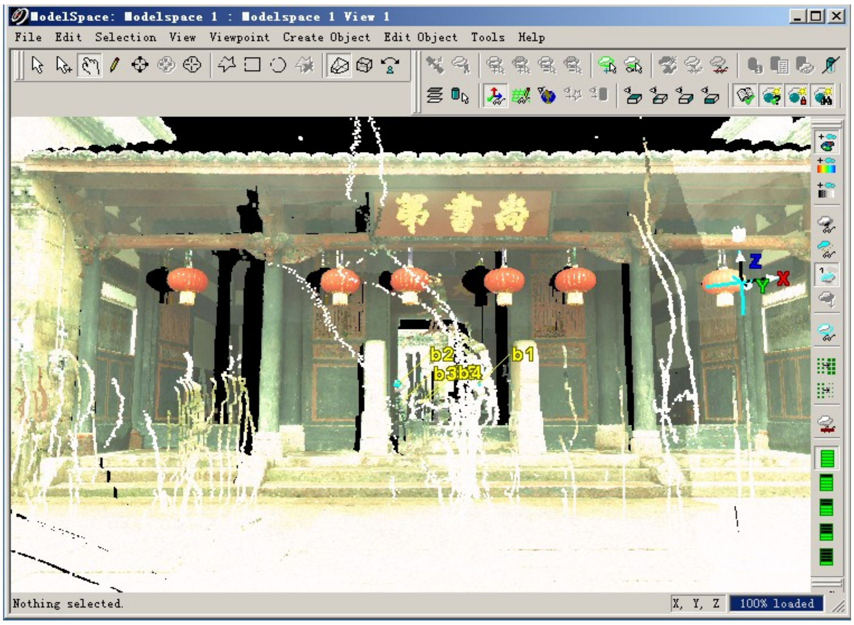


Figure 2-20 Noise caused by the passing vehicles or pedestrians

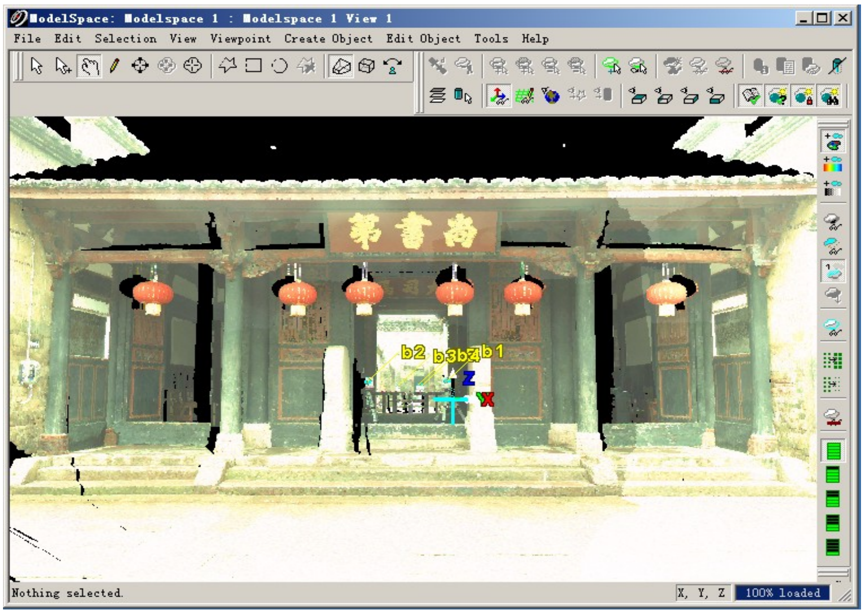


Figure 2-21 The point clouds after noise elimination

Beyond that, the data saved for later use is very important since the data can be extracted for later use after finishing the noise elimination, so it is necessary to export the point clouds as *.Ptx or *.Pts format files. In this project, the scanning area of Shang Shu Di was about 900m^2, there were 16 measuring sites and 8 measurement targets set, the scanning accuracy was medium resolution, and the actual data volume generated was 18.6GB. After eliminated noises and saved the data as *.Ptx format files, there was only 8.72GB of data volume (*.Pts format files with the same data volume). Therefore, it greatly reduced the size of the point clouds and saved 53.12% of storage space.

2.5.2 *Construction of Historic Building Components Database*

The point clouds collected by a 3D laser scanner has the feature of "measurement one time, permanent use". So the establishment of a 3D data information table would assist the effective management of historic building components. Users can call and view building component parameter information and eventually establish a historic building components database.

Currently, noise elimination can only be carried out after splicing in Cyclone 7.3 software, whereas the data volume is so big after splicing, which has haunted us for a long time. Therefore, our research team gained the experience of splicing, noise elimination, reducing data volume, and the generation of CAD graphics using AutoCAD software, and presented a specific solution which is "packet processing, integrated splice" (Zhang et al., 2014). For multiple stations, it is necessary to group, firstly, one group composed of several stations, and then each group spliced and with noise eliminated, then put the point clouds model into AutoCAD to slice and describe the CAD drawing. Finally, a 3D data information table of historic building components is established through the insert or external redeployment feature of AutoCAD. *Table 2-3* illustrates the 3D data information table of the pillars from Shang Shu Di.

Table 2-22. 3D data information table of pillars.

ID	Code	Type	Diameter of pillar bottom	Diameter of pillar top	Height of pillar diameter	width of pillar diameter
PFX1Y1Z1	PF	Round	471mm	406mm	No	No
PFX2Y2Z2	PF	Square	No	No	303mm	301mm
PFX3Y3Z3	PF	Round	477mm	398mm	No	No

According to the actual needs, there are many properties involved in the database, including not only the property of spatial data, such as floor area, material, location, size and social history, etc., but also attribute information, such as literature information, historical and cultural information. *Table 2-4* illustrates the database structure for a single building. Finally, a building components database with perfect classification and easy extraction would be established through data processing indoors, which can achieve the multidimensional use of the mapped data.

Table 2-23. The database structure for a single building.

Character	Type	Length	Name
Leb	Float	80	Length of building
Wib	Float	80	Width of building
Hed	Float	80	Height of door
Wid	Float	80	Width of door
Lay	Int	5	Layers
Buit	Datatime		Build time
Ima	Image		Image information
Rem	Text	20	Remarks

2.6 Conclusions in this Chapter

Historic buildings have embedded potential for sustainability. They often use comparatively low energy and durable materials, and historic neighborhoods are often characterized by density, short distances and mixed use, which make them a relatively efficient model of sustainable development. Furthermore, demolishing or replacing these buildings would require a major reinvestment of energy and resources. Therefore, the retention, rehabilitation and reuse of historic buildings can play a pivotal role in the sustainable development of the city.

Historic building mapping and modeling are the basic work for reconstruction and VR presentation in the field of historical and cultural heritage protection. Meanwhile, it not only provides important basic data for the research of architectural history and theory and architectural history teaching, but also provides a reference for succeeding and developing traditional building culture and exploring modern architectural creation (Wang, 2006). The traditional data collection method is simple and intuitive; however, it is a time-consuming, labor-consuming, and painstaking job; and there are measurement omissions, mistakes and other issues. The results cannot accurately depict specific components, especially in shaped and complex components and their detailed spatial characteristics. 3D laser scanning technology can be used to efficiently create accurate CAD drawings and 3D models that overcome the above disadvantages, and the 3D space images can also be used in VR applications.

In the actual application process, 3D laser scanning technology still has existed issues that need further exploration and solutions: to begin with, a terrestrial scanner can hardly scan a building completely, as there are always occluded areas which cannot be reached by the laser beams. Hand-held scanner and airborne scanner need to be considered with terrestrial scanner to scan a building more comprehensive in the actual application. Moreover, time-consuming and labor-consuming are required to

3D modeling through fitting patches on the physical object's surface using the point clouds. Software technology capable of automatic fitting and generation 3D model needs further development and improvement.

In addition, 3D laser scanning is becoming a standard technology for the 3D modeling of complex scenes. Laser scans contain detailed geometric information, but still require interpretation of the data for making it useable for mapping purposes. With the development of integrated software development technology, 3D laser scanning technology and building information modelling (BIM) technologies will offer new possibilities for capturing, mapping, modeling and the analysis of building information in the future.

Chapter 3 : Virtual Reality Integrated Automatic Presentation Script for Improving Urban Design Concepts Understanding

This Chapter aims to use virtual reality (VR) integrated automatic presentation script (APS) technology to improving users' urban design concepts understanding in Tatsumi region of Tokyo Bay Zone, Japan (It is a virtual design contest project in order to adding new city facilities and adjusting land use, to meet the need of 2020 Olympic Games in Tatsumi region). We built a virtual environment and set simulation scenarios to proposing urban design concepts, then created APS for auxiliary guiding users to understand the concepts of urban design. We examined how APS affect participants' cognition and evaluation of Sustainable Taches and Reactivate Space (STARS), and eventually improving their understanding through validation experiment and using quantitative and qualitative methods.

3.1 Introduction

Urban planning and design is a very complex process consisting of tasks that require joint decision making. In such tasks, the communication through different kind of communication medias to present and convey design concepts is of critical importance (Isikdag, U., & Zlatanova, S., 2010). Although there are a variety of communication medias can be used today (e.g. 2D plans, sketches, CAD, GIS, videos, VR), presentation of meaningful visual information can be neglected to the detriment of the communication process (Kaplan R. et al., 2008).

What concepts users can get from these different communication media? And what is successfully conveyed by each type of media? It is commonly acknowledged that users often have trouble understanding traditional 2D plans, which can lead to discontentment with the end result (Joseph R. and Perera U., 2013). Sketches are often favored by designers as a communication media to present initial design concepts in a more fluid style for communication. However, comparatively little is known about the pact on users of designers' design concepts (Bates-Brkljac N. et al., 2009). Besides, some visualization tools such as CAD and GIS allow planning designs to be published as ''true" electronic maps, searchable drawings and other auxiliary document materials. However, only users who with professional skills can operate these document materials; and technical training are usually a prerequisite to interpret those (Wu et al., 2010).

Heft H. and Nasar J. L. (2000) found that reactions to static displays do not parallel those of dynamic displays. They found that preference ratings (how much a person liked a scene) were significantly lower for dynamic compared to static conditions. It can therefore be argued that dynamic presentations of a future environment are likely to evoke cognitions and reactions closer to those that would be found in the real world, than those that would be evoked by static images or document materials. Thus, planners and designers try to use video as a communication media to convey design concepts to the users. However, viewed and fixed route of video, which restricts cognition of the environment and thus to an extent predetermines feedback. As in serial vision, the field of vision is too narrow to truly represent and capture what human eyes can see (Carmona M. et al., 2003).

As Steven B. G. stated (2010), a good design begins with a good design concept. Designers are trying to solve a problem and their concepts will lead the way and give them direction for their design decisions. Therefore, urban design concepts understanding play an important role during the process of design alternatives discussion. With the increasing of dynamic, interactive and experiential characteristics, virtual reality (VR) has become able to simulate real environments with various degrees in urban planning and design. VR is a visualization and communication medium that makes it possible for all interested parties to have access to a common representation and a better understanding of the planned urban environment (Roupé, M. et al., 2014), and the use of VR presentations are becoming a more and more frequent means of communicating information and displaying data to the public at large (Larsson P. et al., 2001). However, it is difficult to convey urban design concepts to users simply by using VR presentations. Many methods of presenting virtual environments can be prohibitively expensive or require specialist equipment and programming (Conniff A. et al., 2010), as well as the integration of additional objects representing vegetation and street regions (Haala N. et al., 2005). Even participants can freely navigation in the virtual environment; it is difficult for them to clearly understand the designer's intentions without any auxiliary guidance (Zhang, et al., 2015). Thus, there is a need for techniques to assist in systematic understand the designer's intentions, and guide participants purposefully walkthrough in the virtual environment to further understand design concepts. Moreover, due to their interactivity and to the sense of presence they afford, the growth of VR technologies has introduced new interesting ways to study spatial cognition (Morganti, F. et al., 2008), and the cognitive rationale and evaluation of the designs proved to be comparable across the two conditions (Skorupka, A., 2009).

Automatic presentation script (APS) in this dissertation is defined as presentation techniques which can combine different kinds of communication media (including 2D plans, multimedia and 3D visualization) to express urban design concepts that users can better understand. Thus, from the perspective of designers or planners, they can enter the elapsed time (in seconds) at which they want each action (e.g. play video, show message, play simulation) to occur in a virtual environment. APS is different from the definition of computer science (In computer science, a script is a program). With the integration of VR and APS, urban planners or designers can connect view-point with 3D model, text message, video, navigation and simulation in a virtual environment, so that express the design concepts clearly.

To address this, in this Chapter, we will focus on how to enhance people's cognition and evaluation of the design concepts, and eventually improving urban design concepts understanding in Tokyo Bay of Japan, through using VR integrated APS technology. We built a virtual environment and set simulation scenarios to proposing urban design concepts, then created APS for auxiliary guiding users to understand the concepts of urban design. We examined how APS affect participants' cognition and evaluation of the design concepts, and eventually improving their design concepts understanding.

The structure of this Chapter is as follows. In Section 2, we will take a sustainable planning and design project in Tatsumi region of Tokyo Bay Zone as a case study, and present how to build virtual environment and create APS to proposing design concepts. In Section3, we will discuss the method and validation experiment. Section 4 includes the results of questionnaires, and Section 5 includes the results of qualitative interview. Finally, Section 6 contains our conclusions and future work.

3.2 Implementation of the STARS in Tatsumi Region of Tokyo Bay Zone, Japan

3.2.1 *Case study location*

Tokyo will host the 2020 Olympic Games, and the main Olympics area will be divided into the Heritage Zone and the Tokyo Bay Zone. The Tokyo Bay Zone, being promoted as “a model for the future urban development of Tokyo,” will host 21 venues for gymnastics, tennis, rowing, sailing, swimming and more (Kameda M., 2013). The International Olympic Committee (IOC)’s Executive Board (EB) decision sees the venues for triathlon and all the aquatics disciplines, except water polo, which will move to the existing Tatsumi International Swimming Centre, will remain in their original bid locations, and new athletic stadiums will be built in Tokyo Bay Zone (Shikiba/Tatsumi region).

As stated by Teruyuki Ohno (2014), the sustainability goal is important for the 2020 Tokyo Olympics for two special reasons. One is that the 2020 Tokyo Olympics is intended to demonstrate to the world the recovery from the 2011 Great East Japan Earthquake and Tsunami. Another is that 2020 is the year when a new international framework for addressing global warming will come into effect. Therefore, in order to achieve environmental conservation, sustainable development, to maximize the cost performance in both ecological and scenic sense in Tatsumi region. We try to adding new city facilities and adjusting land use as a content of sustainable planning and design in this project, to meet the need of 2020 Olympic Games in this region, as shown in *Figure 3-1*.

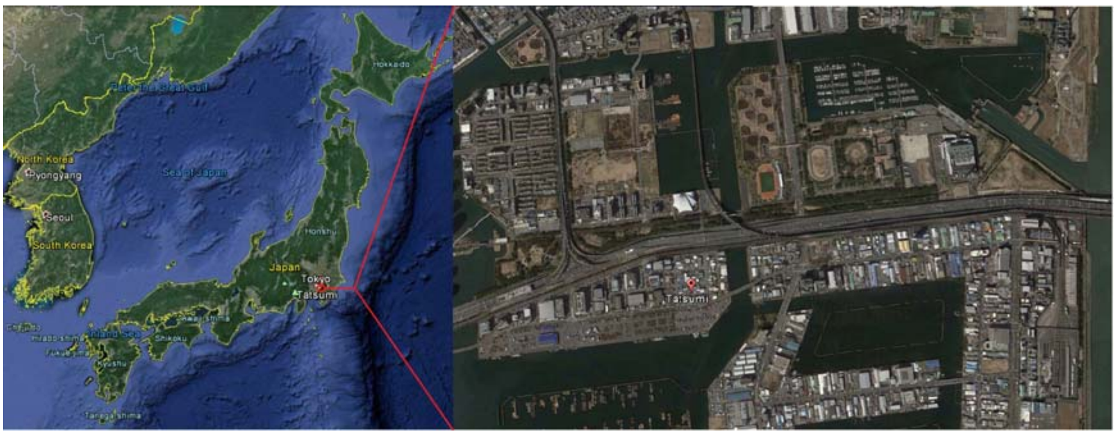


Figure 3-1. Project location: Tatsumi region in Tokyo Bay Zone of Japan.

3.2.2 *Implementation of STARS Using VR Integrated APS Technology*

3.2.2.1 Sustainable Taches and Reactivate Space (STARS)

"Sustainable Taches and Reactivate Space" (STARS) is the design concepts of sustainable planning and design project in Tatsumi region of Tokyo Bay Zone. We hope to provide easy mobility and comfortable stay for visitors from around the world and to live up to the expectation of an advanced environmentally friendly city. Here, Sustainable Taches will ensure the serving of the needs in accommodation, entertainment, food/beverage supply and transportation for the visitors during the Olympics, which will also be used effectively by the local after the Olympic Games, avoiding unnecessary investment and excessive financial burden. Reactivate Space will try to promise the development of the harbor region out of the image of a conventional industrial waterfront and offers an attractive and valuable city environment, promoting the local tourism development.

Currently, Tatsumi region is an industrial district with warehouse and factory, where employees work during the daytime and leave at night. It results the small population of flow rate in the region and will have to face a dramatic increase of the flow of visitors during 2020 Olympic Games. Thus, city facilities in dealing with this condition are needed by that time, and should continually have effective functions after the Olympics.

Light rail transit, as the primary means of regional transportation, appears not high (crowded) in rush hour, and very low in non-rush hours (we have investigated on Jul.18th 2014, on Friday). From the experience of 2008 Olympic Games in Beijing, China, the traffic volume of main subway is 150% higher than normal (JIANG Y. K., 2008), which is far lower than the capacity rate of traffic volume in Tatsumi region. Moreover, in Koto Ward Urban Planning master plan (江東区都市計画マスタープラン, 2011), there is an additional LRT expected in future besides the current two high ways of transportation, which will surely further lower the pressure of individual railway.

Therefore, we draw the conclusion that the Shin-Kiba Station itself does not need expansion. What needs to increase is the capacity of accommodating visitors in this region. If the station were extended, after the Olympics it would gradually return to normal state and then it would be bloated, which is a waste of investment.

In this project, we avoids intense routes of motor vehicle traffic and choose several geographical spots to adjust Tatsumi region, providing accommodation, entertainment，comprehensive service center and bicycle road network to achieve the specific core goals as following:

• Disperse the pressure of the traffic volume of visitors, increase the carrying capacity of local population by adding functional urban facilities and space.

• Advocate the eco-environment idea to the world by adding bicycle transportation network, utilization of solar energy, etc.

• Promote the charm of harbor metropolis through providing an attractive environment with complex urban features, and promoting regional smart development of tourism economic in Tokyo.

3.2.2.2 Virtual environment of the STARS

Virtual environment allows the visualization of design concepts in three dimensions and provides interactive functionalities that reinforce the feeling of immersion into a computer-generated virtual world (Davis, A., 2015). Moreover, 3D models which are used as a preferential means of communication in a virtual environment in order to represent the real world (Kim, D., 2004), and VR is reported to help the participants to better understand planning and design proposals, since they can interact with 3D models under simulated environment (Sampaio, A.Z. et al., 2010). Thus, we used SketchUp to create 3D models, including building models, landscape models, and city facilities models, and imported to UC-win/Road as the design element for virtual environment, *Figure 3-2* illustrates the virtual environment of the STRAS.

Figure 3-2. Virtual environment of the STARS

In the services of the Olympics the 2020 Olympic Games, an Olympic Comprehensive Services Center is designed with a variety of functions in an integrated architecture (Area A in *Figure 3-2*). It locates the nearest to several stadiums for the convenience of transportation, which provides the main parking area of both motor vehicles and bicycles during the Olympics. After the period, the Services Center will continually be used as a memorial exhibition museum of 2020 Olympic Games.

An additional Waterfront Plaza is created by the harbor for the tourists (Area B in *Figure 3-2*), in the company of Daigo Fukuryu Maru Exhibition Hall (第五福竜丸展示館) and Yumenoshima Tropical Greenhouse Dome (夢の島熱帯植物館), simultaneously adding a souvenir shop and fast food restaurant. It provides the parking area for bicycles. In this way the tourism spots are combined together and strengthen the regional population capacity.

By the side of two expected stadiums, there is a subsidiary functional construction “Light Steel Structure Space” (Area C in *Figure 3-2*), which providing temporary staying space and services for guests. It is as a transitional spot from the two stadiums to open space, which links to two existing car parking lot. The construction could be built with light section steel structure, which is easy to remove and recycle after the Olympic Games.

In order to avoid traffic chaos, a Comprehensive Entertainment Mall is built outside Yumenoshiman (夢の島), not far from one of the expected stadiums, in the side of Tatsumi Seaside Park(辰巳の森海浜公園), meeting the need of entertaining and shopping during Olympics (Area D in *Figure 3-2*). Both of the mall and the stadium share the vehicle parking lot together. The reason of choosing this location is that Tatsumi 1-chome is mainly a residential area. The Entertainment Mall in that region can be fully used by the local after Olympics, which avoids unnecessary investment and excessive financial burden of the architecture.

During the Olympic Games, We believe using bicycle is the most energy saving and convenient methods for very region. Therefore, we set up several bicycle rent shops and bicycle parking lot, create a new bicycle transportation network separated from the main vehicle transport network in Tatsumi region (We have shown more detail in the virtual environment). Some of the plants (factories) in Area E (*Figure 3-2*) will be transformed into hostels offering accommodation for visitors, or other service-oriented facilities including Bicycle Rent Shop. The selected accommodation buildings are at the inside of the bay, at a distance from the Shin-Kiba Station, also away from the traffic noise of the main motorways. After the Olympics, they could be restoring to their original functions.

When the virtual environment is large, populated by many roads and models, it may be required to alter some settings (e.g. display, textures, view distance) to improve the performance so as not to affect the interaction between users and the virtual environment, as well as the understanding of design concepts. In this project, we improved the performance of virtual environment through hiding the roads and models which are not affecting the design representation of STARS, and reduce the volume of traffic and number of pedestrians.

Scenario can be treated as the behavior of a disembodied object in virtual environment (Kearney, J. et al., 1999), it represent a coherent view of a possible future state (Grossman and Özlük, 2009). In the STARS, we created characters (including driving cars, pedestrians peoples and bicycle riding persons) and network (including nodes and pathways) for pedestrians, and set the properties of pedestrians, such as maximum population, rate and initial population for the pedestrians in order to clearly express the concepts of disperse the pressure of the traffic volume of visitors and increase the carrying capacity of urban population. Also we added traffic generator then set initial speed and upstream phases for traffic simulations. We tried to construct a dynamic description for the STARS through a series of simulation scenarios.

3.2.2.3 Automatic Presentation Script of the STARS

As mentioned in previous section, APS can be used to select the group (such as viewpoint, multimedia, navigation, and so on) for which the action designers want to occur belongs. In order to clearly express the urban design concepts (STARS), we created APS for auxiliary guiding users to understand the concepts of the design; *Figure 3-3* illustrates the implementation of eco-city planning concept in STARS using VR integrated APS.

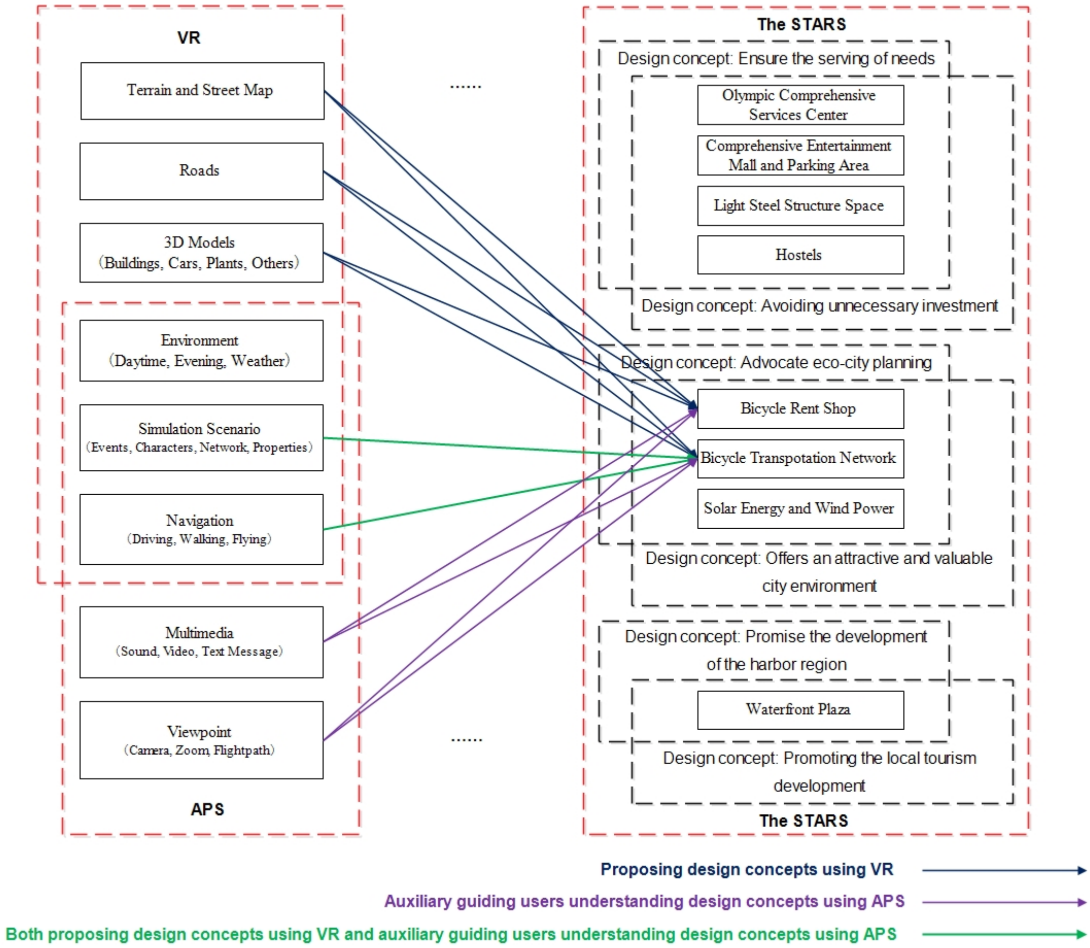


Figure 3-3. Implementation of eco-city planning concept in STARS Using VR integrated APS

Since multimedia can be described as different types of information in a multimedia presentation, including sound, video, text message, still image and animation (Rahim N., et al., 2013), and based on the findings in the literature, average reading speed for English as a second language (ESL) reader is 100 words per minute (WPM) (He, M., 2014; Okazaki, H. et al., 2012). Thus, we used text messages, and created APS to show message to statement the concepts of STARS. We also used camera to designate view points, and controlled micro simulation player to display simulation scenarios to match the text messages, so that the concepts of STARS can be expressed clearly. *Figure 3-4* illustrates the APS of advocate eco-city planning concept.

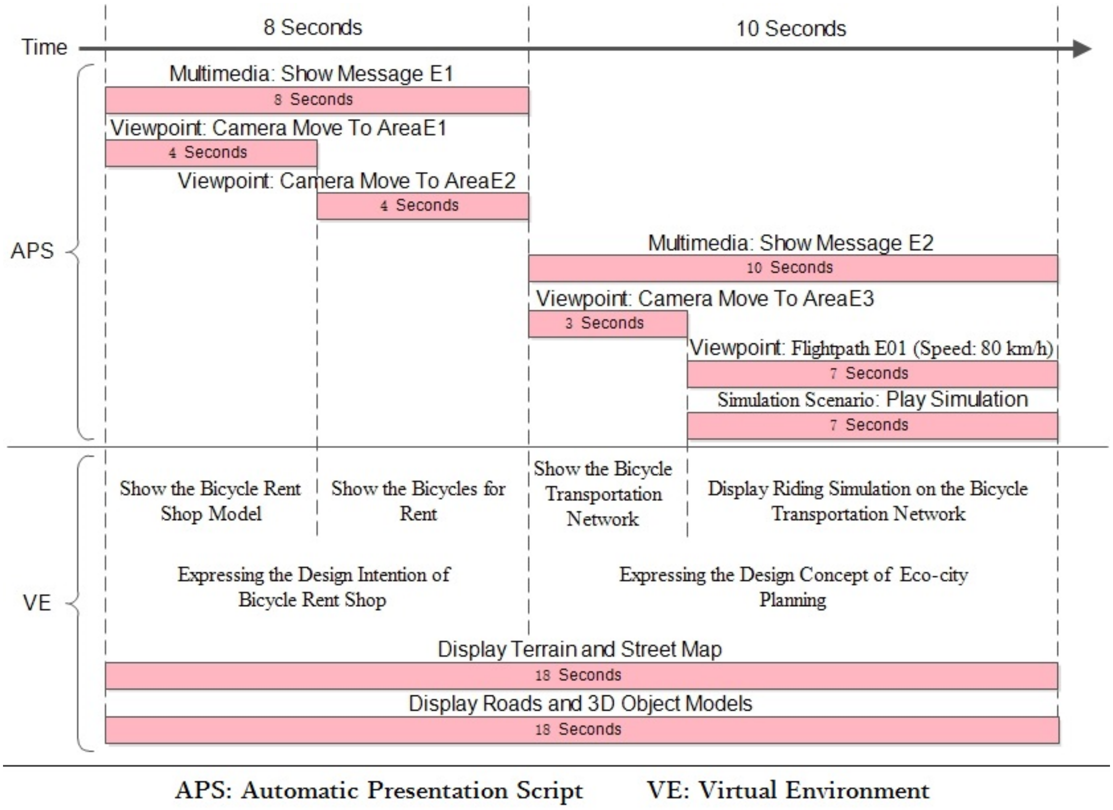


Figure 3-4. APS of advocate eco-city planning concept

Eco-city planning is a key element of urban land use planning in perspective and of ongoing debate of environmental urban sustainable development with a spatial and practical dimension (Wong, T. C., & Yuen, B., 2011). In this script, we show message E1 in the first step, to express the concept of eco-city planning and the bicycle rent shop design in STARS as one way to achieve eco-city planning, then camera will move to the bicycle rent shop and it surroundings to display its representation and location in this project. The display time of APS with the word numbers of text messages have been controlled to 100 WPM. We also convey the green transportation of eco-city planning concept by flying along the bicycle transportation network and playing simulation. The APS of STARS and its running result are shown *Figure 3-5*.

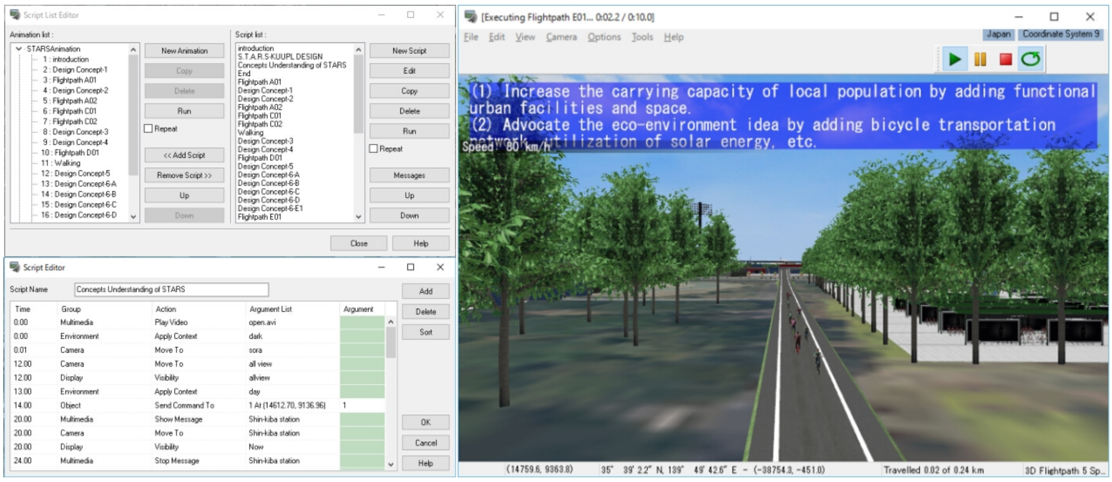


Figure 3-5. APS of STARS and its running result

3.3 Method and Validation

Quantitative and qualitative method is a mixed method which has come of age. To include only quantitative and qualitative methods falls short of the major approaches being used today in the social and human sciences (Creswell J. W., 2003). By using VR techniques urban designers can direct their qualitative studies toward quantitative researches. This can lead to elimination of much of the guesswork in urban design projects (Shakibamanesh A., 2014). Therefore, in this research, the virtual environment will be served as an experimental environment, and quantitative and qualitative method will be used to investigate how APS affect participants' cognition and evaluation of the design concepts.

3.3.1 *Participants*

60 participants of this study were students from Fuzhou University, among them, 27 were undergraduate students, and 33 were graduate students. Half of the participants who have the professional background (Architecture accounted for 46.67%, Urban Planning accounted for 50.00%, and Landscape Architecture accounted for 3.33%), and the other half participants without the professional background. 32 of the participants were male and 28 were female. The participants were assigned to three groups, and each group has 20 participants (10 have professional background and 10 without professional background). The participants' age ranged from 18 to 27 years, with an average age of 22.77 years.

As noted by Elmqvist, N. and Tsigas, P. (2006), even participants can freely navigation in a complex and large-scale 3D virtual environment; it is a difficult task to imposing a high cognitive load on them without any guidance. That is to say, only free navigation is not a good communication media for participants to clearly understand the designer's intentions, auxiliary guidance, such as APS, is essential. Thus, to validate the significant difference among script video (running result of APS), freely navigation, and freely navigation after script video, participants will be divided into three groups on average. The first group will run and view the APS; the second group will freely navigate in the virtual environment of the STARS, and the third group will run and view the APS as the beginning, then freely navigate in the virtual environment. *Figure 3-6* illustrates the flow chart of validation experiment.

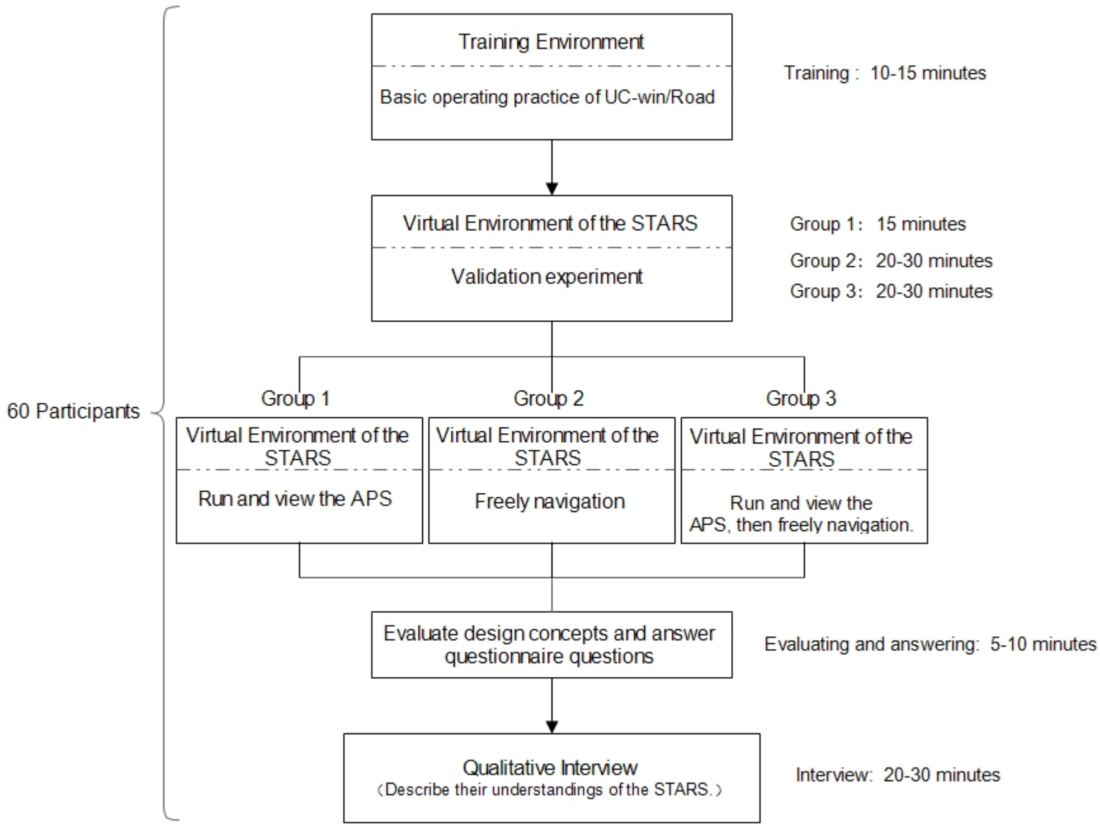


Figure 3-6 The flow chart of validation experiment

3.3.2 *Procedure*

To begin with, we introduced the basic operation of the software platform (UC-win/Road) to the participants so that they can run the APS and freely navigation in a training environment by using keyboard and mouse (In order to collect more accuracy experimental data, we used a simple virtual environment for training. The training environment is different from the virtual environment of the STARS.), the participants practiced in the training environment until they felt comfortable with the operation, typically for 10-15 minutes.

Then, three groups of participants were asked to explore the virtual environment, evaluate the design concepts and fill out the questionnaire questions. The duration of group 1 is controlled in approximately 15 minutes, and for group 2 and group 3, the duration of each exploration is controlled in approximately 20-30 minutes to make sure that participants can fully experience virtual environment and retain an effective memory of the design concepts after the exploration. The questionnaire was developed to identify the effect of APS as well as the participants' cognition and evaluation of the design concepts (level of satisfaction). It will construct by merging a number of standard questionnaires, with questions on a 1-5 Likert scale. The participants had to answer questions about the increase of carrying capacity for local population, advocate of eco-environment idea to the world, and the promotion of the charm of harbor metropolis, see *Figure 3-7(a)-(c)*.

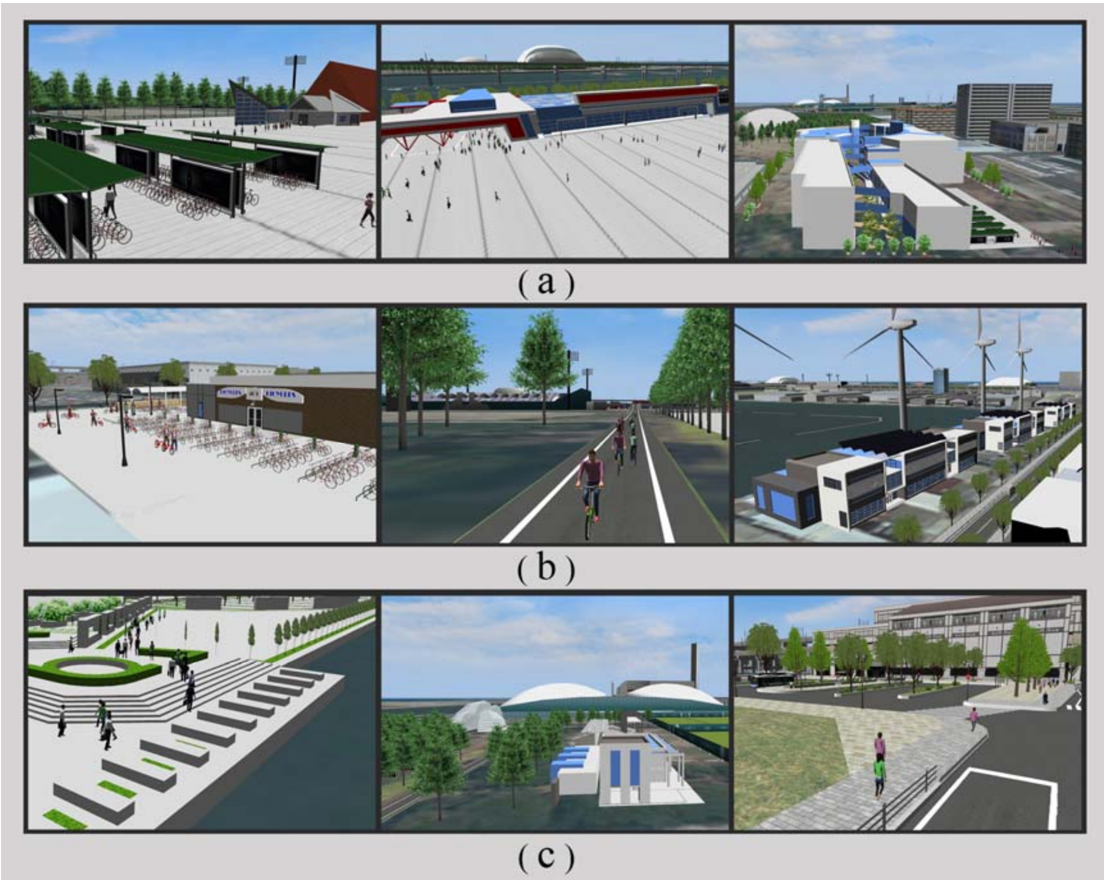


Figure 3-7 (a) Adding functional urban facilities and space; (b) Adding bicycle transportation network, utilization of solar energy and wind power; (c) Providing an attractive environment.

Finally, participants were asked to describe their understanding of the design alternatives, including design concepts, design goals, design partitions, the functions and features of design, and the defects of design, as the qualitative interview after they finished the questionnaire and have a rest. The interview was conducted one on one in order to further understand participants' urban design concepts understanding. During the interview, we recorded participants' answers using a digital voice recorder. Each interview took about 20-30 minutes.

3.4 Results of Questionnaires

3.4.1 *Reliability Analysis*

Reliability, also known as the degree of reliability, is the extent to which an assessment tool produces stable and consistent results. There are four general classes of reliability estimates, include inter-rater reliability, test-retest reliability, parallel-forms reliability and internal consistency reliability, each of which estimates reliability in a different way. Internal consistency reliability is usually measured with Cronbach's alpha, a statistic calculated from the pairwise correlations between items, and expressed as a number between 0 and 1. Internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test. Internal consistency should be determined before a test can be employed for research or examination purposes to ensure validity (Tavakol, M. et al., 2011). This research mainly uses internal consistency reliability estimates. All α values are shown in *Table 3-1*.

Table 3-1 Cronbach's alpha values for all scales.

Domain	Number of items in each Scale	Cronbach α
Cognition of the STARS	9	0.726
Evaluation of the STARS	7	0.820

Cronbach's alpha coefficient values above 0.700 are considered acceptable; values above 0.800 are preferable (Tan, C.L. et al., 2015). The results show that the Cronbach's alpha values of the cognition and evaluation of the STARS are above 0.70. Therefore, it is desirable to use tests with good measures of reliability, so as to ensure that the test score reflect a high internal consistency.

3.4.2 *Cognition of the STARS*

To analyze the data of the quantitative responses related to the cognition of STARS, we categorized the responses based on professional background and groups.

The groups were divided into script video, freely navigation, and freely navigation after script video participants, and the professional background was divided into participants who with professional background of architecture, urban planning, or landscape, and participants who without professional background. *Table 3-2* shows the means (M) and standard deviations (SD) for the questions related to the cognition of the STARS.

Table 3-2. Descriptive statistics of the cognition of STARS (M±SD).

Group	Professional background	*M*	*SD*
Script video	With	3.79	0.35
	Without	3.89	0.34
Freely navigation	With	3.37	0.44
	Without	3.59	0.21
Freely navigation after script video	With	3.96	0.41
	Without	4.26	0.47

The results indicate that the cognitive evaluation of freely navigation after script video was the highest, followed by the script video; freely navigation was the lowest group; meanwhile, participants who without professional background cognized the STARS as easier (with higher means) than those participants who with professional background.

Table 3-3. Analysis of variance (ANOVA) for the cognition of STARS.

Variable	*SS*	*df*	*MS*	*F*	*P*
Groups	3.960	2	1.980	14.087	0.000
Professional background	0.629	1	0.629	4.474	0.039

As shown in *Table 3-3*, there was very significant differences among the three groups [$F_{(2,\ 56)}$= 14.087, $P<0.001$], and there was significant differences between participants who with professional background and participants who without professional background [$F_{(1,\ 56)}$= 4.474, $P<0.05$].

Table 3-4. Multiple comparisons for the cognition of STARS.

(I) Group	(J) Group	*Mean Difference* (I-J)	*SD*	*P*
Script video	Freely navigation	0.36	0.12	0.004
	Freely navigation after script video	-0.27	0.12	0.028
Freely navigation	Script video	-0.36	0.12	0.004
	Freely navigation after script video	-0.63*	0.12	0.000
Freely navigation after script video	Script video	0.27	0.12	0.028
	Freely navigation	0.63*	0.12	0.000

* The mean difference is significant at the .05 level.

Thus, the follow-up analysis is conducted by multiple comparisons test. Table 4 shows the test results of multiple comparisons for the cognition of STARS. The results indicates that the significant differences of freely navigation after script video group was higher than script video group and freely navigation group, as well as the script video group was higher than the freely navigation group.

3.4.3 *Evaluation of the STARS*

To examine the effect of groups and professional background in the evaluation of design concepts, we analyzed the data of the quantitative responses related to the evaluation of design concepts through descriptive statistics and analysis of variance (ANOVA). *Table 3-5* shows the descriptive statistics of the evaluation of the STARS. The results indicate that the design concepts evaluation of freely navigation after script video was the highest, followed by the script video; freely navigation was the lowest group. The evaluation of participants who with professional background in script video group (the first group) and freely navigation group (the second group) was higher (with higher means) than the participants who without professional background; and the evaluation of participants who without professional background in freely navigation after script video group (the third group) was higher (with higher means) than the participants who with professional background.

Table 3-5. Descriptive statistics of the evaluation of the STARS (M±SD).

Group	Professional background	*M*	*SD*
Script video	With	4.17	0.38
	Without	4.03	0.40
Freely navigation	With	3.77	0.29
	Without	3.54	0.24
Freely navigation after script video	With	4.24	0.49
	Without	4.60	0.37

Table 3-6 shows the results of analysis of variance (ANOVA) for the evaluation of design concepts. The results indicate that there was very significant differences among the three groups [$F_{(2,\ 56)}$= 19.619, P <0.001]. However, there was no significant differences between participants who with professional background and without professional background [$F_{(1,\ 56)}$= 0.002,P >0.05]. This means that the three kinds of communication media effect on the design concepts understanding of the STARS obviously.

Table 3-6. Analysis of variance (ANOVA) for the evaluation of the STARS.

Variable	*SS*	*df*	*MS*	*F*	*P*
Groups	5.890	2	2.945	19.619	0.000
Professional background	0.000	1	0.000	0.002	0.962

To further obtain the detailed information among the three groups, the follow-up analysis is conducted by multiple comparisons test. *Table 3-7* shows the results of multiple comparisons for the evaluation of design concepts. The results indicates that the significant differences of freely navigation after script video group was higher than script video group and freely navigation group, as well as the script video group was higher than the freely navigation group.

Table 3-7. Multiple comparisons for the evaluation of the STARS.

(I) Group	(J) Group	*Mean Difference* (I-J)	*SD*	*P*
Script video	Freely navigation	0.443	0.123	0.001
	Freely navigation after script video	-0.321	0.123	0.011
Freely navigation	Script video	-0.443	0.123	0.001
	Freely navigation after script video	-0.764*	0.123	0.000
Freely navigation after script video	Script video	0.321	0.123	0.011
	Freely navigation	0.764*	0.123	0.000

* The mean difference is significant at the .05 level.

3.5 Results of Qualitative Interview

As stated by Turner (2010), interviews provide in-depth information pertaining to participants' experiences and viewpoints of a particular topic. In order to further understand participants' design concepts understanding, and validated whether VR integrated APS can improve participants' urban design concepts understanding, it is important to transform qualitative data into meaningful quantitative results (Srnka & Koeszegi, 2007).

Thus, to begin with, we analyzed and selected participants' answers from their records of design alternatives descriptions. Then, we summarized different indicators and calculated word frequencies per individual participant for each indicator. Furthermore, we counted the total frequency of each group in the case of participants who with professional background and without professional background. Finally, we used chi-square test to determine whether there is a significant difference between the expected frequencies and the observed frequencies in the indicator categories. The results are shown in *Table 3-8*.

Table 3-8. Frequency table of each group in different indicators from the design alternatives descriptions.

Group	Script video		Freely navigation		Freely navigation after script video		χ2	P
Professional background	With	Without	With	Without	With	Without		
Design concepts	35	44	31	17	60	40	6.433*	0.040
Design goals	30	25	26	14	31	17	1.488	0.475
Design partitions	47	43	40	20	54	36	3.192	0.203
Functions and features of design	65	72	66	59	67	68	0.755	0.686
Defects of design	10	5	12	5	13	8	0.320	0.852

* Significant at the 0.05.

The results indicate that participants evaluated the most indicators related to the functions and features of design alternatives. They repeatedly talked about the problems and advantages regarding reasonable design, clear goals, express clearly, eco-energy saving and sustainable development. As shown in Table 8, there was significant differences among the three groups in the understanding and evaluation of design concepts（$\chi 2=6.433$， $p=0.040<0.05$）. Nevertheless, there was no significant differences in the evaluation of design goals ($\chi 2=1.488$， $p=0.475>0.05$), design partitions ($\chi 2=3.192$， $p=0.203>0.05$), functions and features of design ($\chi 2=0.755$， $p=0.686>0.05$), and defects of design ($\chi 2=0.320$， $p=0.852>0.05$).

The boxplot of total frequencies of design concept expressions among three groups is shown in *Figure 3-8*. It is clear that these participants who with professional background in freely navigation after script video group refer to design concepts have most frequency, while these participants who without professional background in freely navigation group has least frequency.

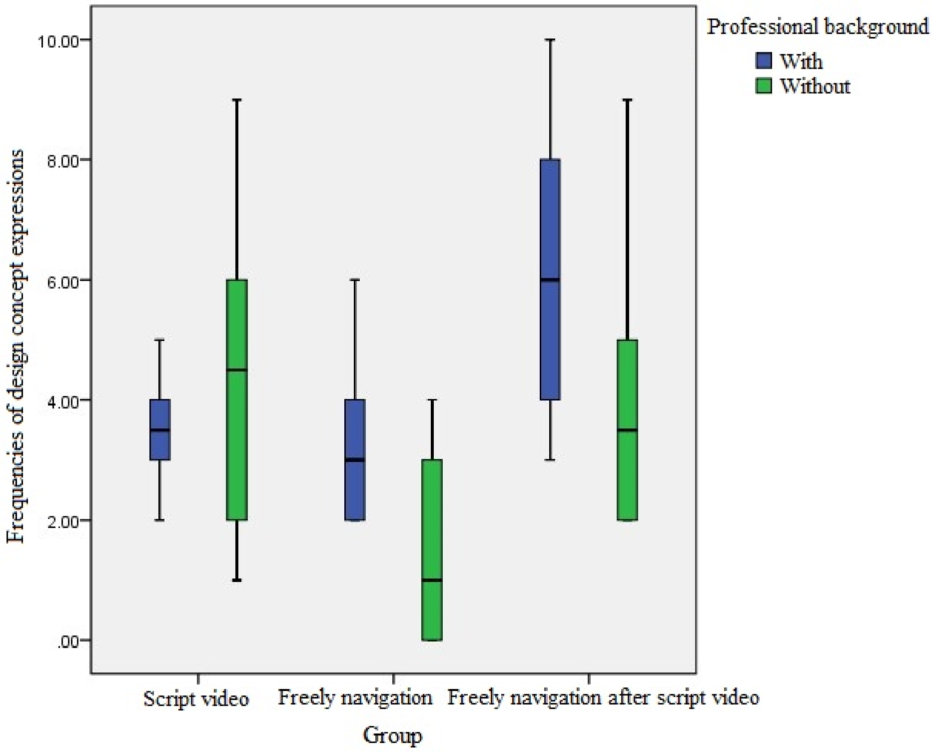


Figure 3-8 Boxplot of total frequencies of design concept expressions among the three groups

To sum up, the frequencies of design concept expressions in script video (the first group) and freely navigation after script video (the third group) is higher than freely navigation group (the second group). To a certain extent indicated that the script video affects participants' cognition and evaluation of the design concepts, and VR integrated APS can improve urban design concepts understanding.

3.6 Conclusion and Future Work in this Chapter

In this Chapter, we have presented how APS affect participants' cognition and evaluation of the STARS, and how to improve urban design concepts understanding through VR integrated APS technology. This study has focused on VR visualizations in the context of urban planning and design, where reasonable communication media is valuable in systematic understand the designer's intentions, and guide participants to further understand design concepts.

The results show that participants of freely navigation after script video group cognize the STARS and evaluate the STARS are the easiest (with the highest means), followed by the script video group; freely navigation was the lowest group; and there is very significant differences among the three groups. That is to say, freely navigation after script video is the best communication media for planners or designers to communicate with their users, and convey the design concepts to them.

Furthermore, the participants without professional background cognize the STARS as easier than those who with professional background, and there is significant differences. Nevertheless, participants with professional background in script video group (the first group) and freely navigation group (the second group) evaluate the STARS as easier than those who without professional background, while the participants without professional background in freely navigation after script video group (the third group) evaluate the design concepts as easier than those who with professional background; and there is no significant differences between participants who with professional background and without professional background. This further indicates that freely navigation after script video is an ideal communication media for planners or designers to convey design concepts to their users regardless of whether participants have professional background or not.

Additionally, the qualitative interview results also indicate that participants with professional background in freely navigation after script video group refer to design concepts have most frequency, this also means that the script video affect participants' cognition and evaluation of the design concepts.

In conclusion, the use of VR integrated APS technology is helpful to design concepts understanding of the STARS, due to it improves the efficiency of the understanding as well as to allow the interactivity with the virtual environment; and the application of VR integrated APS for improving urban design concepts understanding will brings new perspectives to urban design. However, the use of keyboard and mouse to explore the virtual environment in this study has limited the degrees-of-freedom of evaluate the design alternatives. Moreover, due to the complexity of 3D models, the use of SketchUP to create 3D models and export to "*.3d" format has yielded massive amounts of data. This affects not only the processing speed of the computer when importing to UC-win/Road, but also the execution of APS and the fluency of freely navigation during participants' cognition and evaluation process. Therefore, the future work will focus on the application of more degrees-of-freedom interface device (such as head/eye-tracking device) to enhance participants' interaction with virtual environment, as well as the solution of massive amounts of data in 3D modeling.

Chapter 4 : Cloud-based Virtual Reality Integrated Automatic Presentation Script for Understanding Urban Design Concepts in Consensus Process

In this Chapter, we contribute an application of cloud-based virtual reality (Cloud-based VR) integrated automatic presentation script (APS) for providing a broader participation way for users to understand urban design concepts in consensus process. We will take One Foundation Disaster Prevention Park in China as a case study, and build a Cloud-based VR platform to proposing design concepts, and create APS for auxiliary guiding users to understand the concepts of urban design and deliberate design alternatives in a design report meeting through the Internet.

4.1 Introduction

In the process of urban planning and design, a consensus process among a variety of users is required (Innes, J.E., 1996). A consensus can therefore be achieved through social and technical constructions which enable unfettered dialogue for understanding, discussing and deliberating (Burgess, H. and Brad, S., 2003; Poplin, A., 2013). Thus, the understanding of urban design concepts is the most important for achieving consensus. Traditional method of understanding, discussing and deliberating involves the use of committee meetings and application of visualization tools to present design alternatives and convey design concepts. An integration of geographic information systems (GISs) with public participatory tools represents one of the latest innovations in this area (Carver, S. et al., 2001; Brown, G. et al., 2011). However, these technologies and other map-based applications were frequently criticized as being too complex for the majority of potential users; they often experience difficulty understanding the design concepts (Steinmann, R. et al., 2005). Moreover, different visualization tools were used in different phases of the planning process, and the users need to gather in the same place and at a fixed scheduled time in different phases.

New forms of collaboration and technical solutions emerged during the Web 2.0 era (Poplin, A., 2012). For example, Google Maps, Google Earth and City Engine can be used by lay users and non-experts without intense training (Jiang, B., 2015; Singh, S. P. et al., 2014). As stated by Wu (2010), the Internet is undoubtedly the best way of sharing and exchanging urban planning information.

Shen and Kawakami (2010) developed an online visualization tool to attain consensus on townscape design within local planning committees. In this system, participants can select design elements to visualize different alternatives in real time, and experience dynamic scenes of generated virtual townscapes in the VRML world. In their case study, this visualization tool were successful in sharing a common image, and participants were motivated to become involved in deliberation on various aspects of planning and design during committee meetings, and participants can explore from the Internet without spatial and temporal limitations.

Moreover, Gordon, E. et al (2011) proposed that new digital immersive technologies may help users to understand design concepts in consensus process and move the whole project towards “collaborative rationality”. In order to improve the understanding of users with respect to the planning concepts for reaching a consensus, Shen, Z.J., Kawakami, M. and Kishimoto, K. (2012) attempted to support planners in presenting their planning concepts during virtual meetings using web-based multimedia materials. Additionally, Vemuri, K., Poplin, A. and Monachesi, P. (2014) developed a game that aims to support design concepts understanding in a complex urban planning situation. Their study case was taken from India and focused on a very diverse slum area Dharavi. The complexity emerges due to the variety of different stakeholders’ interests and their specific visions about how this area could be developed and renewed.

Despite there is a strong hierarchical administrative system in China, it is found that the consensus process did not work well, due to a lack of users interaction interface and efficient information exchange during the top-down planning process, and the difficulties in specifying detailed planning contents. The findings echo the recent experiences in Western countries that emphasize the needs of interaction, negotiation and consensus building in the planning process (Luo, X.L. et al., 2008). VR system has been used as a tool for understanding design concepts and negotiating design alternatives, to gain consensus (Lorentzen, T. et al, 2009), and the Internet provides informational services through various devices, it has evolved from an information distribution tool into a network for informational interaction (Deng, Z. et al., 2015).

So, the combination of VR technology and the Internet will become a feature of the next era, and provided a broader way for improving urban design concepts understanding in consensus process. However, most online VR platforms have the limitations of data compression, hardware performance, network bandwidth and costs in currently. Moreover, the Clients need to download the virtual environment and avatar models from the Sever, and then held on the local computer (Smith, A. et al., 1998). Thus, the virtual environment need to be compromised with several spatial entities and events , and these entities and events ought to supply a environment in which accommodate human activities such as navigation, interaction and communication.

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell, P. et al., 2011). There is no exact definition of Cloud-based VR currently. From a technical point of view, Cloud-based VR is a new technical which combine cloud computing with VR, and provide synchronous transmission and interactive services for large amounts of data, such as video, 3D model data and virtual scene. In consensus process, users can employ Cloud-based VR system in a participative process and the Cloud-based VR technology can serve as a software tool for planning to present design concepts, and for users to share designs and communicate with each other to reach mutual goals through the Internet (Shen, Z.J. et al., 2014).

To address this, in this Chapter, we will focus on how to improving urban design concepts understanding of One Foundation Disaster Prevention Park in consensus process, through using Cloud-based VR integrated APS. We will build a Cloud-based VR platform to proposing design alternatives, and create APS for auxiliary guiding users to understand the concepts of urban design and deliberate the design alternatives through the Internet.

The structure of this Chapter is as follows. In Section 2, we will discuss the research approach in this study. In Section 3, we will present how to build a Cloud-based VR platform that allow users access the virtual environment to understanding design concepts and deliberating design alternatives through the Internet. In Section 4, we will take a Disaster Prevention Park as a case study, and validate the effectiveness of Cloud-based VR platform in improving urban design concepts understand in consensus process. Finally, in Section 5, we will complete the research with conclusion and future work.

4.2 Virtual Environment Design Approach

Virtual design tools such as 3D modeling and simulation are becoming increasingly sophisticated and integrated. We believe their potential is best realized when they feed into an advanced design process that brings to life the interactions between designers and between each design element. So, in order to promote the use of Cloud-based VR technology for improving urban design concepts understanding in consensus process, we present a case study of a Disaster Prevention Park planning and design project in southwest of China. Our study did not consider details on the park location; we made the detailed planning in function orientation, architectural design and infrastructure planning of the park. We created 3D models according to the design concepts and design alternatives in a virtual environment.

In this research, we build a Cloud-based VR platform to proposing design alternatives, and create APS for auxiliary guiding users to understand the concepts of urban design in design alternatives report meeting, so that the participants, including the users and the designers, can share common virtual environment, discuss and solve planning and design problem through the Internet. The designers can easily modify the design alternatives in the virtual environment through calling 3D model database to insert 3D models, and the users can compare different design alternatives as well as clearly understand the design concepts and reach a consensus in design alternatives eventually.

4.2.1 *Basic Environment Design*

In virtual environment design, UC-win/Road is a software platform that is used to generate and present a visible and interactive 3D environment. The software can be used for various applications such as urban planning, traffic simulations, and construction demonstrations. The extensive features and visual options allow the formation of detailed virtual demonstrations can be presented and manipulated in real time.

The work of virtual environment design comprises three components. First, we will import the terrain data and street map information to create terrain for virtual environment so that the design can be carried out in this land. In this step, we will not consider details on the park location, because the users did not get the right to use this land from the government, they are negotiating with the government by now. Second, we will use SketchUp to create 3D models, and export to "*.3d" format that can easy be imported to UC-win/Road as the design element of 3D model database for virtual environment design. As a good 3D modelling software, SketchUp successfully unites principles of line drawing with 3D for a bare-bones program that lets designers produce surprisingly complex 3D artwork. Third, we will import the 3D models, including building models, landscape models, infrastructure models, and adjust the visual options such as weather and sun position, and set human agents move through pre-defined routes, to design the virtual environment.

4.2.2 *Design Concepts expression*

In a sense, the virtual environment will be used as the basic environment to represent the design alternatives. The virtual environment can be observed through the software's interface which called "VR-Cloud Client" on the desktop PC of each client. Free navigation in real-time allows the client users to observe the 3D virtual environment from any location and angle. Simulation scenarios will be created that help client users to understand the different functions of Disaster Prevention Park in normal time and in disaster time. APS will be designed to express the design concepts and more clearly. For basic simulations, people act as intelligent agents and obey the behavioral characteristics, and vehicles also act as the intelligent agents and obey traffic rules. When one people or one car is controlled by the mouse or keyboard of client computer, client users can walk or drive freely through a road network or scenario, and a responsive virtual environment enhances the user's sense of presence.

The hearts of consensus are understandings, discussing and deliberating (Susskind, L. et al., 1999). Thus, we will configure the Cloud Server that users can explore, understand and evaluate the design concepts via the mouse and keyboard operation, discuss and solve some planning and design problems through the Internet, and achieve consensus on design alternatives.

4.3 Cloud-based Virtual Reality Platform

Cloud-based VR is based on UC-win/Road (VR-Cloud Edition) and is used to share 3D virtual content over the network, whether on an office LAN or on the Internet. Clients who access the content are able to navigate through the virtual environment using basic UC-win/Road navigation modes (free, travel, driving and so on). The global parameters of the virtual environment such as the time of the day and the weather can also be configured by the clients. Cloud-based VR also provides cloud-based collaboration features. Users can create graphical annotations at any location in the virtual environment to provide better understanding of the modelled environment. Clients can also discuss using 3D forums. They can create new discussions or reply to discussion of other users.

4.3.1 *The Framework of Cloud-based Virtual Reality*

The framework of Cloud-based VR Platform is shown in *Figure 4-1*. This platform has a central "Server" which contains the data for the virtual environment, a range of avatar models and also acts as the communications hub for understanding and online discussion. The individual participants have a "Client" on their local computer which provides the tools to view and move through the virtual environment and to also discuss or communicate via a dialogue box in which one would type comments visible to other users. "Client" software can be downloading from the website by free, and connects with the "Server" through the Internet.

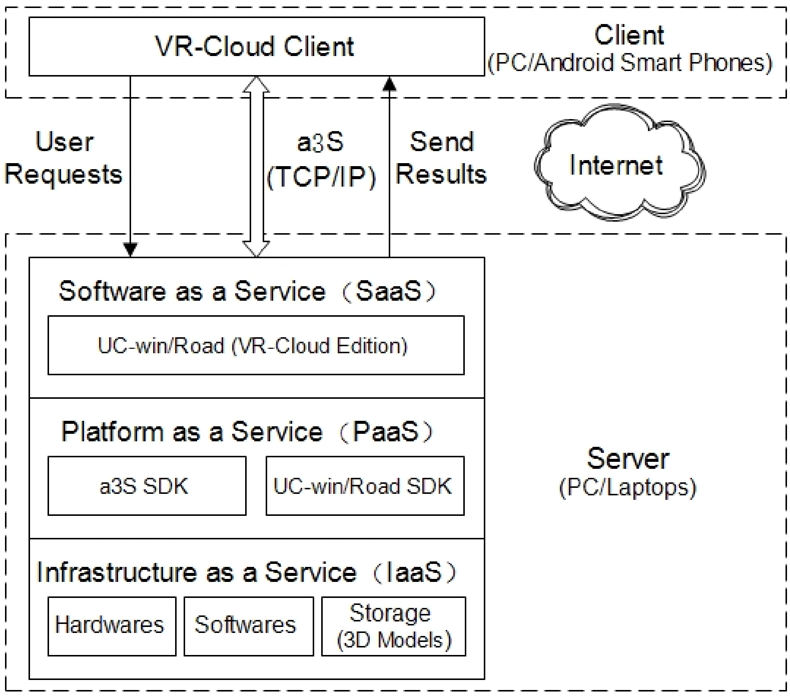


Figure 4-1. The framework of Cloud-based VR Platform.

In this framework, anything as a Server (a3S) is multimedia cloud technology that allows high quality video and audio to be supported and streamed between the server and client application, as well as the high-speed transmission of large-capacity data

(Ito, Y. et al., 2013). a3S can connect the core parts controlling TCP protocols, the server and each client. It also controls commands, and manages the synchronization and authorization system.

4.3.2 *The Working Process of Cloud Server*

The working process of Cloud Server is shown in *Figure 4-2*, there are six steps in this process, including load terrain data and street map, create (or modify) and import 3D models for the design alternatives, create a virtual environment (VE), create simulation scenarios and APS, explore or evaluate the design and configure the Cloud Server.

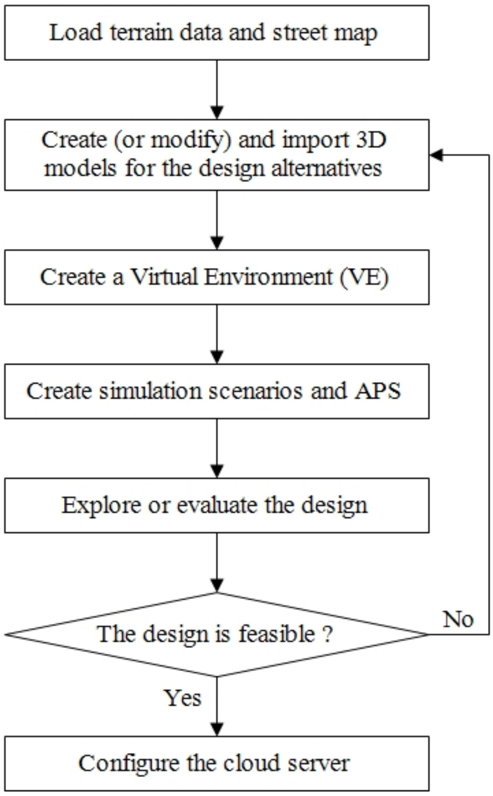


Figure 4-2. The working process of Cloud Server.

According to the requirements of design program, One Foundation (namely the owner) wanted to construct a disaster prevention part inside the Bei San Huan Road in Chengdu city of Sichuan Province. Furthermore, some scholars have pointed out the problem of the disaster prevention park system in Chengdu city after the occurrence of the 5.12 Wenchuan earthquake, and analyzed the actual situation of Chengdu city with the urban population density distribution, transport distribution and disaster prevention park, probed into the planning and design of the city's disaster prevention park, they believed that the new disaster prevention park can be considered inside the

Bei San Huan Road (Tian Y. et al., 2010). Therefore, we load the terrain data of southwest of China and import the street map of the inside of Bei San Huan Road in Chengdu city, as shown in *Figure 4-3*.

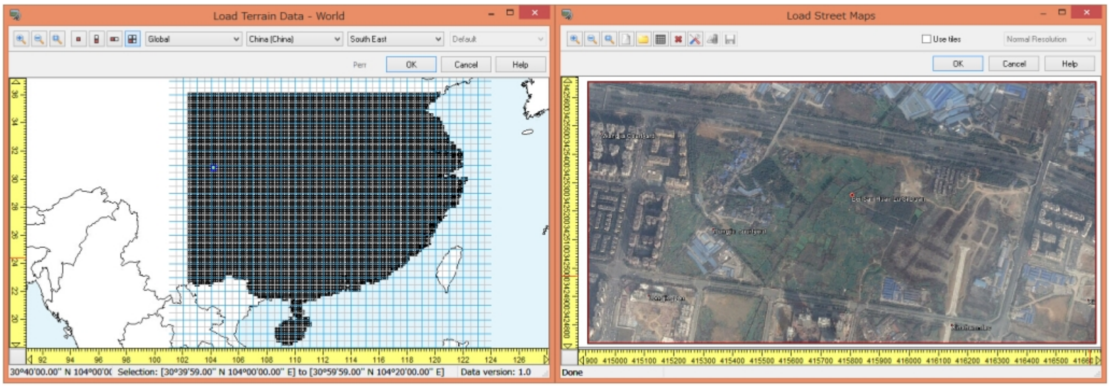


Figure 4-3. Load terrain data and street map.

In order to create a virtual environment, the basic work is to creating 3D models for the design alternatives. Currently, there are many kinds of modelling software, such as 3DS Max, SketchUp, Maya, which are often used in urban planning and design. Due to the easy operating and compatibility of SketchUp, we used SketchUp Pro 2015 to create different kinds of 3D models and import to UC-win/Road (VR-Cloud Edition) as the 3D model database for creating the virtual environment. We created building models, landscape models, and infrastructure models, such as tents, communications facilities, water tank, photovoltaic module, which are necessary in the disaster times. *Figure 4-4* shows one of landscape model which was created by SketchUp Pro 2015 in the disaster prevention park of One Foundation, and *Figure 4-5* shows the virtual environment of design alternatives after imported the 3D models.

Figure 4-4. 3D modelling in SketchUp Pro 2015.

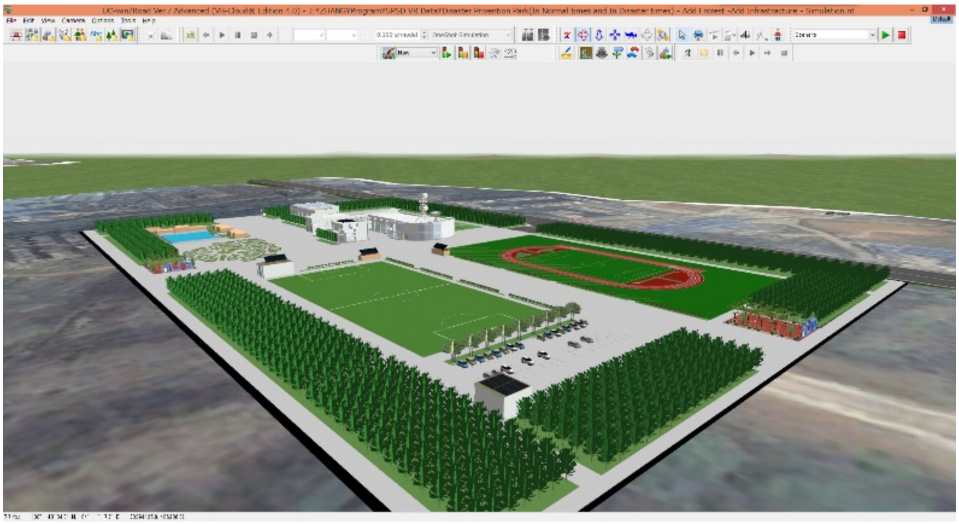


Figure 4-5. The virtual environment of design alternatives.

Simulation scenarios will provide a dynamic virtual environment for online discussion so that users can better understand the design alternatives. In this paper, we try to set the human behaviors connected with the function of Disaster Prevention Park, in normal times and in disaster times, through setting scripts. *Figure 4-6* shows the simulation scenario of playground in normal times.

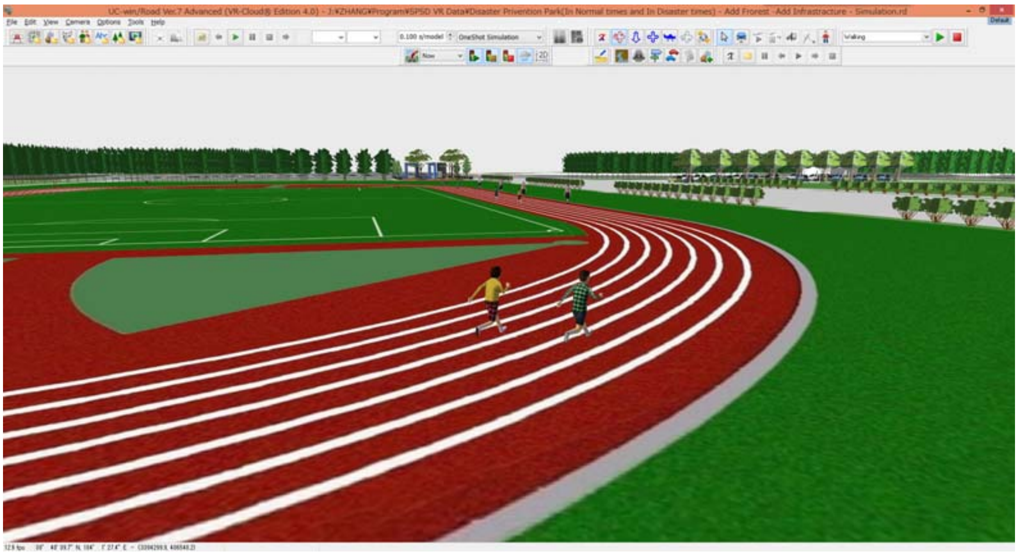


Figure 4-6. Simulation scenario of playground in normal times.

4.4 Case Study: Planning and Design of One Foundation Disaster Prevention Park

As an important part of sustainable urban development, disaster prevention and mitigation is a significant guarantee to achieve sustainable economic and social development. One Foundation is a representative of NGO (Non-Governmental

Organization), which plays an important role in disaster prevention and mitigation in China. However, due to the lake of an independent command system, as well as a clear disaster management system in disaster times, resulting in some problems, such as confusion of personnel management and low efficiency of relief supplies distribution, when the NGO responses to natural disasters. Moreover, there are no permanent establishments for disaster management; it is difficult for the NGO to carry out disaster prevention education and volunteer training work in normal times, as the "supplementary" of government. Therefore, One Foundation (namely the users) wanted to build a disaster prevention park which was integrated the functions of education and training, earthquake experience, emergency command, evacuation and rescue, in Chengdu city of China.

4.4.1 *Functional Orientation of Disaster Prevention Park*

One Foundation Disaster Prevention Park covers an area of 160 acres, its functional orientation drawing on the experience of International, especially the construction experience of Disaster Prevention Park in Japan. The functional orientation of Disaster Prevention Park is divided into normal times' function and disaster times' function. In normal times, the park has two main functions: social culture function and environmental protection; and social culture function including rest and recreation, spiritual civilization and disaster prevention education, such as outdoor recreation, sports, dissemination of scientific knowledge, disaster prevention training and so on; environmental protection mainly embodied in maintaining ecological balance and beautify the urban landscapes, such as erosion control, fresh air, relieve heat island effect and so on. In disaster times, due to a large area of public open space, the park can be used as emergency shelter and fire greenbelt, as well as emergency command center, rescue helicopter landing sites, relief supplies distributing center, emergency medical service location and the residence of relief workers. The functional orientation and supporting facilities of One Foundation Disaster Prevention Park were shown in *Table 4-1*.

Table 4-1. The functional orientation and supporting facilities of Disaster Prevention Park.

Time	Main function	Supporting facilities
In normal times	Rest and recreation	Playground, leisure square, landscape and make green by planting trees, flowers, etc.
	Education and training	Classrooms, relief exhibition hall, disaster prevention training center, earthquake experience room, reading room, etc.
	Daily operations	The park management office, relief product exhibition hall, sales department, catering center, accommodation center, etc.
In disaster times	Emergency command center	Information summary room, commander room, lounge, office equipment, communications equipment, emergency medical service location, etc.
	Emergency Shelters	Emergency tent dormitory, emergency water supply facilities, emergency toilets and bathing facilities, emergency power supply facilities, emergency sewage system, etc.
	The residence of relief workers and relief supplies distributing center	Relief supplies reserve and distribution center, parking, rescue helicopter landing sites, accommodation center, etc.

4.4.2 *Design Concepts Understanding and Design Alternatives Evaluating in Consensus Process*

In order to validate the effectiveness of Cloud-based VR platform in improving urban design concepts understanding in consensus, we have applied this platform to express the design alternatives and design concepts in design alternatives report meeting, and tried to convey our design concepts to the users (One Foundation) and other people who was interested in this project. We discussed and modified the design alternatives in a virtual environment based on Cloud-based VR platform, and eventually reached a consensus on the design alternatives. *Figure 4-7* showed the working process for reaching a consensus in design report meeting.

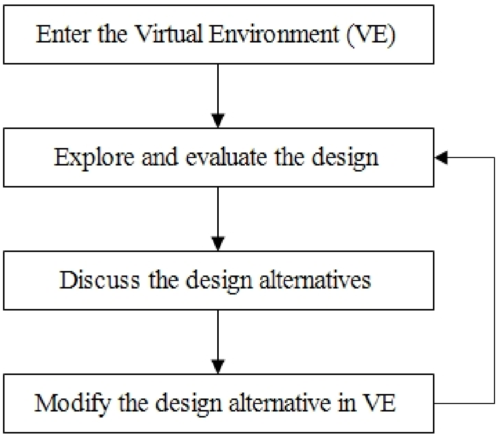


Figure 4-7. The working process for reaching a consensus building in design report meeting.

The users can enter the virtual environment through VR-Cloud Client which is client software that can be downloaded from the website by free, and connects with the Cloud Server through the Internet. Users can input the server's IP address to connect with the Cloud Server, and then enter the virtual environment, as is shown in *Figure 4-8*.

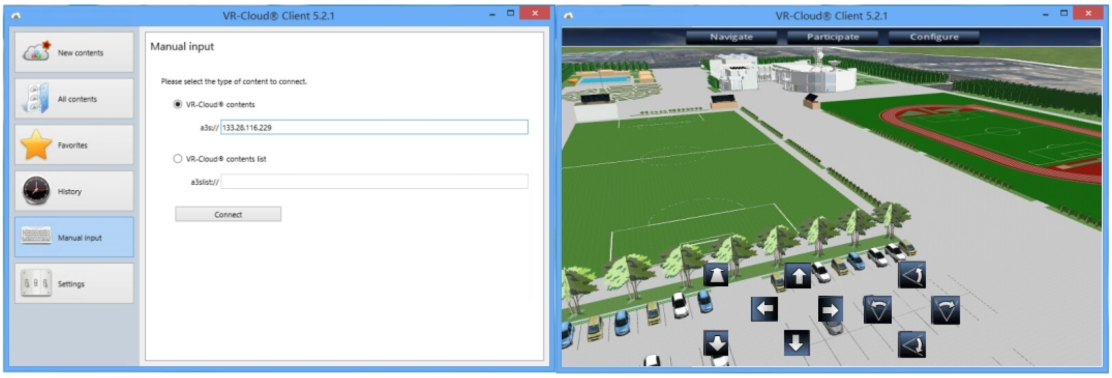


Figure 4-8. Enter the virtual environment.

In the design alternatives report meeting, we discussed the Disaster Prevention Park from functional orientation to overall layout, to infrastructure planning with the users. In this Chapter, we focused on the architectural design of Disaster Management Center and the infrastructure planning of the park since the two parts are the core content of the construction of Disaster Prevention Park, and the following section will focus on these two aspects to conduct discussion.

4.4.2.1 Architectural Design of Disaster Management Center

Based on the functional orientation of One Foundation Disaster Prevention Park, and combined with the construction experience of Disaster Prevention Park in Japan, the Disaster Management Center responsible for disaster prevention education, training and daily operations in normal times, and in disaster times, its main function are emergency shelter and fire greenbelt, as well as emergency command center, rescue helicopter landing sites, relief supplies distributing center, emergency medical service location and the residence of relief workers and so on. According to the “Design Code of Office Building” (JGJ67-2006), the average office space per person should be not less than $4m^2$ (MOC, 2006), and the “Emergency shelter for earthquake disasters--site and its facilities” (GB 21734-2008) requires the construction area of Disaster Management Center of Disaster Prevention Park should be more than 2000m2 (SAC, 2008). Therefore, in the first alternatives of Disaster Management Center architectural design, we considered the building of Disaster Management Center consists of two parts: the main building and the Disaster Experience Hall, and with a total construction area of $5000m^2$. Since the Disaster Experience Hall needs MTS shake table to supports seismic experience, and in order to avoid affect the main building; it is important to separate the two parts, and one part as a single building; the Disaster Experience Hall has two stories, and the main building has three stories.

The users considered about their actual needs of disaster prevention in southwest of China, and discussed the architectural design of Disaster Management Center in detail with us, and put forward some suggestions. First of all, taking into account of the reserve and distribution of relief supplies, it is best to separate the Relief Supplies Reserve and Distribution Center from the main building. What’s more, the height of all buildings should not exceed 8 meters or two stories, in order to better achieve the purpose of disaster prevention. Last but not least, besides the Disaster Management Center, there are Disaster Prevention Schools in the locality, and they have the formal educations, so the Disaster Management Center should take full account the function of rescue training.

During the discussion, we modified the first alternatives in the virtual environment combined with the suggestions of the users, and proposed the second alternatives. The functional planning of Disaster Management Center in two alternatives and the 3D effect drawing of Disaster Management Center in two alternatives were as shown in *Figure 4-9* and *Figure 4-10* respectively, and we reached a consensus on the second alternatives eventually.

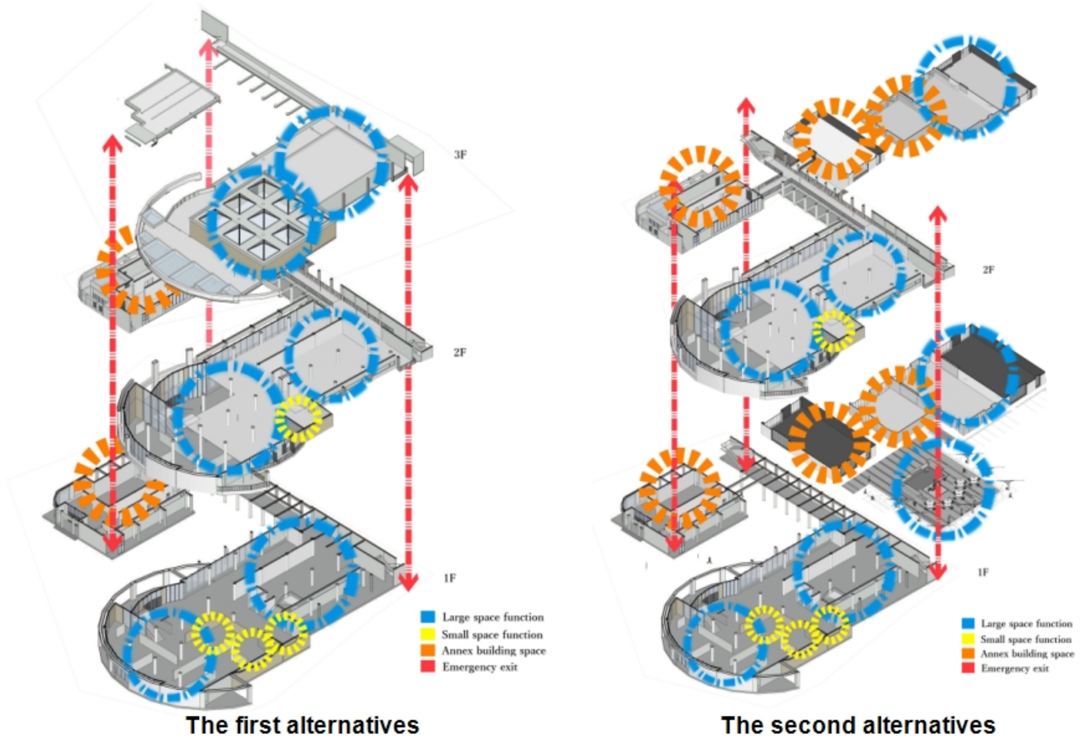


Figure 4-9. Functional planning of Disaster Management Center in two alternatives

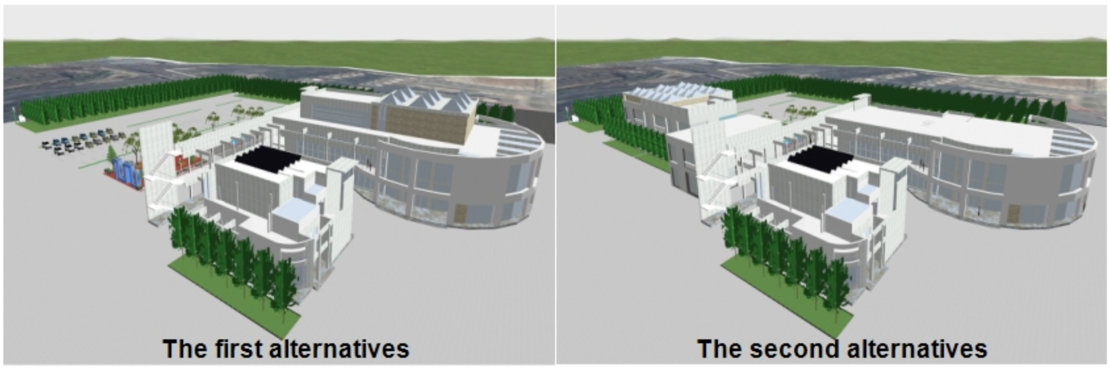
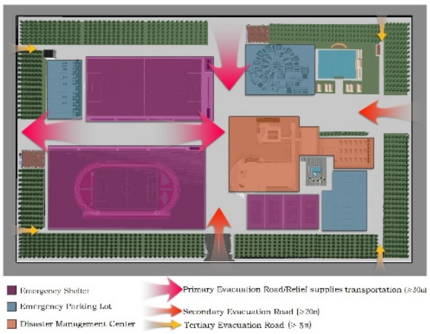
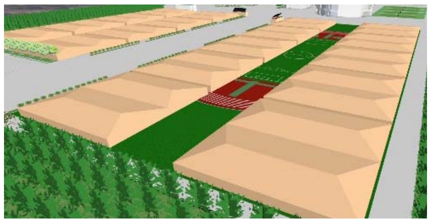
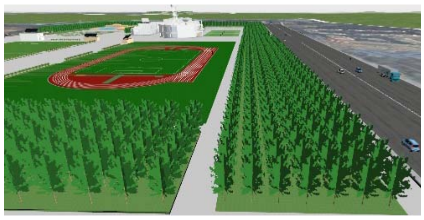
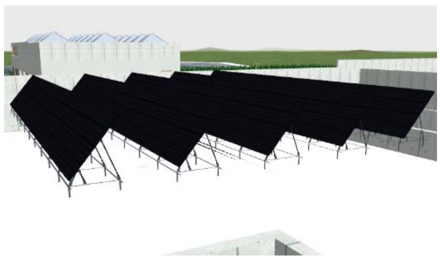
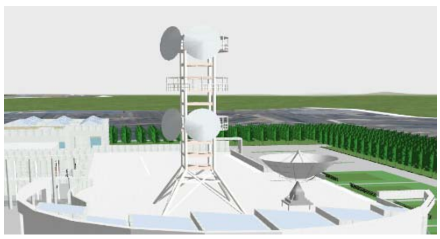


Figure 4-10. 3D effect drawing of Disaster Management Center in two alternatives

4.4.2.2 Infrastructures planning of Disaster Prevention Park

The infrastructures of the Disaster Prevention Park include evacuation road, emergency shelter, greenbelt, emergency water supply, emergency power supply, emergency communication and so on. We planning and design the infrastructures of One Foundation Disaster Prevention Park based on the standard of "Emergency shelter for earthquake disasters-site and its facilities" in China (GB 21734-2008), as shown in *Table 4-2*.

Table 4-2. Infrastructures planning of One Foundation Disaster Prevention Park.

<table>
<tr><th>Infrastructures</th><th>Main functions and requirements</th><th>3D presentation in virtual environment</th></tr>
<tr><td>Evacuation Road</td><td>Evacuation road connection with all emergency shelters and the Disaster Management Center, to ensure the roads unblocked and keep its effective evacuation and relief supplies transportation. The evacuation roads around the emergency shelters should be more than 2 ways, and the width should be more than 5m.</td><td>
</td></tr>
<tr><td>Emergency Shelter</td><td>Emergency Shelter is the place for people to live temporarily when they cannot live in their previous residence, and the average area per person in emergency shelter should be more than 2㎡.</td><td></td></tr>
<tr><td>Greenbelt</td><td>Greenbelt is used for isolating traffic noise, maintaining ecological balance and beautifies the urban landscapes in normal times, while used for isolating fire from the secondary disaster after earthquake. It around the park and the width is 25m.</td><td></td></tr>
<tr><td>Emergency Water Supply</td><td>Emergency water supply including swimming pool and water tank. In disaster times, the water stored in swimming pool can be used for bathing, washing and flushing toilets, while the water tank can provide drinking water for the first period that people can survive in three days.</td><td>
</td></tr>
<tr><td>Emergency Power Supply</td><td>Emergency power supply including solar photovoltaic system and minitype dynamotor, that can provide power for living, medical treatment and communication in disaster times.</td><td></td></tr>
<tr><td>Emergency Communication</td><td>Emergency communication can be used for contact with the outside world when wireline, cell phones and other conventional means of communications fail in disaster times.</td><td></td></tr>
</table>

In the virtual environment, the users viewed the design alternatives according to our design concept, and discussed the infrastructures planning with us enthusiastically. In the beginning of this design, considered there are toilets and bathing facilities near the swimming pool, where is located in the northwest of the park, and inside the Disaster Management Center; we had not increased emergency toilets and bathing facilities. The users believed that besides the refugees, there may be the other local people who come to use toilets and bathing facilities due to the taps run dry after earthquake. So they advised to increase emergency toilets and bathing facilities in infrastructure planning, and these facilities will not affect the park in normal times as far as possible.

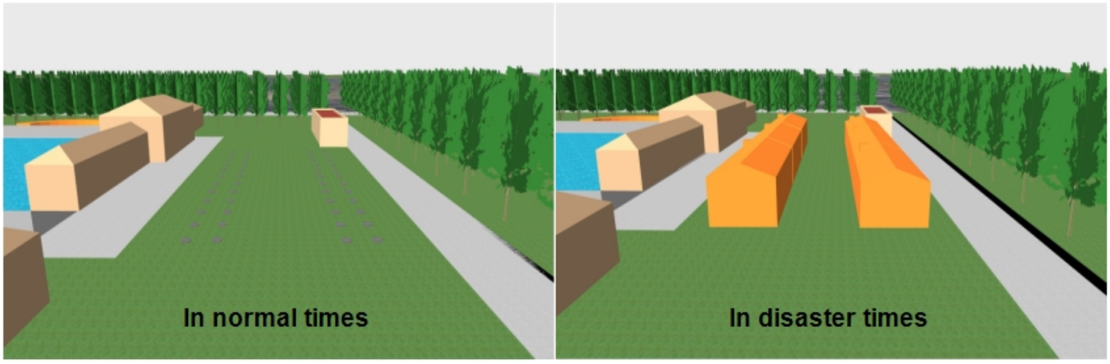


Figure 4-11. Emergency toilets and bathing facilities

In order not to affect the landscape of park in normal times, we considered using septic tank under the ground, then covered lawn and reserved sewage covers on the ground. So it is the green lawn in normal times, and it is easy to change as the emergency toilets and bathing facilities when set up mobile house or tent in disaster times. *Figure 4-11* shows the planning of emergency toilets and bathing facilities in Disaster Prevention Park.

4.5 Conclusion in this Chapter

VR combine with cloud computing are an advanced information technology, and its application to urban planning and design is a challenging topic. The Cloud-based VR integrated with APS we proposed in this Chapter can clearly express the design alternatives and design concepts, effectively solve the problem of miscommunication in the process of design concepts transfer and design alternatives discussion in urban planning and design, and eventually reach a consensus on the design concepts and design alternatives, so that promoting the feasibility and real-time of urban design, saving discussion time of design project, and improving design efficiency.

However, there are still some deficiencies exist in Cloud-based VR platform. For example, although it can directly edit 3D models in the virtual environment, its editing functions are just scaling, rotating and other simple operation; as for complex editors such as structural adjustment, material replacement, it need to be edited in SketchUp and then import to UC-win/Road. Therefore, the future work will focus on improving the functions of 3D model editing in the virtual environment.

Chapter 5 : Conclusion

In this PhD research, we integrated Cloud-based VR and APS to provide a broader participation platform to create a common virtual scene for improving users' urban design concepts understanding in consensus process. Through this platform, the users can clearly understand the design concepts and engage with the discussion of design concepts. This research is useful to improve users' urban design concepts understanding, and eventually reach a consensus on design concepts and design alternatives. As a research for planning support system, we took three new techniques of VR application in urban planning and design as our focus, respectively they are: 3D laser scanning, APS, and Cloud-based VR.

It is well known that consensus building is a dynamic and iterative process composed by several rounds where the individuals express, discuss, and modify their opinions until to get an agreement. In the consensus reaching process, the Cloud-based VR platform plays an important role in transferring knowledge and creating a basis for debate, while 3D model is a vital part as communication media in this platform. The creation of accurate and realistic 3D models that can be used in virtual environment still remains a challenging problem in spatial information science field, including urban planning and design.

To achieve this problem, this research using 3D laser scanning technology to collect 3D point clouds of physical objects for historic building mapping and modeling, then compared the results with the traditional method in detailed component mapping. The results shown that 3D laser scanning technology is an accurate and efficient method to obtain 3D data for mapping which can be used to create accurate and realistic 3D models, and as a data source for APS. Meanwhile, the collected data can also be used in VR presentation, and as an important basic data for the research of architectural history and theory.

Additionally, since the VR serves as a consensus building tool and as a presentation tool for a design project in currently, how to enhance user's cognition and evaluation of urban design concepts through effective communication media and eventually improving their urban design concepts understanding are the problems troubling the urban designers for a long time. To address this, we conducted a validation experiment with 60 participants to examine how different communication media affect participants' cognition and evaluation of design concepts. The results indicated that participants of freely navigation after script video group (namely VR integrated APS group) cognize and evaluate the design concepts easier than script video group, while script video group cognize and evaluate the design concepts easier than freely navigation group; and there is very significant difference among the three groups. That is to say, freely navigation after script video is the best communication media for planners or designers to convey design concepts and improve their users' urban design concepts understanding. Moreover, an interesting finding was that participants without professional background cognize the design concepts as easier than those who with professional background, and there is significant difference. This further indicated that freely navigation after script video is an ideal communication media for planners or designers to convey design concepts and improve their users' urban design concepts understanding regardless of whether users have professional background or not.

Finally, as cloud computing is becoming the most reliable and efficient way to share hardware, software and platform in form of services via Internet, the combination of cloud computing with virtual reality (Cloud-based VR) will provide an advanced means to assist with virtual environment exploration and consensus building. Thus, this research took One Foundation Disaster Prevention Park in southwest of China as a case study, and tried to demonstrate how to reaching consensus on design alternatives discussion remotely. We built a virtual environment and set simulation scenarios to proposing design alternatives, then created APS for auxiliary guiding users to understand the design concepts. After that, a Cloud-based VR platform was built for communicating and deliberating through the Internet. The application results demonstrated that the Cloud-based VR platform integrated APS we proposed in this research can be served as an information exchange platform for planners or designers to clearly express design alternatives and design concepts, as well as to provide an interaction environment for users to further explore design alternatives, and eventually reach a consensus.

Overall, the three new techniques we focused in this PhD research are useful for data collection, mapping and modeling, improving users' urban design concepts understanding, and eventually reaching a consensus in design alternatives. Through the Cloud-based VR integrated APS technology, planners or designers can realistically present and successfully develop good design decisions that help create consensus among the many people involved, not only to aid the professional participants but also the layperson, so that promoting the feasibility and real-time of urban design, saving discussion time of design project, and improving design efficiency. However, there still are a few limitations in this stage: To begin with, the 3D modeling method directly through point clouds remains relies on manual operation, thus time-consuming, labor-consuming and inaccuracy are inevitable. Then, the use of keyboard and mouse to explore the virtual environment in this research has limited the degrees-of-freedom to evaluate the design concepts. Next, the model editing capabilities of Cloud-based VR platform are just scaling, rotating and other simple operation; as for complex editors such as structural adjustment, material replacement, it need to be edited in 3D modeling software in advance, then import to the platform.

For future work, software technology capable of automatic fitting point clouds and generating 3D model needs further development and improvement. Moreover, more degrees-of-freedom interface devices (such as head/eye-tracking device) should be considered in future applications to enhance participants' interaction with virtual environment. Last but not the least, more comprehensive model editing capabilities of Cloud-based VR platform should be developed to conveniently modify or replace 3D models of the design alternatives during the discussion process, so that provide an advanced and efficient platform for urban planning and design.

Publications:

Zhang, Y., Zhang, Y., Shen, Z., Nishino, T. and Chen, X. (2015). "3D Laser Scanning Technology-based Historic Building Mapping for Historic Preservation: A Case Study of Shang Shu Di in Fujian Province, China", *International review for spatial planning and sustainable development*, Vol.3 No.2 (2015), pp. 53-67, ISSN: 2187-3666 (online), Copyright@SPSD Press from 2010, SPSD Press, Kanazawa. (Scopus) Doi: http://dx.doi.org/10.14246/irspsd.3.2_53.

Zhang, Y., Shen, Z., Wang, K., Kobayashi, F. and Lin, X. (2015). " Cloud-based Virtual Reality for Consensus-Building in Urban Planning and Design: A Case Study of One Foundation Disaster Prevention Park in China", *Proceeding of International Conference 2015 on Spatial Planning and Sustainable Development* , Taipei University of Technology, Taipei, pp. 764-782, 7 Aug.-9 Aug. 2015.

Zhang, Y., Shen, Z., Wang, K., Kobayashi, F. and Lin, X. (2016). " Cloud-based Virtual Reality Integrated Automatic Presentation Script for Understanding Urban Design Concepts in Consensus Process", *International review for spatial planning and sustainable development*, 16 pages, ISSN: 2187-3666 (online). (Accepted, Scopus)

Zhang, Y., Shen, Z., Nishino, T. and Sugihara, K. (2016). "Virtual Simulation Integrated Automatic Presentation Script for Improving Concepts Understanding of Sustainable Taches and Reactivate Space - A Case Study in Tatsumi Region of Tokyo Bay Zone, Japan", *Computers, Environment and Urban Systems*, 17 pages (under preparation).

Zhang, Y., Zhang, Y. (2013). "An Embedded-technology-based Security Monitoring System Design of Intelligent Building", *Sensors & Transducers*, Vol. 156 No.9 (2013), pp. 89-94, ISSN: 1726-5479, International Frequency Sensor Association (IFSA), Spain. (EI Journal) Doi: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.405.9765

Appendix:

A. Design Concepts of the STARS

B. Questionnaires and Interviews

No.____________

Questionnaires and Interviews about VR Integrated APS for Urban Design Concepts Understanding

Note:

Please fill out your basic information and tick the best answer with "✓" that closest to your sentiment.

一. Basic information:

1.1 Your age: _____ years.

1.2 Your gender: A. Male B. Female

1.3 Your academic qualification:

A. Undergraduate student; B. Graduate student; C. Doctoral student.

1.4 Your professional background:

A. Architecture;

B. Urban planning;

C. Landscape architecture;

D. Others.

二. Basic operation:

2.1 Would you run the automatic presentation script: (Only for group1 and group3.)

A. Yes; B. No.

2.2 Would you use the mouse and "J" key on the keyboard to switch to the area (or model) that you want to review in the virtual environment: (Only for group2 and group3.)

A. Yes; B. No.

2.3 Would you open traffic and pedestrian simulation: (Only for group2 and group3.)

A. Yes; B. No.

2.4 Would you use mouse and arrow keys on the keyboard to freely navigation in the virtual environment: (Only for group2 and group3.)

A. Yes; B. No.

三. Questionnaire about the cognition evaluation of the STARS:

Each item is given a 5-point scale with "1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree", please tick the best answer with "✓".

1

Item	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
3.1 The length of automatic presentation script is reasonable. (Only for group1 and group3.)	1	2	3	4	5
3.2 The information of the design alternatives expressed clearly.	1	2	3	4	5
3.3 The representation form of design alternatives can express the intent of planner and designer completely.	1	2	3	4	5
3.4 In the script, messages are consistent with virtual scene. (Only for group1 and group3)	1	2	3	4	5
3.5 The layout design of traffic planning is reasonable, such as the flow rate of population and vehicle.	1	2	3	4	5
3.6 The landscape design is reasonable.	1	2	3	4	5
3.7 The embodiment of eco-energy saving concept is reasonable.	1	2	3	4	5
3.8 The expression of the charm of harbor metropolis is reasonable.	1	2	3	4	5
3.9 The solution of traffic problems in Tatsumi region is reasonable.	1	2	3	4	5

四. Questionnaire about the accuracy of evaluation:

4.1 Do you think the STARS reflects the content for which the following items:

A. Travel planning of harbor city;

B. Meet the need of 2020 Tokyo Olympics;

C. Traffic planning of coastal city.

4.2 What impresses you most for the STARS?

A. Architecture design;

B. Traffic layout;

C. Venue layout;

D. Sustainability and eco-energy saving.

4.3 How many design partitions in the STARS:

A. Two; B. Three; C. Four; D. Five.

五. Questionnaire about the evaluation of the STARS:

Each item is given a 5-point scale with "1 = strongly unreasonable, 2 =

2

unreasonable, 3 = neither reasonable nor unreasonable, 4 = reasonable, and 5 = strongly reasonable", please tick the best answer with "✓".

Item	Strongly unreasonable	Unreasonable	Neither reasonable nor unreasonable	Reasonable	Strongly reasonable
5.1 The STARS takes into account the traffic problems of tourists during the Olympic Games.	1	2	3	4	5
5.2. The STARS takes into account the dietary problems of tourists during the Olympic Games.	1	2	3	4	5
5.3 The STARS takes into account the accommodation problems of tourists during the Olympic Games.	1	2	3	4	5
5.4 The STARS takes into account the sustainable development of urban environment.	1	2	3	4	5
5.5 The STARS takes into account to increase the carrying capacity of local population.	1	2	3	4	5
5.6 The STARS takes into account to advocate the eco- energy saving concept.	1	2	3	4	5
5.7 The STARS takes into account to promote the charm of harbor metropolis.	1	2	3	4	5

六. Interviews:

Ask the participants to answer the following questions in detail one on one, and record participants' answers through digital voice recorder.

6.1 Please describe the design concepts of the STARS in detail?

6.2 What goals can be achieved in the design alternatives, and how to reflect these goals?

6.3 How many design partitions in the design alternatives, and what is your understanding of each partitions?

6.4 Please describe the differences (advantages and disadvantages) between script video and freely navigation? (Only for group3)

6.5 Please use 10 to 20 words to describe functions and features of the design alternatives?

6.6 For this design, which part do you think needs to be improved and deepened (the defects of this design)?

References

Abdelhameed, W. (2012). Micro-simulation function to display textual data in virtual reality. International journal of architectural computing, 10(2), 205-218.

Abmayr, T., Härtl, F., Mettenleiter, M., Heinz, I., Hildebrand, A., Neumann, B., & Fröhlich, C. (2004). Realistic 3D reconstruction–combining laserscan data with RGB color information. Proceedings of ISPRS Internation Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 35(Part B), 198-203.

Al-Kodmany, K. (1999). “Using Visualization Techniques for Enhancing Public Participation in Planning and Design: Process, Participation, and Evaluation”. Landscape and Urban Planning, Vol. 45. No. 1, pp. 37-45.

AlQahtany, A., Rezgui, Y., and Li, H.J. (2014) gave a comprehensive review of the current state of urban planning in Saudi Arabian cities and specifically within the capital city of Riyadh, and discussed some of the schemes that have been adopted, then proposed a consensus-based framework for the sustainable urban planning development.

Arayici, Y. (2007). “An approach for real world data modelling with the 3D terrestrial laser scanner for built environment”, Automation in Construction, 16(2007), 816-829.

Arayici, Y., Hamilton, A., & Gamito, P. (2005). Built environment reverse and forward prototyping.

Armesto-González, J., Riveiro-Rodríguez, B., et al. (2010). “Terrestrial laser scanning intensity data applied to damage detection for historical buildings”, Journal of Archaeological Science, 37 (2010) 3037-3047.

Banai, R. (2010). Cities and regions: the urban sustainability, planning, pedagogy, and technology nexus. Education, 2010.

Bates-Brkljac N. et al., (2009). Assessing perceived credibility of traditional and computer generated architectural representations. Design Studies, Vol. 30. No. 4, pp. 415-437.

Biljecki, F., Stoter, J., Ledoux, H., Zlatanova, S., & Çöltekin, A. (2015). Applications of 3D City Models: State of the Art Review. ISPRS International Journal of Geo-Information, 4(4), 2842-2889.

Bloomberg, M. R., Burney, D. J., and Resnick, D. (2012). BIM Guidelines, New York City Department of Design + Construction, New York City. Available from: http://www.nyc.gov/html/ddc/downloads/pdf/DDC_BIM_Guidelines.pdf [Accessed 9 May, 2016].

Brockmeier, J. (2010). After the archive: remapping memory. Culture & Psychology, 16(1), 5-35.

Brown, G., & Weber, D. (2011). “Public Participation GIS: A new method for national park planning”. Landscape Urban Plan. doi:10.1016/j.landurbplan.2011.03.003

Burgess, H. and Brad S. (2003). “Consensus Building” Beyond Intractability. Eds. Guy Burgess and Heidi Burgess. Conflict Information Consortium, University of Colorado, Boulder. Accessed 26 May 2015. Available at http://www.beyondintractability.org/essay/consensus-building

Caracena, T. M., Gonçalves, J. G., Peerani, P., & Vendrell, E. (2014). Virtual Reality based accurate radioactive source representation and Dosimetry for Training Applications.

Carmona M., Heath T., Oc T. and Tiesdell S. (2003). Public places-urban spaces, the dimensions of urban design, Architectural Press.

Carver, S., Evans, A., Kingston, R. and Turton, I. (2001). “Public participation, GIS, and cyberdemocracy: evaluating on-line spatial decision support systems”. Environment and Planning B: Planning and Design, Volume 28, pages907-921.

Chen, L., & Zhu, Y. (2012). Bridge Design Concept and Innovation of Chengdu-Dujiangyan Intercity Railway-Post Wenchuan Earthquake Reconstruction Project in Sichuan, China. In Proceedings of the 1st International Workshop on High-Speed and Intercity Railways (pp. 205-216). Springer Berlin Heidelberg.

Chen, P. H. and Truc, N. T. L. (2008). Automatic 3D modeling development and application for hydraulic construction. The 25th International Symposium on Automation and Robotics in Construction, pp.435-439.

Cheng, X.J. and Jin, W. (2006). “Study on reverse engineering of historical architecture based on 3d laser scanner”, Journal of Physics Conference Series, 48(1), 843-849.

Conniff A. et al. (2010). A comparison of active navigation and passive observation of desktop models of future built environments. Design Studies, 31(5): 419-438.

Creswell J. W. (2003). Research design: Qualitative, Quantitative, and Mixed Methods Approaches (Second Edition). Thousand Oaks, CA: Sage.

Cuesta, R., Sarris, C., Signoretta, P., & Moughtin, J. C. (2012). Urban design: Method and techniques. Routledge.

Danhof, M., Schneider, T., Laube, P., & Umlauf, G. (2015). A Virtual-Reality 3d-Laser-Scan Simulation. BW-CAR| SINCOM, 68.

Davis, A. (2015). Virtual Reality Simulation: An Innovative Teaching Tool for Dietetics Experiential Education. The Open Nutrition Journal, 2015, 9, (Suppl 1-M8) 65-75.

Demir, N. et al., Bayram, B., Alkis, Z., Helvaci, C., Cetin, I., Vogtle, T., … & Steinle, E. (2004,July). Laser scanning for terrestrial photogrammetry, alternative system or combined with traditional system. In ISPRS xx. Symposium, Com. V., WG (Vol. 2).
Deng, Z., Lin, Y., Zhao, M. and Wang, S. (2015). “Collaborative planning in the new media age: The Dafo Temple controversy, China”. Cities, 45(2015):41-50.
Ding S. N. (2008). Rethinking Design Process: Using 3D Digital Models as an Interface in Collaborative Session. Engineering Design Graphics Journal, 72(3):1-9.
Elmqvist, N., & Tsigas, P. (2006). On Navigation Guidance for Exploration of 3D Environments. Göteborg, Sweden.
Eran, S., SAYED, J., & ROSDI, M. (2005). The Design and Development of a Virtual 3D City Model.
Fan, Y., Dong, J., et al. (2012). “Discussion on 3D laser scanning technology and the comprehensive application of related software”, Surveying and Mapping of Geology and Mineral Resources, 28 (3), 21-23. (In Chinese)
Felasari, S., & Peng, C. (2012). Supporting Urban Design Learning with Collective Memory Enhanced Virtual City: The Virtual Jalan Malioboro Experiment.
Foth, M., Hearn, G. N., & Klaebe, H. G. (2007). Embedding digital narratives and new media in urban planning.
Gaidyte, R. (2010). 2D and 3D Modeling Comparison.
Gordon, E., Schirra S., Hollander J.(2011). “Immersive planning: a conceptual model for designing public participation with new technologies”. Environment and Planning B: Planning and Design 38, 505–519.
Grossman, T. A. and Ö. Özlük. (2009). "A Spreadsheet Scenario Analysis Technique That Integrates with Optimization and Simulation." INFORMS Trans. 10(1): 18-33.
Haala N. et al. (2005). Towards Virtual Reality GIS. Photogrammetric Week 05: 285–294.
Hasebrink, U., & Domeyer, H. (2012). Media repertoires as patterns of behaviour and as meaningful practices: A multimethod approach to media use in converging media environments. Participations, 9(2), 757-779.
He, M. (2014). Does extensive reading promote reading speed? The Reading Matrix, 14, 16–24.
Heft H. and Nasar J. L. (2000). Evaluating Environmental Scenes Using Dynamic Versus Static Displays. Environment and Behavior, 32(3): 301-322.
Holopainen, M., Kankare, V., et al. (2013). “Tree mapping using airborne, terrestrial and mobile laser scanning–A case study in a heterogeneous urban forest”, Urban Forestry&Urban Greening, 12(2013) 546–553.
Horne, M., Thompson, E. M., & Podevyn, M. (2007). An overview of virtual city modelling: emerging organisational issues.
Huo, X., Liu, Y., Zhang, G., & Yang, H. (2013). A RESEARCH ON DIGITAL TECHNOLOGY’S APPLICATION IN PRESERVATION PLANNING OF WENMING HISTORICAL AND CULTURAL BLOCK IN KUNMING. ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 1(2), 355-360.
Innes, J.E. (1996). “Planning through consensus building: a new view of the comprehensive planning ideal”. J. Am. Plan Assoc. 62(4), 460-472.
Isikdag, U., & Zlatanova, S. (2010). Interactive modelling of buildings in Google Earth: A 3D tool for Urban Planning. In Developments in 3D Geo-Information Sciences (pp. 52-70). Springer Berlin Heidelberg.
Ito, Y., Soulier, C., Pencreach, Y., Hafferty, B. & Hafferty, P. (2013). “The application of cloud computing in transport planning using interactive 3D VR simulation technology”, in: N. Dawood and M. Kassem (Eds.), Proceedings of the 13th International Conference on Construction Applications of Virtual Reality, 30-31 October 2013, London, UK.
Jia-Chong, D. and Hung-Chao, T. (2007). “3D laser scanning and GPS technology for landslide earthwork volume estimation”, Automation in Construction, 16(2007), 657-663.
Jiang, B., Larsen, L., Deal, B., & Sullivan, W. C. (2015). A dose–response curve describing the relationship between tree cover density and landscape preference. Landscape and Urban Planning, 139, 16-25.
JIANG Y. K. (2008). Analysis on Beijing Subway Flows during the 29th Olympics. Journal of Transportation Systems Engineering and Information Technology, 8(6):46-51.
Joseph R. and Perera U. (2013). DREAM – IT – 3D RECONSTRUCTION AND BUILDING INFORMATION MODELLING. International Journal of Engineering Sciences & Emerging Technologies, volume 6, issue 2, pp: 258-266.
Jutraz, A., & Zupancic, T. (2015). Virtual Worlds as Support Tools for Public Engagement in Urban Design. In Planning Support Systems and Smart Cities (pp. 391-408). Springer International Publishing.
Kameda M. (2013). Compactness key to Olympics plan. The Japan Times. http://www.japantimes.co.jp/news/2013/09/13/national/compactness-key-to-olympics-plan/#.VjhykhGhfVg
Kaplan R., Kaplan S. and Austin M. E. (2008) Factors shaping local land use decisions: Citizen planners' perceptions and challenges. Environment and Behavior, 40(1): 46-71.
Kearney J., Willemsen P., Donikian S., and Devillers F. (1999). Scenario languages for driving simulation. In Proceedings of DSC’99 (Driving Simulation Conference), pages 123–133, July 1999.
Kibria, M. S. (2008). Functionalities of geo-virtual environments to visualize urban projects (Doctoral dissertation, TU Delft, Delft University of Technology).
Kim, D. (2004). 3D Visual Urban Simulation: Methods and Applications, Korean Local Administration Review.

Kua, H. W., & Koh, S. (2012). Sustainability Science Integrated Policies Promoting Interaction-Based Building Design Concept as a Climate Change Adaptation Strategy for Singapore and Beyond. In Green Growth: Managing the Transition to a Sustainable Economy (pp. 65-85). Springer Netherlands.

Larsson P., Västfjäll D., Kleiner M. (2001). The actor-observer effect in virtual reality presentations. Cyberpsychol Behav, 4(2): 239-46.

LI, H., & WU, L. S. (2007). Application of 3D Laser Scan Technology in Virtual Reality [J]. Journal of Nanchang University (Engineering & Technology), 3, 008.

Lim, E. H. (2012). 3D Urban Modelling (Doctoral dissertation, Monash University

Liu, L. A., Friedman, R., Barry, B., Gelfand, M. J., & Zhang, Z. X. (2012). The dynamics of consensus building in intracultural and intercultural negotiations. Administrative Science Quarterly, 57(2), 269-304.

Lorentzen, T., Kobayashi, Y., and Ito, Y. (2009). “Virtual reality for consensus building: case studies”. Book series of lecture notes in computer science, Volume 5531, Springer Publishing, Berlin/Heidelberg, Pages 295-298.

Luo, X. L., and Shen, J. F. (2008). “Why city-region planning does not work well in China?”. Cities, 25(4):207-217.

Mahdjoubi, L., Moobela, C. and Laing, R. (2013). “Providing real-estate services through the integration of 3D laser scanning and building information modelling”, Computers in Industry, 64 (2013) 1272–1281.

McTague, C., & Jakubowski, S. (2013). Marching to the beat of a silent drum: Wasted consensus-building and failed neighborhood participatory planning. Applied Geography, 44, 182-191.

Mell, P. and Grance, T. (2011) “The NIST Definition of Cloud Computing”. US Nat’l Inst. of Science and Technology; http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

Minatani, K., Watanabe, T., Yamaguchi, T., Watanabe, K., Akiyama, J., Miyagi, M., & Oouchi, S. (2010). Tactile map automated creation system to enhance the mobility of blind persons—Its design concept and evaluation through experiment. Computers Helping People with Special Needs, 534-540.

MOC. (2006). Design code for office building (JGJ67-2006), Ministry of Construction of the People’s Republic of China. (In Chinese)

Morganti, F., Rusconi, M. L., Paladino, A., Geminiani, G., & Carassa, A. (2008). The use of virtual environments for survey spatial ability evaluation in topographical disorientation. Behavioural neurology, 19(1, 2), 81-85.

Moughtin, C. (2003). Urban design: Method and techniques. Routledge.

Okazaki, H. et al. (2012). Development of an e-Learning Program for Extensive Reading. In L. Bradley & S. Thouësny (Eds.), CALL: Using, Learning, Knowing, EUROCALL Conference, Gothenburg, Sweden, 22-25 August 2012, Proceedings (pp. 228-233).

Phan, V. T., & Choo, S. Y. (2010). A Combination of Augmented Reality and Google Earth’s facilities for urban planning in idea stage. International Journal of Computer Applications, 4(3), 26-34.

Poplin, A. (2012). “Playful public participation in urban planning: A case study for online serious games”. Computers, Environment and Urban Systems 36 (3): 195–206.

Poplin, A. (2013). “Digital serious game for urban planning: “B3—Design your Marketplace!””. Environment and Planning B: Planning and Design 2013, volume 40, pages1-19.

Pucci, B., & Marambio Castillo, A. E. (2009). Olerdola's cave, Catalonia past and present: a virtual reality reconstruction from terrestrial laser scanner and gis data. In 3rd. International Workshop 3D Virtual Reconstruction and Visualization of Complex Architectures (pp. 1-14).

Rahim N., et al. (2013). A survey on components of virtual 'umrah application. The International Journal of Multimedia & Its Applications (IJMA), Vol.5, No.5, pp17-27.

Ralph, P., & Wand, Y. (2009). A proposal for a formal definition of the design concept. In Design requirements engineering: A ten-year perspective (pp. 103-136). Springer Berlin Heidelberg.

Roberts, M., & Greed, C. (2014). Approaching urban design: the design process (Vol. 5). Routledge.

Roupé, M., Bosch-Sijtsema, P., & Johansson, M. (2014). Interactive navigation interface for virtual reality using the human body. Computers, Environment and Urban Systems, 43, 42-50.

Rusu, R. B., Marton, Z. C., Blodow, N., Dolha, M., & Beetz, M. (2008). Towards 3D point cloud based object maps for household environments. Robotics and Autonomous Systems, 56(11), 927-941.

Saal, K. (2010). Virtual 3D Urban Design from Laser Scan Data. The Global Magazine of Leica Geosystems , 14-16.

SAC. (2008). Emergency shelter for earthquake disasters-Site and its facilities (GB21734-2008), Standardization Administration of the People's Republic of China. (In Chinese)

Sampaio, A. P. Henriques, O. Martins (2010). Virtual Reality Technology Used in Civil Engineering Education. The Open Virtual Reality Journal, 2 (2010), pp. 18–25.

Shakibamanesh, A. (2014). Improving results of urban design research by enhancing advanced semi- experiments in virtual environments. International Journal of Architectural Engineering & Urban Planning, Vol. 24, No. 2, December 2014.

Shen, Z., & Kawakami, M. (2010). An online visualization tool for Internet-based local townscape design. Computers, Environment and Urban Systems, 34(2), 104-116.

Shen, Z.J., Kawakami, M. and Kishimoto, K. (2012). “Web-Based Multimedia and Public Participation for Green Corridor Design of an Urban Ecological Network”. Geospatial Techniques in Urban Planning, Springer.

Shen, Z.J., Ma, Y., Sugihara, K., Lei, Z.H. and Shi, E. (2014). “Technical Possibilities of Cloud-Based Virtual Reality Implementing Software as a Service for Online Collaboration in Urban Planning”. Int. J. Communications, Network and System Sciences, 7, 463-473.

Singh, S. P., Jain, K., & Mandla, V. R. (2014). Image based virtual 3D campus modeling by using CityEngine. American Journal of Engineering Science and Technology Research, 2(1), 01-10.

Skorupka, A. (2009). Comparing human wayfinding behavior in real and virtual environment. In Proceedings of the 7th International Space Syntax Symposium (p. 104). Stockholm: KTH Royal Institute of Technology.

Smith, A., Dodge, M., and Doyle, S. (1998). “Visual Communication in Urban Planning and Urban Design”. Centre for Advanced Spatial Analysis Working Papers, London, June 1998.

Srnka, K. J., & Koeszegi, S. T. (2007). From words to numbers: How to transform qualitative data into meaningful quantitative results. Schmalenbach Business Review, 59, 29–57.

Steinmann, R., Krek, A., Blaschke, T. (2005). “Can online map-based applications improve citizen participation”. E-Government: Towards Electronic Democracy Lecture Notes in Computer Science Volume 3416, pp 25-35, Springer.

Steven B. G. (2010). Thoughts on Developing A Design Concept, http://vanseodesign.com/web-design/design-concept-thoughts/

Sundaram, M. A. S., & Bhattacharya, B. (2013). Earthenware Water Filter: A Double Edged Sustainable Design Concept for India. In ICoRD'13 (pp. 1421-1431). Springer India.

Susskind, L., McKearnen, S., Thomas-Lamr, J. (1999). The Consensus Building Handbook: A Comprehensive Guide to Reaching Agreement, Sage Publications, Inc., California.

Tan CL, Hassali MA, Saleem F, Shafie AA, Aljadhey H, Gan VB (2015). Development, test-retest reliability and validity of the Pharmacy Value-Added Services Questionnaire (PVASQ). Pharmacy Practice, 13(3):598. doi: 10.18549/PharmPract.2015.03.598

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach’s alpha. International Journal of Medical Education, 2, 53–55. doi:10.5116/ijme.4dfb.8dfd

Teruyuki Ohno (2014). The 2020 Tokyo Olympics and Sustainability. http://jref.or.jp/en/column/column_20140424.php

Tian Y., Sun L., Li B., Luo Y. (2010). “Discussion on planning and design of Chengdu disaster prevention-reconstruction park”, Sichuang Building Science, 36(6): 232-235. (In Chinese)

Turner, D. W., III (2010). Qualitative interview design: A practical guide for novice investigators. The Qualitative Report. 15(3), 754-760.

Velazco, E. (2012). 3D Digital Modeling for Urban Design+ Planning.

Vemuri, K., Poplin, A. and Monachesi, P. (2014). “YouPlaceIt!: a Serious Digital Game for Achieving Consensus in Urban Planning”, 17th AGILE Conference on Geographic Information Science (AGILE 2014), Workshop Geogames and Geoplay, Castellón, Spain.

Wallace Roberts & Todd. (1991). Downtown design study: urban design concept: City of London.

Wang, Q. 2006. “Historic building mapping”, China Architecture & Building Press, Beijing. (In Chinese)

WG II, I. S. R. S. (2004). Applications of 3D city models based spatial analysis to urban design.

Wong, T. C., & Yuen, B. (2011). Eco-City Planning. Policies, Practice and Design: Springer Science+ Business Media BV.

Wu, H., He, Z., Gong, J. (2010). “A virtual globe-based 3D visualization and interactive framework for public participation in urban planning processes”. Computers, Environment and Urban Systems 34 (4) 291–298.

Xiao, W., Vallet, B., Schindler, K., & Paparoditis, N. (2016). Street-side vehicle detection, classification and change detection using mobile laser scanning data. ISPRS Journal of Photogrammetry and Remote Sensing, 114, 166-178.

Yang, X., Ergan, S., & Knox, K. (2015). Requirements of Integrated Design Teams While Evaluating Advanced Energy Retrofit Design Options in Immersive Virtual Environments. Buildings, 5(4), 1302-1320.

Zang, C. (2006). “Application of the 3D laser scanning techniques to the study of cultural relics conservation”, Architectural Journal, 24 (12), 54 -56. (In Chinese)

Zhang, Y., Zhang, Y. and Chen, X. (2014). “Research on application of 3D laser scanner in ancient architecture mapping”, Experimental Technology and Management, 31(1), 79-82. (In Chinese)

Zhang Yuanyi, Shen Zhenjiang, Wang Kai, Kobayashi Fumihiko and Lin Xinyi (2015). Cloud-based Virtual Reality for Consensus-Building in Urban Planning and Design－A Case Study if One Foundation Disaster Prevention Park in China, The proceedings of International Conference 2015 on Spatial Planning and Sustainable Development, pp86, (SPSD2015, Taipei) (2015,8).

江東区都市計画マスタープラン(2011): http://www.city.koto.lg.jp/kusei/keikaku/52792/7709.html