Effectiveness Assessment on Urban Planning Analyzed in Virtual Reality Environments

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Abstract—**Public participation is very important to the success for urban planning projects. This study tries to establish two different systems, the 3-dimensional digital model and the 360 panoramic QTVR photos models, to simulate the feasibility and effectiveness of the participants' experiences feedback got from both environments, by the case study area of Hangzhou CBD, Zhejiang Province, China. This study used Logistic Model to calculate the parameters and their significance to understand if the participant would be interested or not. The results showed that different age/gender people would be impacted by different indicators. It is also found that both QTVR system and 3D system have advantages and disadvantages for representing the indicators' characteristics for participants.**

Index Terms—**effectiveness assessment, urban planning, virtual reality environments, 360 panoramic simulations**

I. Introduction

Recently, there are much more digital cities reported in the world, and it is found that these 3D cities were applied to various representations and technologies for different purposes. However, some important issues have been asked in the creation of 3D digital cities, such as: What are the values of city models. Who are the users? How to utilize digital city models? How to receive feedbacks from its application? Apparently, a 3D digital city has dimensions other than the technical and practical that are social, cultural, political, ideological, and also theoretical (Chiu, 2005) [1].

Therefore, public participation is very important to the success of an urban planning project, since any urban planning project will ultimately become part of the life of the public (Ergazakis et al., 2011 [2]; Collie, 2011 [3]; Doukas et al., 2011 [4]).

The earlier and the more intensively the public is involved in an urban planning project, the more likely the project will succeed. Greater public participation in the urban planning processes is a political goal in Europe and something that citizens have grown to expect (Rafiee et al., 2009 [5]).

In the UK and Europe, local authorities are increasingly being required to make urban planning data available electronically, primarily over the Web (Hetherington et al., 2007 [6]).

Pedestrian movement in urban areas is mainly examined by means of simulation technologies (Ian et al., 2009 [7]; Horrocks et al., 2009 [8]). Harmeet and Robyn analyzed modeling subgroup behavior in crowd dynamics DEM simulation (Singh et al., 2007 [9]). Johann proposed a virtual product to experience the customer participation (Fuller, 2007 [10]). Nguyen and Monica made a comparison of different input devices for a 3D environment (Yang, 2010 [11]). Modern urban planners and designers tend to use the VR model to understand the feelings of the people about the environment (Colombo, 2006 [12]; Chiou et al., 2008 [13], Tang et al, 2007 [14]).

However, the planners do not always know which kind of the participants/users should be invited to join in the study to optimize the information collection for the later planning.

Scholars have also worked hard to find the methods on how to collect information from digital cities' feedback. The digital cities model and a prototype of an interactive visual simulation system are developed for presenting city images, which will help to catch a sense of sequential movement and people can virtually experience window-shopping and strolling activities in a specific area by using the system (Morozumi, 2005 [15]).

Scholars ever tried to depict a digital approach toward environmental design concerning with the space that surrounds people.

This kind of study demonstrates that a 3-dimensional digital archive can be supportive in environment design. 3-dimensional digital archive becomes a platform for

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environmental design examination. Scenario writing is employed to simulate how people involved in space, and by using a scenario, the object of a design and activities can clarify the concrete target of a design (Kaga, 2003 [16]).

In this paper, it tries to answer the following 3Ws' questions:

(1) Why does it aim to develop such integration method?

(2) What are the advantages of this integration method?

(3) Where can people/planners use this method?

This study tries to establish two different systems, a 3-dimensional digital model and a digital model linked with 360 panoramic photos, to simulate the feasibility and effectiveness differences of the participants' experiences between two of them.

II. METHODOLOGY

A. The Study Area

The study area in this paper is Hangzhou CBD in Hangzhou. Hangzhou, as one of the seven greatest ancient capitals in China, is the capital of Zhejiang Province at present, locating close to Shanghai City. Hangzhou CBD is built along Qiantang River, which is as wide as 1000 meters, twice the width of Huangpu River in Shanghai.

It locates to the north of Qiantang River, which contrasts sharply with the delicacy of old downtown of Hangzhou.

In October 2008, the central area of Hangzhou CBD was opened to the public. It will become city complexities functioning mainly in financial and hotel services and will help to promote Hangzhou to be a financial center in the south of the Yangtze River Delta.

In this paper, we choose Hangzhou CBD as the case study area only because it was multi-functional integrating administration, finance, trading, information, business, exhibition, tourism and residence into one district, also because that it performed the functions of a central business district such as integrated service, production and creation, and logistics. It focuses on trades like banking, insurance, securities, information technology and consultancies.

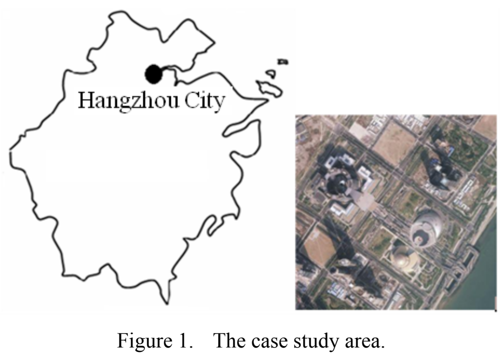

Figure 1. The case study area.

The future Hangzhou CBD is designed and developed to symbolize modernity, openness, grandness and height, to embody the features of Qiantang River in the layout and design of architecture, and to reveal the nimbuses, culture, history, uniqueness and characteristics of the old Hangzhou City. It also functions in the development of logistics, business, culture and sports and residence, etc. (Fig. 1) [17].

B. The Study Objects

In this paper we invited 3 different groups of participates to travel/view in 3 different environments:

(1) the reality environment,

(2) the 3-dimensional digital model, and

(3) the digital model linked with 360 Panoramic photos.

We used the information about the travelling experience in the reality environment as the standard to compare the other two system's feedback.

In order to make the feedback experience getting more accurate, we divided the participants into 4 different groups on the basis of their ages and genders:

- young and middle-aged young men (26~54 years old),
- young and middle-aged young women (26~54 years old),
- students (below 26 years old)
- elder men (above 55 years old)

In order to have further understanding about the experiences of different systems, we mainly collected 3 different indicators' information:

(1) leisure indicator,

(2) landscape indicator, and

(3) Architecture (building).

TABLE I.
THE QUESTIONNAIRES FOR PEDESTRIANS AND VR MODEL USERS

Questionnaires	
1.	The basic attributes of the pedestrians and users, including gender, occupation, age, the average monthly income, etc.
2.	Pedestrian activities within the scope field of the respondents. The investigators were recorded by investigators who followed the walks of pedestrians to make the survey about their activities, including their route choices and crossing behaviors, etc.
3.	Pedestrian visual preference and attraction range. The investigators asked pedestrians about the feelings and experiences at the sight of the 3 different impact factors, and the reasons for the route choices.

TABEL II.
THE DEFINITION OF THE VARIABLES AND CODES IN 2OD-LOGISTIC MODEL

Vars	*Definition*	Code
X_1	Gender	1=male, 2=female
X_2	Occupa-tion	1=employees 2=teachers 3=businessmen 4=housewives 5=students 6=farmers 7=other occupations
X_3	Age	1=Below 26 years old 2=26~54 years old 3=Above 55 years old
X_4	Average income/ per month)	1=Below \$500 2=\$500～\$ 000 3=Above \$1000

X_5	The route choice	1=go east 2= go west 3=go north 4=go south
X_6	The behaviour	1=strolling activity, 2=watching performances 3=window-shopping 4= observing the landscape 5=searching road signs 6=others
X_7	The linger time	*in reality environment:* 1= below 2 minutes, 2=3 ~ 5 minutes, 3=5 ~ 15 minutes, 4=above 15 minutes *in digital environment:* 1= below 5 seconds, 2=6 ~ 30 seconds, 3=30 ~ 60 seconds, 4=above 60 seconds
X_8	The degree of Preference	1 = low 2 = fine 3 = good 4 = high 5 = very high
X_9	Prefer to come back again or not	1= yes, 2 = no

We compared the records between audio and video information to determine similarities and differences. All the participants were invited to answer questionnaires with the following 3 parts:

C. The Study Method

In this paper, we used Logistic Model to calculate if the participants would be interested (for the impact indicator) or not. Here Y has 2 categories of qualitative variables, that is, the Y = 1stands for "has interest" and Y=0 stands for "has no interest". x_1, x_2, ..., x_n are the impact factors as may affect the participants to make the choice of variables. Since Y has only 2 values, here in this study are probabilities for age, gender, trip purpose, feelings of other variables.

Let Y = 1 with probability p when the participant selects "has interest", then Y=0 with probability 1-p when the participant selects "has no interest". Take the natural logarithm ln (p / (1-p)) of p / (1-p), which do logit transformation of p, denoted logit p, then logit p ranges between - ∞ and + ∞. Taking logit p as the dependent variable, equation (1) is established as a linear regression equation:

$$\text{Logit}\, p = \alpha + \beta_{1\,x1} + \beta_{2x2} + \cdots + \beta_{nxn} \qquad (1)$$

In this model, the parameter α is a constant, which shows that when all the independent variable values are 0, the number (Y = 1 and Y = 0 the probability ratio) of the natural logarithm of the parameter is called Logistic regression coefficients $\beta_{I.}$ And when other variables value remains unchanged, the value of a unit increase in the independent variable causes the odds ratio of natural logarithm of the change. Equation (2) is obtained by the transformation:

$$= \frac{\exp(\alpha + \beta_{1xj1} + \beta_{1xj1} + \cdots\cdots + \beta_{1xj1})}{1 + \exp(\alpha + \beta_{1xj1} + \beta_{1xj1} + \cdots\cdots + \beta_{1xj1})} \qquad (2)$$

Through the introduction of nine independent variables "X_1: gender, X_2: occupation, X_3: age, X_4: the average monthly income, X_5: the route choice, X_6 the behaviors, X_7: linger time, X_8: the degree of Preference, X_9: do prefer to come back again to view / travel".

III. Two Systems Analysis

A. The 3-Dimensional Digital Model

We build the models in Multigen Creator and achieve its roaming in Vega. Techniques for the three-dimensional modeling of virtual campus in Multigen Creator are as follows:

- Data preparation: extract modeling construction contour of the campus planning produced in AutoCAD, and save it as *. dxf format. The data format can directly import to Multigen Creator.
- The production of texture: get the digital imaging of campus buildings by digital camera, and then use Photoshop image-processing software to correct, zooming, match the photos. In order not to have the texture information loss and change in a rendering and walkthrough, texture file should be changed into a format supporting RGB, RGBA, INT, INTA, BMP or JPG, and the size of texture should be amended as the length of the pixel - 2n as Vega provided.
- The building of three-dimensional campus model: modeling on the basis of importing the campus plan produced by AutoCAD into Creator.
- Processing of the model data: the principal objective is the organization of model data hierarchy, production of LOD and so on.
- Driving three-dimensional simulation system: use Vega and Visual Studio2005 as application development platform to do the secondary development, establish three-dimensional digital city landscape system, achieving the system features such as walkthrough and analysis.

Fig. 2 illustrates the model showed in a text-based World Wide Web (WWW) browser using Lynx.

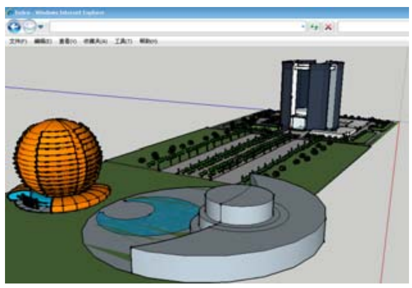

Figure 2. The model showed in a text-based World Wide Web (WWW) browser using Lynx

Hangzhou CBD reconstruction model system has three kinds of terrain models: features, water and terrain model.

It is derived from 1: 500 large-scale topographic maps, and it is digitized from the layered contour lines.

First, use the coverage documents of Yuhuang Mountain to build TIN, then transfer TIN to USGSDEM format (*. dem), and transfer gridding elevation data to DED format. Finally, use TerrainPro tools to generate terrain through the parameter setting, and transform it to Openflight format (*. flt) which MultiGen requires.

Features model. Yuhuang Mountain not only has cabinet-style Rendezvous Pavilions, but also have complex Rendezvous Pavilions.

In MultiGenCreator, the majority of the regular construction could be accurately located and modeled through the benchmark of Yuhuang Mountain plans. But to a small number of irregular ones which cannot be well completed in the Creator, they are built in 3DSMAX.

In the construction of virtual scene, water has the flow characteristic. In order to make the effect of turbulence of water could be used in the Vega, we can use the FlipBook tool.

In the same group node, copy a few lakes, and use the same surface texture. Be careful of the location differences when you are mapping, thereby the effect of wave will be achieved.

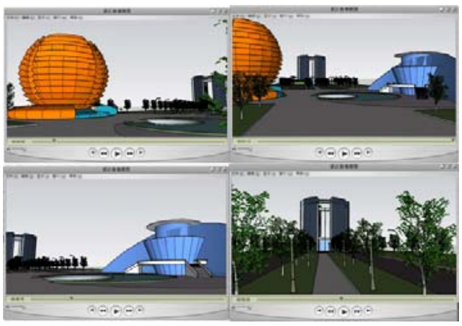

Figure 3. The model played in QuickTime Player

B. The 360 Panoramic QTVR Simulations

We established a digital model with 210 panoramic photos in the case study area. Here we used QTVR, which was developed by Apple Computer Inc., to display a 360 degree panoramic view image. QTVR uses a set of cylindrical images, such as the synthesis of pictures taken with a digital camera in different directions from each representation point (Fig. 4).

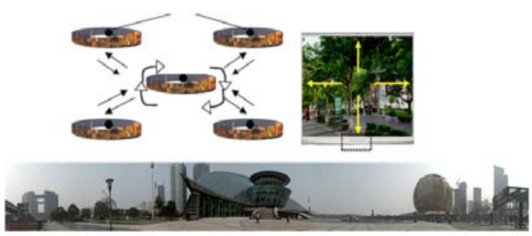

Figure 4. An example of 360 Panoramic QTVR photo in one picture spot

The appliance of the QTVR model is analyzed in the table III as the followings:

TABLE III.
THE APPLIANCE OF THE QTVR MODEL

Num.	*Functions*	*Methods*
1.	360-degree rotating street viewing	Method1: press the mouse's left button, drag the mouse to the position you want to watch.
		Method 2: Click the lower left button to operate the 360-degree rotating.
2.	How to walk on the streets	Method 1: click the footprints to walk freely in the panoramic window as shown in the following figure; this method is especially useful at crossroads and junctions.
		Method 2: Participants can also click the navigation keys at the lower left corner in the panorama window to do the walking and zooming operations.
3.	How to watch the images in full screen	Click the "full screen" button, or double click the mouse's left button in the panoramic window, participants can watch in full screen. Drag the "eye" to where ever you want to go, or double click the "eye" at the place you want to go, and you can switch to the corresponding scene.

At each point, users can rotate their view through 360 degrees by pushing the cursor to the right or to the left in the displayed image, and can even zoom in on some part of an image or zoom out to normal image size just by touching a fixed key. It also allows vertical rotation, but the extent vertical angle depends on the image provided.

Figure 5. The QTVR browser example

When special links are created among these images, respectively tying some area of the neighboring cylindrical images to each other, the user can jump from one to another simply by using the cursor to touch the area that has a link in a displayed image. The participants can do the 360° rotation, and walk forward and backward in this VR model. The VR model system is as described in Figure. 5.

IV. RESULTS AND DISCUSSION

A. Results Analysis

The data in this paper was collected from May to November 2011 in Hangzhou CBD. We have invited 218 participants to have questionnaire surveys, and finally got 186 effective questionnaires back. In this study we use SPSS 15.0 to record and analysis the data. Compared with 9 variables, we got the model parameters and the Wald SIG. results as shown in Table Iv.

In the result comparison, besides the deviations during the calculation, we found that the kinds of p value that reached statistical significance are X_1, X_3, X_5, X_6, X_7. Among them, gender, age, the liner time have the greatest p value, which means that all these kinds of factors would have great impact on people to show their strong or little interest during their traveling/ viewings. Among them, the gender shows that whatever male or female both would have significant p value that means we can choose both man and woman to have tests. The average monthly income and the route choice have both low p values, which mean that these kinds of factors would make little impact on people.

TABLE IV.
THE PARAMETERS AND THEIR SIGNIFICANCE AFTER THE MODEL BEING OPTIMIZED IN 3D MODEL

	3D			
			p	
Var.	*Code*	*df.*	*Have strong interest*	*Have no interest*
X_1		2	0.000	0.712
	1	1	0.164	0.178
	2	1	0.016	0.052
X_2		7	0.811	0.806
	1	1	0.356	0.025
	2	1	0.046	0.031
	3	1	0.428	0.533
	4	1	0.003	0.058
	5	1	0.021	0.018
	6	1	0.625	0.539
	7	1	0.731	0.568
X_3		3	0.004	0.012
	1	1	0.190	0.004
	2	1	0.013	0.893
	3	1	0.047	0.024
X_4		3	0.615	0.707
	1	1	0.006	0.068
	2	1	0.030	0.021
	3	1	0.453	0.025
X_5		4	0.000	0.000
	1	1	0.325	0.951
	2	1	0.005	0.256
	3	1	0.498	0.002
	4	1	0.035	0.642
X_6		6	0.024	0.037
	1	1	0.072	0.021
	2	1	0.034	0.035
	3	1	0.019	0.654
	4	1	0.048	0.598
	5	1	0.245	0.869
	6	1	0.428	0.326
X_7		4	0.000	0.000
	1	1	0.016	0.000
	2	1	0.000	0.012
	3	1	0.425	0.538
	4	1	0.510	0.355
X_9		2	0.015	0.289
	1	1	0.216	0.000
	2	1	0.003	0.562

By the feedback about the feeling on usage of the two systems in 4 different groups, in the Wald SIG. which had reached statistical significance are:

TABLE V.
THE PARAMETERS AND THEIR SIGNIFICANCE AFTER THE MODEL BEING OPTIMIZED IN QTVR MODEL

	QTVR			
			p	
Var.	*Code*	*df.*	*Interesting*	*Not interesting*
X_1		2	0.000	0.631
	1	1	0.315	0.498
	2	1	0.312	0.345
X_2		7	0.820	0.422
	1	1	0.356	0.025
	2	1	0.046	0.031
	3	1	0.428	0.533
	4	1	0.003	0.058
	5	1	0.021	0.018
	6	1	0.625	0.539
	7	1	0.068	0.097
X_3		3	0.000	0.015
	1	1	0.111	0.120
	2	1	0.013	0.893
	3	1	0.047	0.024
X_4		3	0.023	0.036
	1	1	0.006	0.068
	2	1	0.030	0.021
	3	1	0.453	0.025
X_5		4	0.000	0.000
	1	1	0.325	0.951
	2	1	0.005	0.256
	3	1	0.498	0.002
	4	1	0.035	0.642
X_6		6	0.012	0.035
	1	1	0.072	0.021
	2	1	0.034	0.035
	3	1	0.019	0.654
	4	1	0.048	0.598
	5	1	0.245	0.869
	6	1	0.428	0.326
X_7		4	0.000	0.005
	1	1	0.016	0.000
	2	1	0.000	0.012
	3	1	0.425	0.538
	4	1	0.510	0.355
X_9		2	0.019	0.654
	1	1	0.031	0.685
	2	1	0.057	0.851

Group 1:
Understanding in 3D: *Wald SIG.*=0.006,
Interested in 3D: *Wald SIG.*=0.005
Group 2:
Understanding in QTVR: *Wald SIG.=0.002,*
Interested in QTVR: *Wald SIG.=0.002,*
System in QTVR: *Wald SIG.=0.000*
Group 3:
General assessment in QTVR: *Wald SIG.=0.002,*
Understanding in 3D: *Wald SIG.*=00.002,
Interested in QTVR: *Wald SIG.*=0.006,
System IN QTVR: *Wald SIG.*=0.001
Group 4:
General assessment in QTVR: *Wald SIG.*=0.002,
Understanding in 3D: *Wald SIG.*=00.001,
System in QTVR: *Wald SIG.*=0.000

TABLE VI.
THE FEEDBACK ABOUT THE FEELING ON USAGE OF THE TWO SYSTEMS ABOUT GENERAL ASSESSMENT AND UNDERSTANDING

Wald SIG.	*General assessment*		*Understanding* (Architecture/ Buildings)	
	QTVR	*3D*	*QTVR*	*3D*
Group 1	0.495	0.574	0.520	0.006
Group 2	0.625	0.512	0.002	0.842
Group 3	0.002	0.698	0.756	0.002
Group 4	0.002	0.325	0.461	0.001

TABLE VII.
THE FEEDBACK ABOUT THE FEELING ON USAGE OF THE TWO SYSTEMS ABOUT INTERESTING AND SYSTEM'S FEEDBACK

Wald SIG.	*Interest* (If it's needed to establish a website, which one do you prefer to have between the following two systems)		*System* (Do you think the system can completely simulate the reality environment)	
	QTVR	*3D*	*QTVR*	*3D*
Group 1	0.486	0.005	0.511	0.485
Group 2	0.002	0.948	0.000	0.756
Group 3	0.006	0.512	0.001	0.759
Group 4	0.453	0.412	0.000	0.485

V. DISCUSSION

This study utilize the integration method by 3D and VR environment assessment to provide an appropriate approach for the case study area's planning, presenting a virtual reality environment for tourists to imitate VR tour, achieving the simulated experiences. According to the analysis of influencing level on participants with disparity in age can reveal that the landscape factor has great effect upon the elderly than other three age flocks, while leisure factor has little effect on all 4 different kinds of participants.

As a conclusion, the results show that different aged/gender people would be influenced by different indicators. According to the data we got, we found that both QTVR system and 3D system had advantages and disadvantages. But if we can combine these two systems by inviting different groups of people to have experiences on their own interests, the situation would be much better. The cost may be lower, and the effectiveness will be better.

By answering those 3Ws' questions at the beginning of this study, this paper optimizes the traditional urban planning procedure, and establishes a new and more efficient planning method, which can get information from more people, especially in collecting the psychological information of the common people.

So as to not only save energy and cost in planning, make it more efficient and effective, but also protect the environment resource to its maximum.

We had also found that among all the participants invited to have tests in 2 systems, the young people, especially the students show stronger interests and understanding about architecture/buildings' information in 3D system, while the elder man show stronger interests and using much more time to view about the landscape's information. After the questionnaire we have made some further study on it.

We found that because the young people tend to use computer much more frequent and fluently, and knowing much more about software which helped them to get easier understanding about the logic architecture construction designing information. But the elder men has less digital literacy and prefer to see the lively scence, which result in that they prefer the one helps them easier to imagine the landscape scenes.

So, as a conclusion, after the hard work and the huge database comparison study, we strongly recommend that people could combine QTVR and 3D systems to have a much more technical and effective virtual reality environment. But, if the environment needs to be used to invite people to evaluate the effectiveness of the designing, the proportion of the participants could be as following:

- Architecture designing evaluation: it's better to invite more young people than the people of other ages;
- Landscape designing evaluation: it's better to invite more elder people;
- Leisure designing evaluation: any of the age people could be invited.

However, because this method is fresh new way, so some practical attempts should be done in enriching and improving the method.

On one hand, the resources evaluation related with STR planning not only involve in ecological resources factors evaluation and experience indicator evaluation, but also linked with other indicators. For example, the evaluation of physical environment indicators and socio-economic attributes of land use, the relevant natural factors, e.g. hydrology, geomorphology, topography, plants, weather, etc. are also needed to be considered. In this study, because the lack of data, the environment evaluation indicators are focused on natural attributes, the socio-economic factors are not considered enough. The whole evaluation system is still needed to be improved, so the accuracy and the rationality of the results is not quite satisfied. And the evaluation system's indicators should be completed in the further research.

On the other hand, VR technology is a new method of collecting information for STR planning, which brings the opportunities for participants to have simulated tour before the construction completed. Because it meets the needs of the audience for the information as much as possible, and make the best effects of information transmission. The most significant feature of virtual tourism presenting is telepresence. So the further study is to make the VR environment more realistic and complicated through much more detailed maps, interactions and animations. And the focus is to improve the database access, to perfect judgments and analysis.

Furthermore, planners must recognize the limitation of both QTVR and 3D technology for participants' experience information collection. If planners just simply gather information from all participants, but ignore different kinds of participants' preference and be biased according to different factors, the outcome of final implementation may be deviated from the target.

Therefore, by demonstrating repeatedly the feedback data from participants' experience information by different cases, planners can save cost and increase efficiency to obtain an optimal designing.

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