CYCLING VIRTUAL TOUR

A Remote Online Travel System Based On Interactive Technologies And Its User Experience Evaluation

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Abstract. Virtual reality has been widely adopted into various fields of human life. It is entering the world of tourism to remote places. This paper proposes a brand-new interaction design system for remote online virtual tourism based on bicycle riding behavior and projection mapping technologies. Through the user experience evaluation experiments of this system, the research found that this interactive system can effectively improve the realism and sense of the presence of the virtual environment. It can also enhance the delectation and satisfaction of the virtual tour. At the same time, this system can reduce the simulator syndrome which plays as a common problem in the traditional virtual tour experience.

Keywords. Interaction design; immersive environment; virtual tour; user experience.

1. Background

Sightseeing in another place is one of the most enjoyable leisure and entertainment activities for people. However, due to the high cost of traveling, the potential safety hazards of epidemics, and other inevitable problems, people have begun to seek virtual tourism as an alternative to traditional tourism. How to make virtual tourist places present the equivalent experience as real places is a question that designers and engineers have been discussing.

As it is already known that the human experiences towards a particular place rely on the “sense of place”(Ghani, Rahman et al. 2018), which is related to the studies of presence in the context of a virtual environment(Ghani, Rafi et al. 2016). Presence or telepresence is commonly defined as a user’s subjective sensation of “being there”(Lessiter, Freeman et al. 2014) and is known to be a fundamental concept for understanding and evaluating the effectiveness of virtual environments(MacIntyre, Bolter et al. 2004). Theoretically, with appropriate software and IT equipment, it is possible to take deliberate, planned, and realistic virtual trips to different scenic spots(Polechoński and Tomik 2019).

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2. Related Works

Existing researches discovered that the size of the media display(Lessiter, Freeman et al. 2014), the naturalness of a visual representation(Wijnand, Ijsselsteijn et al. 1998), and the user's interaction with the virtual envrionment(Hendrix and Barfield 1996) are highly correlated with the presence feeling of the visual virtual environment. In this scenario, many cut-edging technologies, especially immersive virtual reality technologies have come into people's sight, aiming to enhance the virtual tourism experience.

2.1. MEDIA DISPLAY SYSTEM

To achieve an immersive media display environment, most researchers choose Head Mounted Display (HMD) or CAVE Automatic Virtual Environment(CAVE) as the visual display device. Rhiu reported using HMD as the media display device to simulate people's driving and walking environment achieved a better user experience than desktop display devices(Rhiu, Kim et al. 2020). Oprean claimed choosing HMD as immersive environment experiences toolkits may help architecture and landscape design students understanding remote site information easily(Oprean, Verniz et al. 2018). Lebiedź tried CAVE as the immersive virtual environment to test virtual tours and architectural visualizations on the application which allowing a virtual walk through the Coal Market in Gdańsk(Lebiedź and Szwoch 2016). After all, although HMD and CAVE could provide an immersive virtual environment, the nausea problem caused by the simulator syndrome, the shadow problem caused by projection light blocked by experiencers in the CAVE severely affect the virtual tourism experience and reduced the level of presence.

2.2. VISUAL REPRESENTATION METHODS

Three hundred sixty-degree (360°) immersive panorama video(Nagy, Stoddart et al. 2018, Kachach, Perez et al. 2020), a high-fidelity 3D digital site model(Kersten, Tschirschwitz et al. 2018), and two mixed(Pizarro Lozano 2016, Rhee, Petikam et al. 2017) are the most popular visual environment construction solutions. Although most 360 videos only provide 2D visual media, they still present a high degree of realism since they are based on real environment information. Besides, the experiencer can freely choose the viewing angle in a panorama video, so it can greatly improve the presence feeling of the virtual environment. The advantages of the 3D digital model lie in the independence of the experiencers to choose the tour route. However, since most of the 3D digital model environments are built based on 3D scanning point cloud information(Wessels, Ruther et al. 2014), it requires high-performance hardware support(Kersten, Tschirschwitz et al. 2018). Globa tried to fuse the panorama video and the digital design model into one visual environment to improve the presence feeling of experiencers(Globa, Wang et al. 2019). It also has been proved compositing 3D virtual objects into the background of the 360-video can increase the realism of the virtual objects(Rhee, Petikam et al. 2017).

2.3. VIRTUAL ENVIRONMENT INTERACTION DESIGN

Interaction with the virtual environment plays a vital role in the immersive environment spatial presence perception(Schubert, Friedmann et al. 1999). Existing research includes automatically adjust travel speed based on viewpoint quality to avoid the information defiency(Freitag, Weyers et al. 2016), adding multiple sensory interaction design such as sound(Globa, Wang et al. 2019) (Johansson 2019)to increase the realism of the scene, attaching descriptive literature to the virtual environment to make it easier for people to understand the spatial location of their environment(Ciolfi and Bannon 2007, Argyriou, Economou et al. 2020), and so on. However, most of the current interaction design research is to study the change of output information during the interaction process to increase the authenticity of the virtual tour. There is very limited research discussing how to improve the information input systems during the virtual tour to increase the perception of reality.

3. Research Hypothesis

In real traveling, tourists hardly use controllers as their tools to help them navigate or recognize the environment, nor would they watch the world with wearing heavy glasses on their heads. This unnatural interactive mode may decrease the authenticity of the virtual tour. Thus, the research wants to explore a new virtual traveling interactive method based on natural travel behavior simulation and test if it will increase the authenticity of the virtual environment.

We chose bicycle as the interactive information input interface since cycling is a relatively common way of traveling and sightseeing, and we decided to use immersive projection mapping(IPM) as the information display system since we want to minimize the physical impact of the display device on the experiencer. A panoramic video has been adopted as visual environment information because it has consistently shown a high degree of realism in previous studies.

4. Cycling Virtual Tour System Design and Technical Implement

The entire remote online travel system consists of four subsystems: 360 dynamic media information formed by a panoramic camera, interactive information processing system formed on Unity3D platform, information input system formed by Arduino, information output system formed by Resolume Arena and projectors (Figure1).

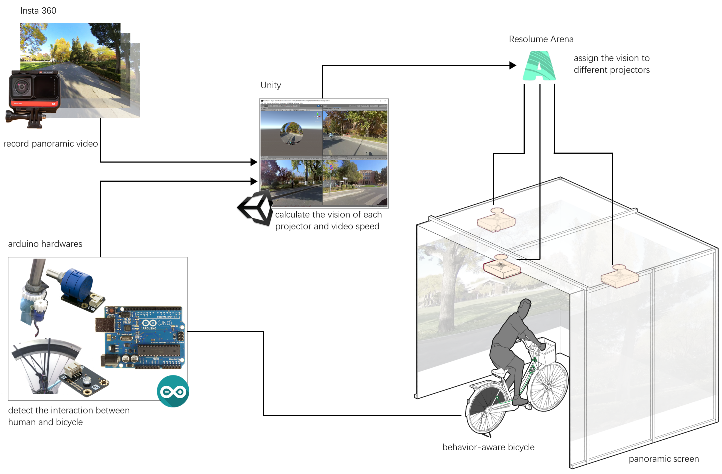

Figure 1. Cycling Virtual Tour System Composition.

4.1. PANORAMIC VIDEO MATERIAL PREPARATION

Recorded by an Insta360 one R, the panoramic video set resolution as 5.7k and 30 frames per second to ensure the clarity and smoothness of basic media information. The panoramic camera was fixed on the handlebar of the bicycle at the same height as the cyclist's eyes instead of wearing on the cyclist's head for ensuring the camera main viewport is always facing the forward direction. A 2.3 kilometers tour route on the University Campus which passed by most of the historical buildings was selected. The video was filmed in the early morning, recorded 10 minutes of the environment digital media. After the video file was initially processed by the Insta360studio software, an mp4 format panoramic video file with a fixed viewing angle was formed, which later played as the background material importing into Unity3D for constructing the virtual tour environment.

4.2. VIDEO PROCESSING IN UNITY3D

Considering the necessity to transform the deformed panoramic video material with the spherical plane into several plane images for projection, the video needs to be intensively processed. In the Unity3D software, we use the panoramic video as video material and map it on the inner surface of a sphere. In this way, a normal angle of view can be obtained by taking views from the center of the sphere to the surface with the "Camera" object. As we were constructing an immersive environment, it is required to ensure that the field of view is filled with virtual images, which means that the horizontal width of the image is 210 degrees and the vertical is 180 degrees. However, after many rounds of tests, we noticed that from the perspective of user experience, there is a limited difference from the vertical viewing angle of 60 degrees to 180 degrees when experiencers riding a bicycle. Therefore, three cameras were adopted in the Unity3D to obtain the video view with 210 degrees horizontally and 60 degrees vertically from the spherical surface.

4.3. INFORMATION INPUT SYSTEM

As an interactive virtual environment, sensors need to be added to the bicycle for collecting user behavior information. In this experiment, we adopted a rotary encoder and a light sensor as information input devices. The rotary encoder was placed on the top tube of the bicycle to detect the direction of the bicycle's handlebar through gears. The light sensor was installed on the seat stay of the bicycle. By placing light barriers on the wheels, the light sensor could easily catch the rotation frequency of the wheel according to the change of light brightness.

The signals of the sensors were converted by Arduino into angle information and speed information and then transmitted to the Unity3D platform as the rotation angle of the cameras' perspective and the playback speed of the panoramic video. In this way, the panoramic video in Unity3D camera view could be changed in real-time according to the bicycle usage status.

4.4. INFORMATION OUTPUT SYSTEM

Projecting each camera display in the Unity3D onto the physical walls to form an immersive interactive environment was the last procedure. We picked Resolume Arena as the video projecting software platform to correct the parallax problem in the projection process. Via utilizing a screen capture plug-in, three "Game" windows in the Unity3D were captured separately into Resolume Arena and respectively assigned to the target projectors for virtual environment establishing.

After all, we achieved a remote online travel system that could change the immersive environment view direction and the traveling speed through cycling behaviors simultaneously.

5. Evaluation

5.1. EXPERIMENT PREPARATION

Since the research attempts to test whether this new system could improve the user experience of the virtual tour, a systematic user experience experiment on the system has been conducted(Figure2). As mentioned before, the virtual traveling system is unique in both the information input method and the information output method, so it contains two variables: the information input method(Controller and Bicycle) and the information output method(HMD and IPM). By successively changing the variables in the experiment, the research attempted to explore the influence coefficient of each variable on the participants' sense of presence and the virtual environment experience satisfaction level. Because when the output information is the same, the effect of shifting the input information is equivalent, the experiment set up three experimental environments: IPM+Bicycle as the target environment, HMD+Controller and HMD+Bicycle as the control environments(Figure3). Every experimental environment provides participants with an interaction design that changes the viewing angle of the tour and the speed of movement(Figure4). All the experimental environments used the same parameters, such as walking route, viewing angle width, acceleration, etc.

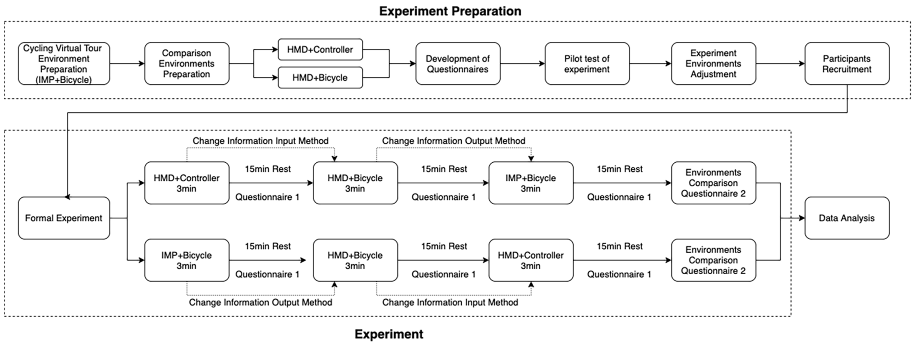

Figure 2. Experiment Design.

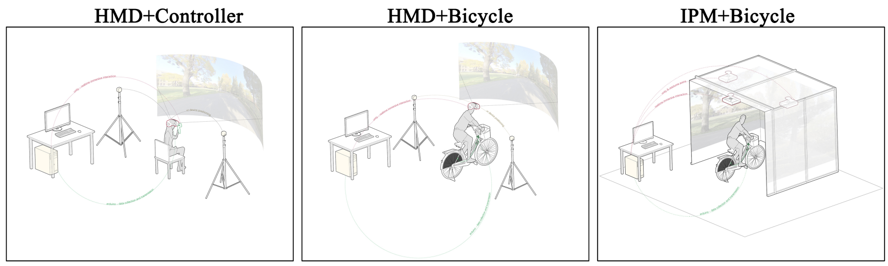

Figure 3. Three Experimental Environment Design.

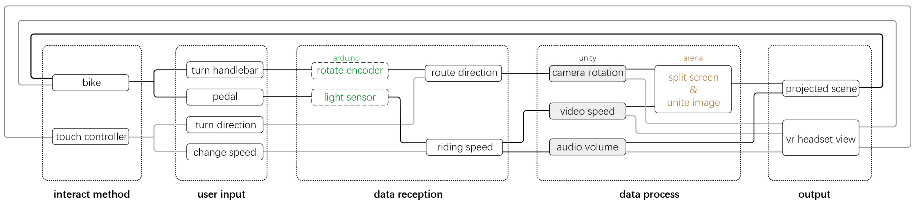

Figure 4. The Interaction Design Logic of Three Experimental Environment.

To verify the experimental hypothesis, the experiment chooses a qualitative research method based on user questionnaires. According to the existing research on spatial presence measurement within immersive environments in the fields of cognitive and computer sciences(Paes, Arantes et al. 2017), presence measured through subjective self-reporting using questionnaires is one of the most common methods of measuring presence(Schuemie, Van Der Straaten et al. 2001). The questionnaire design was based on multiple relevant existing virtual reality space presence evaluation researches(Witmer and Singer 1998, Schubert, Friedmann et al. 1999, Men, Bryan-Kinns et al. 2017, Paes, Arantes et al. 2017). At the same time, the research borrowed parts of Simulator Sickness Questionnaire(SSQ)(Balk, Bertola et al. 2013, Kim, Park et al. 2018) and User

Experience Questionnaire(UEQ) (Laugwitz, Held et al. 2008, Schrepp, Hinderks et al. 2014) to test the user experience of the experiment environments. As a result, the experiment constructed two questionnaires, each contains eight questions. Questionnaire 1 was used to score each experimental environment from 1 to 7, and Questionnaire 2 was used to compare and sort the three experimental environments (each environment option gets 3 to 1 point in order of ranking). By comparing the data between different questionnaires, the stability and reliability of the experimental data can be efficiently increased. Questionnaires are designed as Figure5.

Questionnaire 1	Questionnaire 2
Presence 1. How do you think the similarity between the experimental environment and the real environment? (1-7) 2. Did you feel you are in the environment? (1-7) 3. Did you feel you are moving?(1-7) **Attractiveness** 4. Did you feel happy during the experimental environment?(1-7) 5. Are you satisfied with the experimental environment? (1-7) **Efficiency** 6.Do you feel this interactive method is easy to learn and master?(1-7) **Comfortable** 7. Did you feel dizziness during the experiment?(1-7) 8. Did you feel security during the experiment?(1-7)	**Presence** 1. Please sort the three experiments according to the similarity between the experimental environment and the real environment. 2. Please sort the three experiments according to the involvement of the environment. 3. Please sort the three experiments according to moving speed in the experimental environment. **Attractiveness** 4. Please sort the three experiments according to your pleasure level. 5. Please sort the three experiments according to your satisfaction level. **Efficiency** 6.Please sort the three experiments according to the difficulty of learning and mastering interactively. **Comfortable** 7. Please sort the three experiments according to how much you feel dizzy. 8. Please sort the three experiments according to how much you feel security.

Figure 5. Questionnaires Design.

In order to improve the controllability and operability of the experiment, a pilot experiment with 8 participants was conducted before the formal experiment. Issues such as the duration of a single experiment, the rationality of the placement of the equipment, the speed of information transforming, the angle of lens conversion per unit time, and the safety control measures of the subjects have all been adjusted in the pilot experiment.

The experiment chose to recruit healthy people between 18 and 55 years old as participants. As Faas experimented with 30 participants(Faas, Bao et al. 2014), the sample size in the study of Daniel was also 30 participants (Paes, Arantes et al. 2017), Kim performed the experiments with 24 participants(Kim, Park et al. 2018), Sacks set the sample size as 20 to 25 participants(Sacks, Perlman et al. 2013). Based on those samples, this study set the sample to 32 participants (22 females and 10 males, average age is 24.7).

5.2. EXPERIMENT PROCEDURE

To eliminate the order effect, the order of the study was counterbalanced between subjects. The final sample randomly divided the participants into two groups(each group contains 11 females and 5 males): Group A started with HMD+Controller and sequentially change the information input method and information output method, Group B started with IPM+Bicycle and sequentially change the information output method and information input method. Participants were asked to experience three minutes in each experimental environment(Figure 6), and the experiment allowed to be suspended if the experiencer were suffering from severe dizziness. To minimize the influence of simulator syndrome from the previous test condition on the next test condition, the participants were given a 15-min break between each test condition. During the break, the participants were requested to answer Questionnaire 1. After the participants have experienced all the experimental environments, they were invited to fill in Questionnaire 2 for the three environments comparison.

Figure 6. User Experience Experiments.

5.3. DATA ANALYSIS AND RESULTS

By calculating the scores of the two questionnaires and extracting the average of the scores, the data analysis results can be obtained (Figure7), and we achieved the following outcomes.

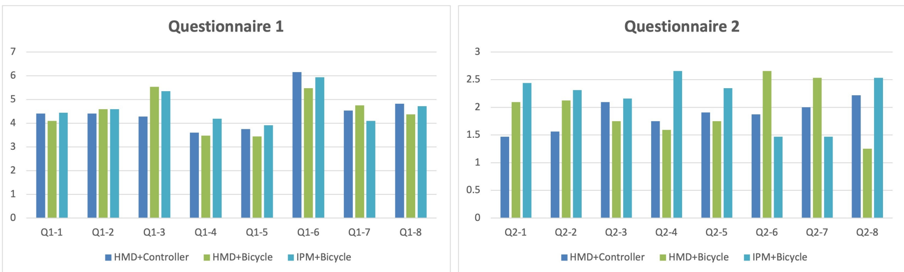

Figure 7. Data Analysis Results.

1. IPM+Bicycle shows superiority in the sense of presence compared to the other two, and the information input system via bicycles contribute more than the projection environment on presence enhancement. Although HMD+Bicycle presented a high sense of presence, the simulator syndrome was too severe for experiencers to enjoy the tour.
2. Participants reported that the user experience of IPM+Bicycle is also more enjoyable, which is reflected both in the pleasure enrichment and satisfaction improvement.
3. IPM+Bicycle is a more natural interactive traveling mode, but it does not show obvious ascendancy on the easement and convenience level of interaction behavior learning and mastering.
4. IPM could effectively decrease the dizziness and increase the security feeling, especially when experiencers were in motion. During the entire experiment,

six participants suspended the experiment nine times in total due to simulator syndrome, accounting for 15.6% of the total number of people and 8.3% of the total number of experiments. 78% of the simulator sickness happened when wearing VR glasses.

6. Conclusion and Contribution

The Cycling Virtual Tour system manifested a better user experience than the traditional virtual tour system with an advanced sense of presence and realism, higher satisfaction degree, and fewer reports of simulator sickness. This research discovered how information input system alteration may influence the virtual tour user experience and providing a design strategy reference for the interactive design of virtual tourism environment in the future.

Additionally, this system can be applied to a variety of spatial environments, such as museums, fitness centers, and family entertainment rooms. Since the projection environment requires a darker light environment, this research providing a new possible direction for the functional design of dark rooms in architecture design.

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