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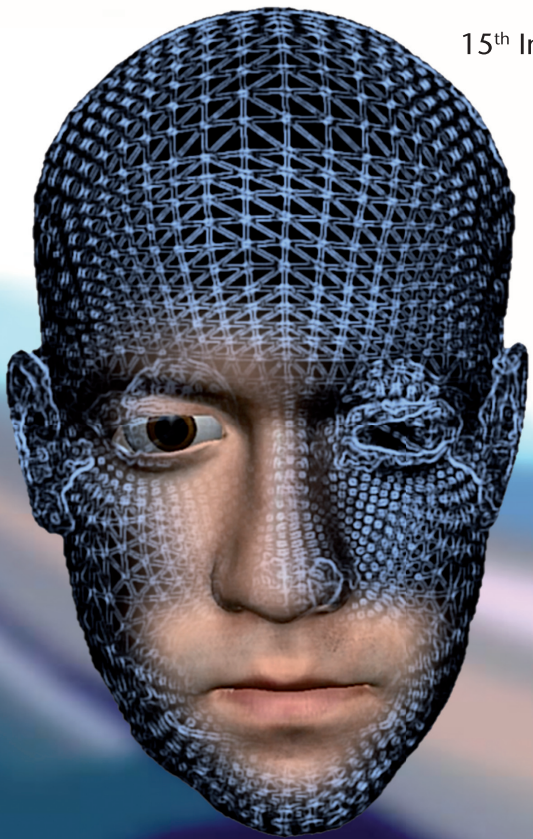

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Identification of Image-Based Virtual Reality for enhancing Spatial Presence Using Repertory Grid Technique

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Abstract. Spatial presence is the binary (on/off) experience of a feeling located in a mediated environment, such as media (e.g., movies) and geometry-based virtual reality. No studies on the spatial presence in image-based virtual reality (IBVR) applications currently exist because of the low interaction functionality of spatial presence. IBVR refers to photo-based images that are stitched together to form a virtual environment. Interaction functions are limited to navigation using hotspot hopping, panning, and zooming in/out within the virtual environment. However, IBVR applications provide highly realistic visuals that can create the spatial presence of users through the use of scenic photographs that are stitched together to create a realistic panoramic view. This paper reports the results of a comprehensive study that attempts to identify which characteristics of IBVR applications can enhance the spatial presence of users. A systematic mental model technique called Repertory Grid was selected as an approach for the data collection because the approach allows users to freely state their opinions. Three different IBVR virtual environments were created to fulfill the Repertory Grid technique requirement. A different virtual environment is necessary to allow users to compare and provide feedback. A discussion is presented based on two aspects of the IBVR: panning, and hotspot hopping. The results indicate that the spatial presence of users can be enhanced through flexible panning; and consistent, and informative hotspots.

Keywords. Spatial Presence; Virtual Reality; Image-based Virtual Reality

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Introduction

Presence has various definitions and can be categorized as tele-presence, spatial presence, social presence, physical presence, and sense of presence. Presence is a major design requirement (Ma & Kaber, 2006; Santarcangelo et al., 2010; Zanbaka, Goolkasian, & Hodges, 2006) and a critical component (Ma & Kaber, 2006) in mediated environments. The success of a system is considered to increase as the percentage level of the presence experience gained by the user increases (Murray, Fox, & Pettifer, 2007; Santarcangelo et al., 2010; Xiao, 2000).

An example of a mediated environment is the Virtual Reality (VR) application, which can be defined as a computer-simulated environment with high or low interaction between a human and a computer (Guttentag, 2010; Williams, 1995).

VR applications can be categorized into geometry-based virtual reality (GBVR) and image-based virtual reality (IBVR). GBVR has attracted the most research on presence because high interaction capabilities provide deep presence for users (Casati & Pasquinelli, 2005; Luciani, Urma, Marlière, & Chevrier, 2004). However, GBVR programming is complicated, and producing a realistic synthetic environment, such as a panorama, is time-consuming (Casati & Pasquinelli, 2005). Therefore, the IBVR has become a promising type of VR that can solve this problem.

IBVR refers to the use of images stitched together to create a virtual environment (Xiao, 2000). This type of VR offers photographic quality realism and provides the user with a 3D illusion during a walkthrough despite the absence of geometric information (Chen, 1995). IBVR applications can provide highly realistic virtual environments despite the use of a computer with low processing performance. The IBVR has three main features: panning, zooming in/out, and hotspot hopping. Panning allows users to perceive broad view margins, which provides a 360-degree environment experience. Zooming in enlarges an image or clarifies an object or area in an image, whereas zooming out shrinks the field of view of the image. The hotspot allows users to shuttle from one scene to another.

The interaction function in IBVR applications is limited because the navigation exists only in the virtual environment. Most IBVR applications have been developed for VR desktop applications. However, users are also expected to experience presence in IBVR environments despite the limited interaction function. The concept of presence in VR applications is not only dependent on the VR equipment. According to Biocca (2003) and Wirth et al. (2007), the way that the minds of users can accept a virtual environment as a real environment, is essential. Therefore, spatial presence, which is based on cognitive theory, is the most relevant factor in this situation.

Spatial presence theory is directly associated with the human mind (Wirth et al., 2003, 2007) and human emotion (Schubert, 2009). Therefore, spatial presence requires that cognitive theories explain the mental mechanisms that enable humans to feel presence when using media or simulated technologies (Biocca, 2003; Lee, 2004; Wirth et al., 2007). Thus, spatial presence can be defined as the experience of a user in being located in a mediated environment, which involves not only the application factor but also the expectation of the user regarding the media and their characteristics.

Research on IBVR characteristics and spatial presence remain lacking. Therefore, the objective of this study is to explore how each IBVR characteristic (hotspot hopping, panning, zooming in/out, and visual realism) can enhance the spatial presence of users. Previous studies used presence questionnaires focusing on SUS(Slater, Usoh, & Steed, 1998), Presence (Witmer & Singer, 1998), ITC-SOPI (Lessiter, Freeman, Keogh, & Davidoff, 2001), and MEC-SP (Vorderer et al., 2004) questionnaires, to obtain the opinions of users. However, the existing questionnaires are not relevant because of their development based on the GBVR characteristics, which differ from those of the IBVR.

A systematic mental model technique called the Repertory Grid was selected as the approach for data collection in this paper. The advantage of using a mental model approach is the freedom that users are provided in giving their opinions (Crudge & Johnson, 2004, 2007). Therefore, the result from the Repertory Grid technique is completely derived from the actual thoughts of the users based on an expected situation. We developed an IBVR prototype in three different VEs to obtain the information from the mental model of the user to aid users in evaluating the differences between the VEs. The users list the IBVR characteristics that would enhance their spatial presence completely based on their mental model opinions.

Related Work

From a human–computer interaction perspective, a primary concern is how to design an effective, efficient, and easy-to-learn interface when experiencing a VR application (Rizzo, 2005). Users should be able to easily learn how to navigate and interact in VE (Rizzo, 2005). Most researchers believe that information consistency with physical reality can obtain high presence (Bouchard et al., 2012; Magnenat-thalmann et al., 2005). A VE that consistently conveys information with real-world experience leads to a greater experience of presence (Bouchard et al., 2012). Devices related to hand tracking, gesture recognition, pointing, and gaze direction are more likely to produce high user presence (Magnenat-thalmann et al., 2005; Rizzo, 2005). Input devices used in VR application such as buttons, sliders, dials, joysticks, and steering wheels (Rizzo, 2005) can be easily mastered by users (Barfield, Baird, & Bjorneseth, 1998), but restricts interaction with the environment (de Kort et al., 2006). These aspects affect the user experience of actually being in that environment, which is known as "presence." However, several studies on user-controlled media revealed the positive effects of such aspects on presence perception during manipulation (Bae et al., 2012). With the support of manipulation equipment such as a mouse or a keyboard, a user can experience high spatial presence (Bae et al., 2012). Users can control and explore the objects in the VR application through manipulation. Navigation without the manipulation function in VR applications could also elicit a user's sense of presence but requires realistic VE presentation (Wirth et al., 2007).

Methods

User requirement specification also forms a crucial part in design methodology. Researches use questionnaires, interviews and etc. in this phase. However, in our study, we used systematic mental model technique. This is because mental model technique can help users to give their opinion without bounding to specific guidelines. Hence, they can freely give their opinion based on their experience.

We chose Repertory Grid technique in our study. The advantage of this technique is that users develop their own Personal Construct to list the IBVR characteristics that can enhance spatial presence experience and they also have to evaluate the application based on the list. Hence, in this section, we will discuss how the Repertory Grid form and three preliminary IBVR applications are designed as required by the repertory grid technique.

Designing the Repertory Grid Form

We design the form based on (Steed & Mcdonnell, 2003). The challenge in designing the form lies in the questions and scenario from preliminary IBVR applications. The questions should clearly describe the objective of the survey, and make it easy for the respondents to understand what they should answer in the form. A pilot study is conducted to ensure that the respondents understand the form.

Developing the Preliminary IBVR Prototype

In Repertory Grid technique, more applications are displayed to respondents, more results can be obtain. According to (Steed & Mcdonnell, 2003), minimum six applications can be used in the repertory grid technique to identify the criteria of a VE. These applications were exhibited to users for a short period during the first pilot study. However, the results shows that, users were unstatisfied with the short duration, particularly in terms of presence experience.

Thus, according to our study, the quality of the application is more important than the quantity of the application. This statement is based on our first pilot study. Even though we provide six applications, four out of six users only do not seriously see all the preliminary IBVR application .

Hence, we want the user to experience the spatial presence by using all IBVR characteristics that is applied in preliminary IBVR application. So that, it is easier for them to list IBVR characteristics that could enhance spatial presence experience in Repertory Grid Form. As such, we consider only three applications. This is because, the respondents of our study is among staff. They do not have enough time to navigate more than 15 minutes. Thus, one IBVR application can take approximately 3 minutes to 5 minutes. In our study, most respondents are willing to participate in the survey for not more than 15 minutes.

We apply psychological theory in the first application. The theories used are destination theory and picture theory because according to (Biocca, 2003), psychological theory can cause the mind of the user to believe that he/she is in the mediated environment. The second preliminary IBVR application consists of a first panoramic view with animation and a second panoramic view without animation. The third IBVR application consists of a panoramic view without sound. These applications are entirely different from one another. The results do not exhibit a connection with spatial presence theory.

Thus, we redesign our preliminary IBVR application. Most criteria for these preliminary IBVR application applications are similar. For example, we apply psychological theory to the first two applications. Hence, a story line is included in these two applications. For the third application, we use the same panoramic view as in the first two applications, but we do not include a story line. A second pilot study is then conducted. The result shows that theory of spatial presence is elicited among the respondents.

Conducting the Experimental Study

In the experimental study, users view the first preliminary IBVR application and list the features that enable them to experience presence. Next, the users view the second application and list the different features that create presence. This activity is repeated until the users can no longer list different features. Upon completing the listing, a short unstructured interview is conducted. The purpose of this interview is to understand the true meaning of each feature listed by the users. During this session, users provide additional ideas regarding the IBVR application.

Analyzing the Results

Previous researchers used various tools for analyzing Repertory Grid data. For this study, we used WebGrid V, an internet application created by the Center for Personal Construct Studies (CPSC). There are many advantages to using WebGrid V as the ability to display grid online. However, we were most interested in two of the analysis methods offered.

'Cluster' analysis uses FOCUS grids to show the highest possible correlation between constructs. The vertices of the grid arrange the elements instead of being sequential, into the 'best fit' placing the constructs along these vertices, with similar constructs along these vertices, with similar constructs closer together. A hierarchy graph rating at the side shows the correlation between particular constructs closer together. A hierarchy graph rating at the sides shows the correlation between particular constructs. Cluster analysis also allows for the threshold of the graph to be adjusted to only show higher or lower correlation. This helps in identifying cases where constructs are similar. Printouts of the percentages allow each correspondence to be numerically verified.

Results

Looking at the isolated Grids provides some insight into how individuals conceptualize their own creative practice, providing an interesting talking point for discussing with respondents. In an individual setting can be an ideal format for gaining rich information using the study as a form of structured interview. However, despite the fact that numerous constructs seem to repeat themselves by emerging independently across participants, we don't yet know if they are actually referring to the same kinds of ideas or whether they are all mean something different. Having constructed the study as a group test we can begin to examine these issues in more detail. The following section provides an exploration of all participants' data taken together; again looking at the correlations between constructs how they are related and what they might mean.

According to above paragraph, we utilize a method suggested by Shaw and Gaines, based on identifying consensus, conflict, correspondence and contrast between constructs; consensus describes where respondents use similar terminology to describe similar attributes, correspondence describes where experts use two different terms to describe similar attributes, conflict describes where respondents use the same term for different attributes and contrast describes where both terminology and attributes differ. We were able to identify consensus and correspondence terms only. However for the scope of this paper, we only represent the result of corresponding terms.

The following sub-sections reports on the criteria of Hotspot and Panning that can elicit spatial presence among respondents. The result is analyzed based on respondents' expectation about hotspot and panning that are provided in three preliminary IBVR applications.

Hotspot Hopping

The strongest correlation between results in figure 1 is between respondent 30th – respondent 8th, respondent 69th – respondent 21st - respondent 9th – respondent 8th - respondent 25th – respondent 70th in 100%. The correlation between respondent 71st – respondent 35th is 88.9%. Overall correlation for this group is 81.5%. Interestingly for this group is the respondents indicate that hotspot function assist them to develop excitement in exploring the virtual environment. Thy can experience the sensation of shuttle from one visual to another visual with hotspot. The sequence of the panoramic view in virtual environment is accepted by the user's mind as normal activity that usually occurs when the user is in the real location.

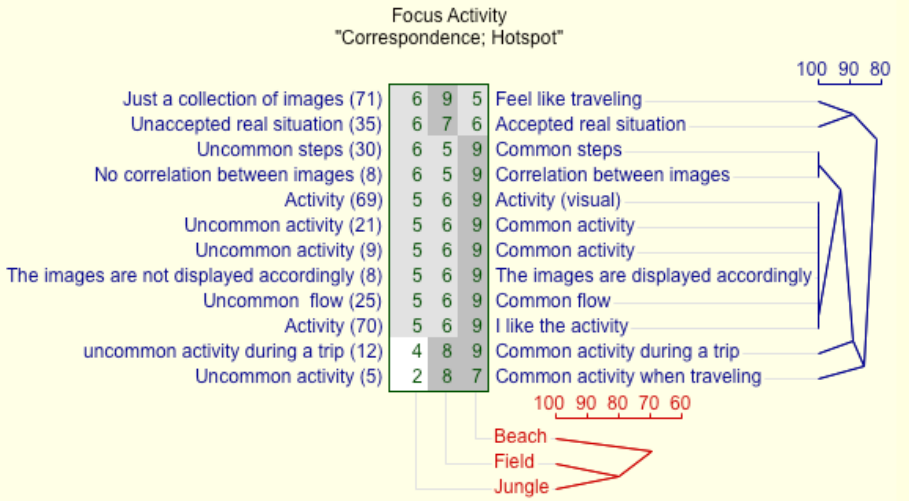

Figure 1. Hotspot 'Activity' Focus Cluster Grid

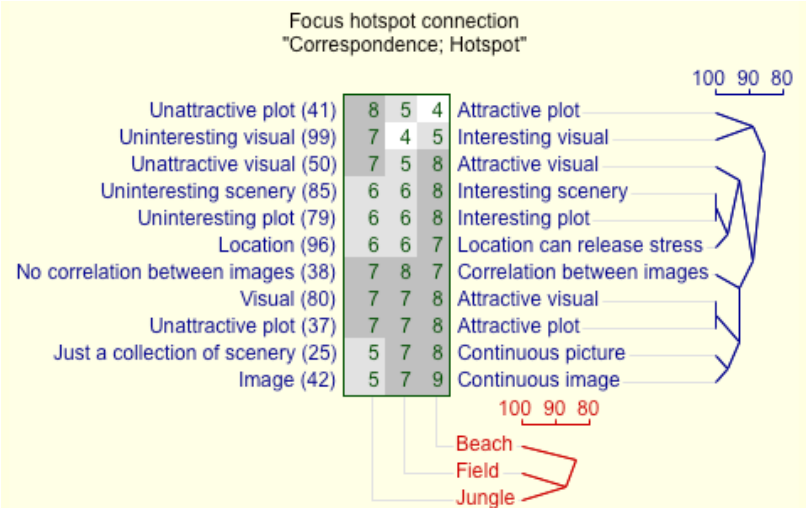

Figure 2. Hotspot 'Connection' Focus Cluster Grid

The grouping in figure 2 appears to describe the function of the hotspot in IBVR application. They indicate that hotspot function is interesting and assist in creating spatial presence experience. The strongest correlation in figure 2 is between respondent 85th – respondent 79th and respondent 80th – respondent 37th is 100%. This grouping also shows a correlation between respondent 25th – respondent 42nd (96.3%), respondent 99th – respondent 41st (88.9%). Overall correlation for this construct is 85.2% and shows that 9 from 11 respondents rank element 'Beach' from 7 to 9. The result shows that hotspot function in beach can be elicit their spatial presence experience. Differences hotspot functionality on the element 'Beach' compared to the other element is the relationship between images. Relationship between images means that when a user clicks 'hotspot', the user can see a sequence of panoramic view that can be accepted by the user's mind.

Panning

The grouping appears to point out towards panning function in Figure 3. Although there are twelve different terms in the construct, the meaning is same. The grouping has the correlation of the set with all the constructs showing 85.2 % correlation. Respondent 33rd –respondent 20th describe the same ranking between elements.

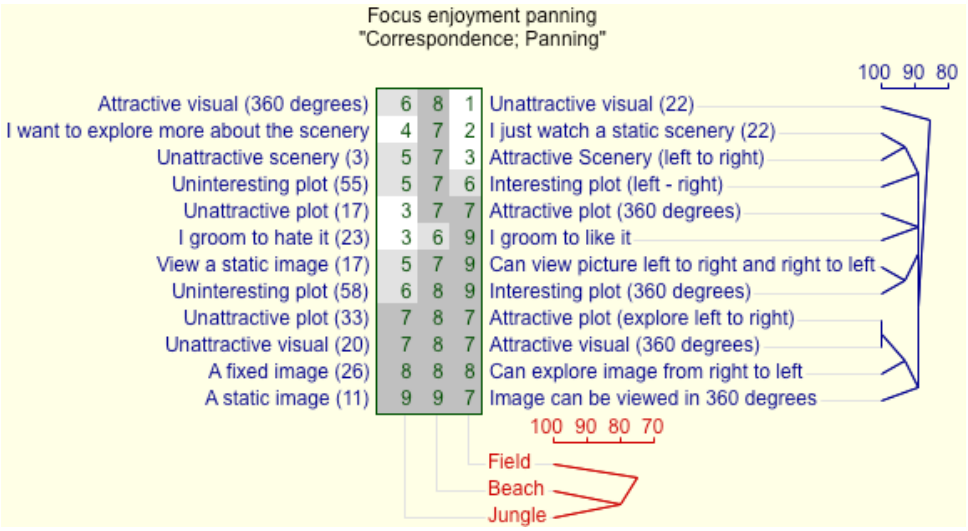

Figure 3. Enjoyment of Panning Focus Cluster Grid

This group shows 92.6% correlation between respondent 22nd – respondent 3rd and respondent 17th – respondent 58th. The rest is corresponding with 88.9%and eleven from twelve respondents indicate that panning function in element 'Beach' in ranking 7 to 9. Panning function in this element is different because all the panoramic view has panning function. Panning function in IBVR application indicates that the user can see the panoramic view in 360 degrees. Hence, panning create and enjoyment of viewing the scenery because users are free to move left to right or right to left as they wished. Although the users shared the same opinion but they rank the best panning function in elements differently. This grouping shows that element beach give the best panning function.

Discussion

A user feels indirectly located in a location when the hotspot, panning, and zooming in/out are easy to use because specific manual references are not required to use these function. Similar to the findings of (Rizzo, 2005), our result revealed that the application should be easy to use and that users should be able to easily learn how to use hotspots in the IBVR application. The spatial presence theory proposed by (Wirth et al., 2007)also refers to the user's mind when first using the IBVR application. Our result clearly indicates that a difficult first use may cause the user to stop using the application.

The connection of the hotspots and visuals is also crucial in developing spatial presence. This connection directly shuttles users from one visual to another in a flow. Although the situation does not exactly mimic real-world activity, the hotspot can provide spatial presence. (Bouchard et al., 2012; Magnenat-thalmann et al., 2005) speculated that activities in the application that are consistent with the real world provide high presence. Our finding revealed that the application can provide user's spatial presence if the flow of the IBVR environment can be accepted in the user's mind. The panning function also contributes in creating a realistic visual.

The icons for hotspot, panning, and zooming in/out should also be consistent to develop a perception of the same location in the user's mind. Our results support that of (Xiao, 2000), who claimed that panning and zooming in/out icons also require information. The result is also related to that of (Bae et al., 2012), who stated that manipulation and navigation using a mouse and keyboard can improve user's spatial presence. However, IBVR applications only apply the navigation function. The end-start hotspot describes a "reverse plot" function as mentioned in (Wirth et al., 2007) spatial presence theory.

Limitations and Conclusion

This study uses non-immersive equipment because we have aimed to develop a low-cost and practical VR application. However, users would experience increased spatial presence if a big screen and HMD were used. Given the result and discussion, the specific criteria of an IBVR application can be used by developers to enhance user spatial presence. The Repertory Grid technique is suitable for use in an exploratory study because users are free to express their opinion without specific questions or items. Users can also provide detailed description on the hotspot, zoom in/out, panning, and visual realism factors.

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