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Calmness in Virtual Environments Enhance User's Spatial Presence Experience

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Abstract

Presence has been described to be crucial in several virtual reality (VR) applications. Among the factors influencing presence, realistic virtual environment has been examined extensively from the angle of geometry-based virtual reality (GBVR) application. The visual of the applications has been manipulated by altering numerous technological characteristics or by adding more sensory information (such as touch and smell). However, realistic virtual environment in GBVR application often required complex programming and takes longer time to develop. As such GBVR application is not acceptable for the application that needs to have a collection of realistic panoramic virtual environments. An alternative solution for above statement is image-based virtual reality (IBVR) application. IBVR refers to photo-based images, stitched together to develop a realistic panoramic virtual environment. Based on this method, many realistic virtual environments can be created in much less time but with limited interaction function. Despite this limitation, realistic virtual environment in image-based virtual reality is expected to enhance user's spatial presence experience, which is supported by spatial presence theoretical model. There a few levels in this theoretical model before the formation of spatial presence, and the most important part in this theoretical model is primary egocentric reference frames (PERF), adapting calmness to produce spatial presence experience. Thus, this chapter describes the summary on adapting calmness as PERF.

Keywords: presence, spatial presence, virtual reality, image-based virtual reality, interactivity

1. Introduction

Virtual reality (VR) is one of the technologies that can produce artificial virtual environment or medium which user can attach and communicate whether in low or high interactivity [1, 2]. VR is grouped with image-based virtual reality (IBVR) and geometry-based virtual reality (GBVR). The most popular is GBVR that has fascinated the most presence researcher because GBVR application can deliver high interactivity and high immersion toward user's presence experience [3, 4]. However, developing high realistic artificial environment in GBVR is time-consuming [4]. As an alternative, a promising type of VR that can produce high realistic artificial environment in much less time is IBVR.

IBVR is defined as simulated artificial environments from a collection of stitch photographs which users can interact and navigate in a 3D realistic artificial environment despite the absence of geometric programming. IBVR can produce more than one realistic virtual environment with a low performance processor. The main navigation functions of IBVR are zooming in/out the margin in artificial environment, hotspot hopping from between a few artificial environments and pan the artificial environment in 360 degrees.

Interactivity in IBVR is limited for navigation compared to GBVR which provides high interactivity to navigate and manipulate. Despite the limited navigation function in IBVR, users can experience presence. The formation is that, however, according to [5–7], despite high interactivity, the degree of user's mind of acceptance of artificial environment more than the real surrounding is essential to experience user's presence. Thus, in [6], a spatial presence theory is proposed which does not focus on interactivity; however, the most important aspect to produce user's spatial presence experience is because of the user acceptance on the visual or the spatial of the artificial environment. This theory convinces that IBVR with high realistic artificial environment and limited functions is still capable of producing and enhancing user's spatial presence experience.

2. Problem statement

Realistic panoramic artificial environment provided by IBVR application, to date, lack of research has been found investigating spatial presence in it due to its low and limited navigation capability that primes researchers and anecdotes believe that it offers low sense of presence [2]. Most important is users can relax when watching the virtual environment or mediated environment to enhance spatial presence experience. Examples of mediated environment are videos, movies, documentaries, pictures, and books. A few researches specify that the collection of realistic plot in mediated environments could elicit and enhance user's spatial presence experience [6]. Thus, it is expected that IBVR which compresses stitched images to produce artificial environments could induce spatial presence experience among users.

There is a researcher who conducts a study of the model parts, namely components and user actions [16]. Based on previous researches, none of them discusses the media characteristics that are involved in order to reach the PERF hypothesis first before a user starts experiencing spatial presence experience. Even though in spatial presence theory by [11], the researches concentrates on the fact that media characteristics can increase user's spatial presence experience via the PERF hypothesis. In addition, no research is conducted on the specific criteria of PERF hypothesis.

3. Literature review

Wirth [11] defined spatial presence as “a feeling of being bodily present in a mediated environment (self-location) and a feeling of being able to act in synthetic environment (possible action).” A spatial presence theoretical model that integrates media factors and human factors are presented in [11], and the formation of a user's spatial presence experience is shown in **Figure 1**.

The formation of spatial presence theoretical model as shown in **Figure 1** is from components in the bottom to produce first level and components to produce second level. Components consist of four parts which are media factors, process components, user actions, and user factors. The formation started from the “empty slot” to adapt mind to the visual in the media. Empty slot is user's mind giving attention

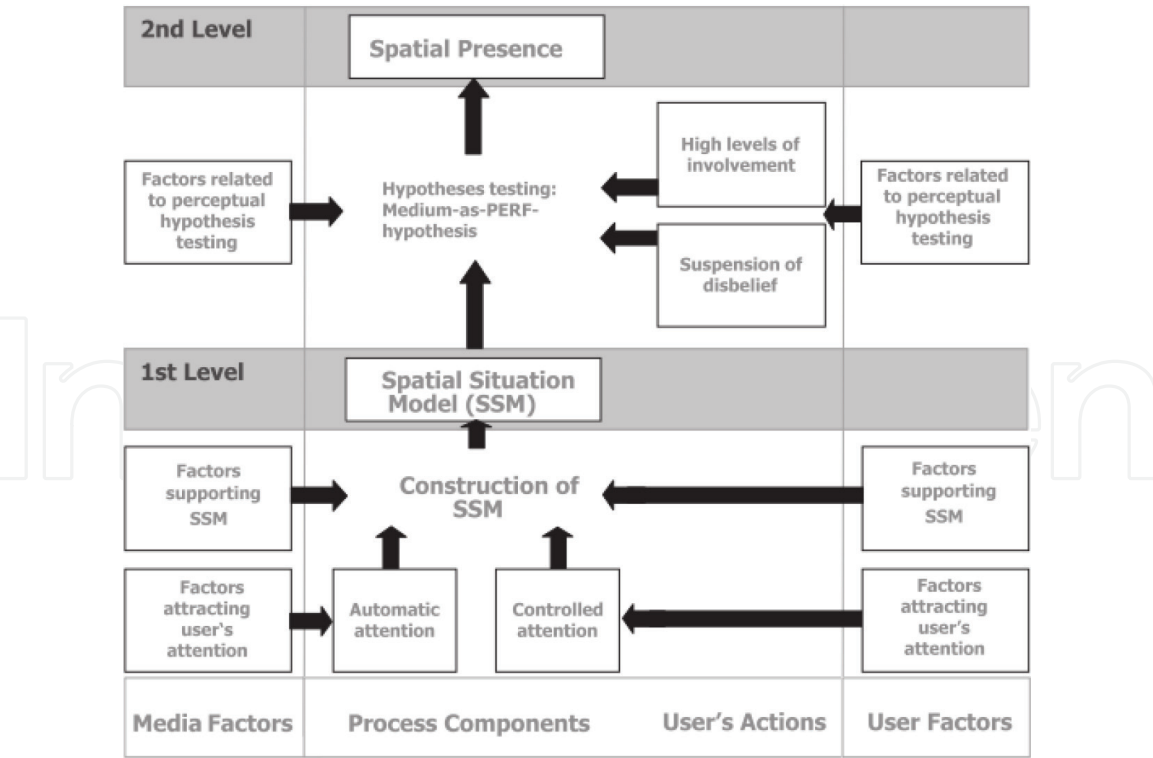


Figure 1.
Spatial presence theoretical model from [11].

to the media. Then, the user's mind will keep receiving input from the media until the percent of adapting media is higher than real surrounding. From this theory, the primary egocentric reference frame is important in bridging the user's mind to spatial presence.

In the second step, a user's spatial situational model allows the user to accept the primary egocentric reference frame (PERF). PERF can be defined as the process where a user's mental model accepts the existence of the mediated environment and unconsciously leaves behind the user's mental model of the real environment.

Based on the diagram of the spatial presence theory in **Figure 1**, primary egocentric reference frame (PERF) is intermediate between three important relationships. The first correlation is between spatial situational feeling and spatial presence experience. The second correlation is between media factors and spatial presence experience. The third correlation is between the user's action and spatial presence experience. These correlations conclude that PERF is an important role in creating a user's spatial presence experience.

The existence of PERF is due to the hypothesis which is constructed by an individual. This hypothesis is developed based on the first individual's perception about what he/she watches. For example, when an individual sees pictures of food, he/she assumes that the food in the picture is delicious. So, PERF hypothesis is that the food is delicious. Once this hypothesis is received by an individual, then the spatial presence experience exists.

Basically from the literature review, a persuasive media factor is agreed by the researchers to produce a user's spatial presence experience. However, lacks of specific characteristics are produced by the researchers about the media factors that can produce a user's spatial presence experience. In fact, this theory informs the reader that spatial presence experience exists if a user feels it as situational. Based on the explanation of the previous subsections, it has been noted that there are a few steps that the user's mind have to experience before experiencing a user's spatial presence experience. Spatial presence theory mentions that if the user is consciously

watching the virtual environment, he will unconsciously forget about what is happening around him/her which means that the user is experiencing spatial presence experience.

As mentioned in the previous section, the spatial presence theoretical model from [6] is suitable for the development of the spatial presence model for IBVR. This section reviews the related work that applies spatial presence theory from [6]. Even though the selected theory is introduced in 2003, the enhancement and validation of the theory is continuously interested by the researcher until 2015. The related works on the selected spatial presence theory are presented in **Table 1** and the descriptions are the following paragraphs.

Wirth [6] presented a spatial presence theory. Again, the author highlights that spatial presence is about the feeling of the synthetic environment that the user has after the PERF stage [6]. Spatial presence is caused by an unconscious spatial cognition. The author indicates that the user responds to the possible actions in the synthetic environment [14]. In the author’s words, “the experience of this feeling in virtual environments, mediated real (remote) environments, or real environments is referred to as spatial presence” [14, p. 163]. What is more from author, “a perceptual emotion consciously experienced as the feeling of being there in virtual environments, mediated real (remote) environments, or real environments is referred to as spatial presence” [15, p. 899].

Sacau et al. [9] also proposed a few individual factors that measured user’s spatial presence experience. The authors start with proposing two individual factors that can provoke user’s spatial situational model; domain specific interest and spatial visual imagery; while absorption is proposed as the individual factor that can provoke user’s spatial presence experience. Moreover, the authors also highlight that PERF is about a condition that can construct spatial presence experience.

Lukowska [10] describes that a research is also needed to give attention for presence experience. The author’s research is about the formation of spatial presence from physical environment to virtual environment. Attention to the VR application makes him/her feel presence. If there is an auditory signal in the physical environment, the user feels distracted. The attention shifts from the virtual environment to physical environment. However, when the user neglects the auditory signal, then the user can shift the attention back to virtual environment. There are two important descriptions related to this model: efficacy of shifting and absorption level. Efficacy of shifting is about the influence of the process in the mediated environment such as VR application in feeling presence. Absorption level is about the impact on a detection process by affecting the perception threshold level.

Enhancement on the model follows with [8]; the role of emotional involvement and trait absorption are proposed to enhance spatial presence theoretical model. Their research indicates that these factors provide a formation process in developing

Author	Timeline	Theory
[6]	Theoretical model	Illustrated diagram
[9]	Theory enhancement	Propose individual factors
[10]	Theory confirmation	Formation on spatial presence
[12]	Theory confirmation	Validating users factors
[8]	Theory enhancement	Proposed emotion
[13]	Theory confirmation	2 factor in spatial presence

Table 1.
Related work on selected spatial presence theory.

user's presence experience. However, a further investigation has to be considered before these factors are applied in spatial presence theoretical model.

Besides enhancing the spatial presence model, Hofer et al. [12] validated the model by using structural equation modeling. There are some items for a variable that is received and discarded. Once again the addition is carried out on part of the user experience factor of spatial presence. These factors are the emotional involvement and absorption trait can make the user experience spatial presence. These additions were validated and show that emotional involvement plays an important role in creating spatial presence but through this validation, it is evident that there also exist two parts, spatial situational model and spatial presence.

4. Research methodology

After the three locations in IBVR applications are developed, testing is conducted. Three steps are involved in this study: familiarization session, constructing elicitation, and understanding the personal construct of the respondents.

4.1 Familiarization session

During this phase, the objective of the study was explained to the users to enable them to list the features in IBVR application that can create a spatial presence. Users were also allowed to explore the virtual environment and this environment is not be used in the following experiment. Before the study starts, respondent is shown with location of flower farm but this location will not be shown in the study. The purpose to show the flower farm is to teach the respondents on a few functions in this application such as hotspot and panning.

Users are allowed to try the IBVR application because of the mental model theory. Mental model for familiar and unfamiliar users with the IBVR application is different [11]. If users are not accustomed to using the application, they may feel bad or lose their willingness to use the application. In contrast, users who are familiar with computer applications already know how to use the IBVR application even though they are unfamiliar with the system. These users should not have a problem exploring the system during an experiment when they are alone in the room.

4.2 Construct elicitation/grid completion

A description of how to develop the personal construct in the repertory grid form is provided below.

- First, a respondent writes the IBVR characteristics that they believe can enhance their spatial presence experience in the “positive” column of the form.
- Second, in the “negative” column, a respondent writes the opposite feature of the IBVR characteristics that they wrote in the “positive” column.
- Third, a respondent rates the three locations in the “rate the type of locations” column. All users are asked to rate each construct in a scale of 1 to 10 (1 = least desired to feel presence and 10 = most desired to feel presence). As a reminder, the respondents are not given examples of IBVR characteristics so that their mental models are not disturbed. The characteristic of such personal constructs is that they are based on individual mental models.

Finally, after respondents were satisfied with their answer, they rated the locations in the repertory grid form. The respondents rated each construct in a scale of 1 to 10 (1 = least desired to feel presence and 10 = most desired to feel presence).

Upon completion of the listing, a short unstructured interview was conducted to understand the meaning of each feature listed by the users. During this session, the user was able to provide additional ideas regarding the IBVR application that they viewed during the construct elicitation session.

4.3 Understanding personal construct from respondents

The repertory grid approach lists IBVR characteristics in the form of quantitative and qualitative data so as to gain a deeper understanding of the IBVR characteristics listed by the respondents. Gathering information from respondents using the unstructured interview technique is important to gain consistent results from them. The interview began by asking participants which IBVR characteristics can provide high impact for their spatial presence. Users then have to justify their answers.

Even though the respondent listed four or six IBVR characteristics, not all IBVR characteristics were considered acceptable. This is because during the interview it became clear that some IBVR characteristics noted down actually refer to the similar IBVR characteristics. As such, instead of four items, only three items were used for analysis. Furthermore, there was a respondent that was not confident with the IBVR characteristic that s/he wrote on the repertory grid form. In that case, the IBVR characteristic was rejected or deleted.

Besides removing any irrelevant IBVR characteristics, grouping is also important before analyzing the data. Every time, after the data from the repertory grid is collected, the data were grouped based on the results of the interviews since there are 100 respondents to avoid confusion.

Furthermore, based on this categorization, it is much easier to group the IBVR characteristics manually. Even though researchers suggested inserting all the data to NVivo, which will give us the result of grouping by using the Word Cloud technique [16], for this study, the data is grouped manually. This is because a different respondent may have given the same IBVR characteristic but the description of that IBVR characteristic is different from the one given by another respondent. In such cases, this IBVR characteristic is not suitable to be part of the same group.

5. Result and analysis

In this study, three locations were used in IBVR application. Five basic features were developed in all locations in IBVR application. These are hotspot, panning, storyline, recorded natural sound, and animation. These features were listed by the respondents in the repertory grid form. These features were also further discussed by the users in the repertory grid form.

Some respondents indicated that the calmness features in the IBVR application helped them feel presence. There are three features of calmness: calm panoramic view, calm color, and calm sound. These features are described in the following subsections. The calmness group in cluster grid for calm panoramic view (a), calm panoramic view (b), calm color (a), calm color (b), calm sound (a), and calm sound (b) is 81.5%, 88.5%, 85.2%, 81.5%, 81.5%, and 81.5%, respectively.

5.1 Calm panoramic view

Respondents argue that a calm panoramic view is one factor that could enhance spatial presence experience. An example of negative and positive statement is

“Scenery uncomfortable/unpleasant/visual displays a collection of scenery - Scenery comfort/pleasant/visual displays a collection of calm scenery.” The respondents liked the panorama virtual environment if they had a preference for that location in the real environment. Therefore, the virtual environment in the IBVR application must have more than one location so that the respondents could choose their favorite place.

Calm panoramic view is realistic panoramic virtual environments that make user feel calm. Based on the interviews, putting additional distracting object should be avoided in a panoramic virtual environment. User will only appreciate the beauty of the environment if there is no [17] distracting object in the virtual environment.

5.2 Calm color

The respondents also described calm colors in a panoramic view as one factor that could enhance their spatial presence experience. An example of negative and positive statement is “Bright color/hot weather/low temperature - Soothing/cool color/comfortable weather/high temperature/refreshment colour.” The reason they chose this location was because they liked the panoramic view. The calm colors that were indicated by the respondents were defined as the light parameters of the panoramic view.

Calm color is about the level of light for panoramic virtual environment which is shown as scenery in a sunny day when the weather is nice and warm. The color of the visual is not too bright to make the user feel calm [17].

5.3 Calm sound

The respondents noted that natural sounds in the field made them feel calm. Hence, they felt as being located within the virtual environment. Examples of negative and positive statement is “Natural sound that distracts my feeling, non-calm sound, I heard the natural sound and I feel distracted, natural sound, the sound make me not calm - Natural sound makes me calm, calming sound, I heard the natural sound and felt calm, meditation natural sound, the sound makes me calm.” In further examination of the interview output, it was concluded that the respondents preferred a natural sound if they liked the virtual environment. Thus a respondent's belief of a sound being calm is subjective. Nevertheless, the most important aspect about sounds is that the sound makes them calm.

Calm sound is defined as meditation sound that is usually used by therapists to make a patient feel calm. The recorded natural sounds make the user feel calm [18].

Respondents also indicate that calmness in the IBVR application have helped them feel spatial presence. When the respondents feel calm when exploring the panoramic virtual environments in IBVR application, they eventually feel spatial presence experience. There are three features of calmness: calm panoramic view, calm color, and calm sound.

6. Discussion

Soothing music can make the user feel calm [28]. As expected, the results of this study are similar to the finding of the aforementioned. A recorded natural sound is required to make users feel calm. Calmness is created if the user prefers the location which is accompanied by the recorded natural sound. As mentioned in [22], users do not feel distracted in a noisy environment if they hear their favorite music. The findings of this research are similar with [23]. The natural sound in a user's favorite

virtual environment can make the user feel calm. If they do not like the natural sound, then they will feel distracted. Consequently, they will lose their attention to the virtual environment and spatial presence experience will not be achieved.

The finding also indicates that the existence of objects in a virtual environment is important in creating calmness. What is more, objects that do not infuriate the respondent are necessary to make him/her feel comfortable and calm. These findings support that a beautiful and clean environment which is in line with the user's favorite places can produce calmness for the user.

Besides a calm environment, this research also identified that the color of the virtual environment is not accepted as the factor in user's calmness. This finding does not support the report of [19–21] which mention the user's emotion when the user watches a dull, gloomy, and attractive virtual environment with the different color of the bench. In Baños et al.'s [19] research, there are colors for each virtual environment. But for this research, there are no specific colors in the virtual environment. Besides that, when the IBVR application is developed, the level of the brightness is same. The user might overlook that the color of visual is an element that produces perceptual realism.

7. Conclusions

This research identified that calmness can produce user's presence experience. Furthermore, the psychology researchers also stated that realistic panoramic virtual environments can produce spatial presence. Furthermore, factors in IBVR such as calm sound and calm scenery make users experience spatial presence when they interact with IBVR application. From calmness, users can experience spatial presence.

Author Notes

This article is adapted from PhD thesis entitled Spatial Presence Model for Image-based Virtual Reality (SPM4IBVR).

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