Measurement of Presence in Large Scale Virtual Environments

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Abstract. It is now widely accepted that a sense of presence in a virtual environment is a crucial part of the success of the 'experience'. This paper extends the authors previous work in naturalistic interfaces and perception of image to test experimentally the degree to which the type of interface and visual nature of the virtual environment determine the experience of presence or 'being there' in a large scale architectural virtual environment.

The importance of presence to the success of architectural virtual environments is an important discussion. Should architectural VEs strive to be hyper-real (with all the attendant hardware issues of manipulating large amounts of data in real-time) or does a degree of abstraction in representation still afford an acceptable degree of presence?

Keywords. Virtual Environments, Presence

The paper presents the results of a series of experiments in which controlled groups, with differing degrees of experience of both architectural education and virtual environments were asked to evaluate the degree to which they felt 'immersed' and 'involved' in different representations of a large scale VE. This builds on previous work on the nAVRgate project (Knight, Brown 1999) in evaluating the degrees of success in the approach. Results of this work will have a direct impact on the future direction of the work in its two areas, that of the physical interface and the nature of the virtual environment.

Previous work had been based on the premise that a natural navigation system would enable an increased degree of involvement and presence. The concept of presence is extremely subjective and behavioural, and can only be loosely described as the feeling of 'being in a place' (Steuer, 1992). Witmer and Singer (1998) suggest that we all experience varying degrees of this feeling on a daily basis, through becoming engrossed in media such as books, TV and cinema. By becoming engaged in a task or storyline, our mind becomes involved and we feel a part of it. They also state that presence is brought about by focusing attention on a 'meaningfully coherent set of stimuli'. It is not yet clear whether there is a threshold of attention to be focused before presence is felt, but it is generally agreed that the amount of attention focused is directly proportional to the amount of presence felt. So a successful immersive Virtual Environments (VEs) should take advantage of our psychological 'ability to "transport" our "presence" to another place that may not exist in reality' (Sadowski & Stanney, 1999)

For virtual reality to be experienced successfully, it must be possible to overlay sensory information derived from interacting with the environment onto the normal proprioceptive channels. These have been defined as "...that continuous but unconscious sensory flow from the movable parts of our body (muscles, tendons, joint), by which their position and tone and motion is continually monitored and adjusted, but in a way which is hidden from us because it is automatic and unconscious" (Sacks, 1985). Proprioception allows us to construct a mental model of our body for any given situation and the disposition of its limbs. Taking this argument further, the type of interface that is employed in a VE can increase the 'naturalness' of an experience by grounding the user in the familiar, that is allowing the interface to reinforce the proprioceptive signals that the user would have experienced in reality.

The nAVRgate project proposes a series of naturalistic interfaces for differing tasks for architectural virtual environments. With a large scale urban VE, navigation methods such as flying are useful in the appreciation of the macro scale, but do little to engage the lay viewer with a scale that can be easily related to. We were interested to experimentally have an indication of the success of this strategy, initial anecdotal evidence from users being supportive. Parallel work by the authors on perception of the rendered image has had a direct impact on the nature of the large scale VE. Reassessing the degree of detail required has enabled the model to be both recognisable computationally efficient. A model of the University campus was chosen for development. For reasons of economy of effort, a small area of the model was chosen for further detailed development. Two versions at different levels of detail were developed and these formed the basis of user testing, one have a reduced level of detail in the form of a basic massing model (high frame rate/low recognition), the second a full detailed model (low frame rate/high recognition). We were interested to determine the optimum compromise between a usable responsive model and giving sufficient detail to be recognisable.

Besides the nature of the image presented, the experiment also focused on the method of control. Would an increased level of detail and 'realism' increase the degree of presence? The test the validity of the bike as an interface method, subjects were asked to use both a conventional mouse and the bike. We were also interested in the degree to which 'cyber-sickness' or motion sickness affected the users. Subjective assessment, by questionnaire, of these factors enables an estimation of the degree of presence for the different types of representation and interface.

Experiment description

We selected groups for feedback testing that had differing degrees of familiarity with the campus differing degrees of experience of virtual environments and differing levels of architectural education. Using a 2D map as a reference, they were asked to make their way from one part of the campus to another, via a given route. The route was chosen to take in a mixture of open and enclosed external spaces where recognizable features would normally play a large part in navigation. This was also a test of their ability to relate the 2D map to the 3D images in the environment. The model used was a representation of the Campus of the University of Liverpool and using the two control methods, we asked volunteers to navigate their way around each environment, performing a specific task in each one. They were then asked to assess their experience by completing a questionnaire.

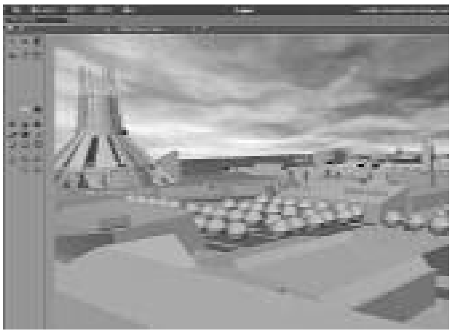

Figure 1 Arial view of Virtual Campus used for tasks

The image was projected was intended to give a view that filled the field-of-view of the participant as motion perception is increased in the periphery of the retina. A wider display, filling the edges of the field-of-view should increase involvement, and therefore presence (Arthur, 1995). The room was in complete black-out at all times of testing – not only for viewing the model projection, but also for blocking out external activities going on in the room so that external distractions were kept to a minimum.

On of the major limitations of low-end, low cost VR is the limitations of refresh rate which is most noticeable in the important peripheral area of vision, distracting the user and inducing eye-strain and headaches. One of the goals of VR is to surround the user's field of vision with visual stimulation. With our stated aims of using standard desktop PCs, we constantly have to trade off the size and level of detail of our models to maintain a suitably high rate. Another significant technology problem caused by a low refresh rate is computer lag. This is the time "between the user initiating an action and the action actually occurring in the VE." (LaViola, 2000) When the user initiates an action, the brain can "expect" a certain result. If this result does not occur when the brain has forecast it, it can create confusion, distraction and contributes to 'cyber sickness'

Four groups and categories of volunteers were selected:

Group 1: Spatially Aware / Knowledge the University Campus

Third year/final year architectural students

Group 2: Spatially Aware / Does not know the University Campus

Architects in practice

Group 3: Spatially Unaware / Knowledge the University Campus

Students from non-design courses

Group 4: Spatially Unaware / Does not know the University Campus

A level applicants/parents

By careful selection of the groups, the affect of previous computer knowledge, spatial skills and knowledge of the campus on task performance was monitored to see if there was a correlation to both the success of completing the task and the degree of presence experienced. It was expected that those with prior knowledge of the campus would have the advantage of being able to mentally orientate themselves with landmarks and complete the task more easily

Two methods of control were used to see if participants preferred using the mouse due to its popular association with computers, or the bike, for its familiarly and manageability. The exercise bike was the ideal interface to use for this type of environment because it is a natural method of outdoor travel in real life. We also wanted to see whether either control method produced and symptoms of sickness and disorientation in the user. Although VR advancements are usually limited by the technology available, there are often times when they are hindered instead by the limitations of the human body. The physiological and psychological effects of immersive VR can prove too intense for some users and result in feelings of illness (cybersickness). This feeling is very similar to motion sickness but where as the latter is induced by vestibular stimulation with vision as a contributing factor, cybersickness is induced through visual stimulation only. The illness has a number of symptoms such as eyestrain, disorientation, headaches, vertigo (swirling surroundings), ataxia (postural disequilibria), nausea and vomiting, and these have serious implications on VEs. Too often the enjoyment of an experience is marred by loss of balance and disorientation. Some users find it hard to cope with the detachment from reality and if when facing troubles when orientating and controlling the pace, may form a dislike of an immersive VE (LaViola, 2000).

The oldest and most accepted explanation for cybersickness is the Sensory Conflict Theory (Claremont, 1931; cited in Kolasinski, 1996). In actual motion, visual stimulation is accompanied by vestibular information from the inner ear, tracking movement and orientation of the head in space. In vection, however, the only stimulus is visual, the eyes register movement, but, because the person is geographically stationary, the inner ear does not sense it. The difference in the ocular and vestibular input is unexpected by the viewer, based on their previous experience, and resulting conflict in the brain causes sickness. We attempted to overcome this problem with the use of the bike. When the user is actually pedaling, they feel as if they are moving in reality and this matches the movement in the environment they are in. With the mouse, the person is only moving their arm – and this contradicts the whole body movement perceived in the environment. It was therefore expected that the use of the mouse would produce more symptoms of cybersickness than the bike.

A theory about cybersickness is the Postural Instability Theory (Riccio and Stoffregen, 1991). The theory centres on the idea that one of our primary goals is to retain postural stability in space. Whenever the environment changes abruptly, postural control is often lost, until the body works out a method of regaining balance. The theory states that the "cause of Cybersickness is prolonged postural instability" (Riccio and Stoffregen, 1991; cited in La Viola, 2000) and that the severity of the symptoms scales directly with the duration of the instability. For example, if a person is on a rollercoaster simulation, and they appear to be at 45° at the top of a peak, their eyes register the steep drop below them and their angle in relation to the ground. They automatically compensate for the uncomfortable angle by leaning backwards but since there is no physical tilt in reality, the person falls. The possibility of this happening was reduced in these experiments by ensuring the user was sitting down, whether on the bike, or on a chair (while using the mouse). The demands on postural control were thus reduced, allowing them to concentrate on the experience instead.

If the nervous system has access to many rest frames, it sometimes has difficulty in selecting a single one (LaViola, 2000). This causes sickness. "The key to avoiding motion sickness is not to remove all conflicting motion cues, but rather to remove those discrepancies which indicate conflicting rest frames." (Prothero, 1998) The crucial aspect for reducing sickness in a VE is to make the visual background agree with inertial cues. We used this concept of the rest frame when planning the use of the bike. The bike effectively became the 'bench': a frame of reference for the user to perceive as ground and orientate themselves by. In this aspect, the blackout became important in stopping visual cues from the rest of the room contradicting this rest frame and detracting from the sense of presence. Care was taken when setting up the test procedure that the shadow of the participants head was projected onto the screen. This (as emphasised in Slater's and Usoh's external factors, 1998) acted as a virtual body, an extra rest frame cue to help maintain stability. The experiment set out to test whether the more the control method mimics the apparent movement within the virtual environment, there would be less likelihood of Cybersickness, and therefore the more presence. Following this, it was expected that the more natural movement of the bike would provide a greater sense of immersion than the mouse.

The measurement of presence to date has been a very vague area. Being such a varied sensation, there is no unit of measurement to quantify it. According to Sadowski and Stanney, 1999, there are two sets of data which could be gathered: objective and subjective (behavioural). Subjective measures can be gathered through questionnaires completed by the user after the experience. Objective data can be gathered throughout the testing procedure, as an indirect record of the user's verbal and physical, reflexive motor responses to the experience. For more sophisticated measurement, it is also possible to take physiological measures directly from the muscles, heart and ocular activities. By placing electrodes at measured intervals on scalp, electroencephalogram (EEG) records the electrical activity and state of the brain - a non-invasive measurement tool. In 1992, Sheridan emphasized the importance of subjective measures over objective ones as the 'essential basic measurement' because presence is not easily amenable to objective physiological measurement. (REF)

Sadowski and Stanney (1999) state that a valid measure of presence should be 'a) Relevant – have a direct connection with presence and its components, b) Reliable – have proven test-retest repeatability, c) Sensitive – to variations in variables affecting presence, d) non-intrusive – to avoid unintentional degradation of performance and/or sense of presence and e) Convenient-portable, low-cost and easy to administer'.

Because presence relies on both internal and external factors, two questionnaires were composed based on the work of Witmer and Singer, 1998. The first questionnaire was compiled as a measurement of the Immersive Tendencies of each participant. It recorded on a semantic scale the amount participants tend to get involved in different things, such as projects computer games, books, TV, etc. and the realism of dreams. Seven questions were designed to assess how involved the participant tends to get in different types of activity. Three questions were designed to find out how much attention is focused when doing these activities, two questions were to establish how easily they are able to block external distractions. One important measurement was of how often the participant has experienced VEs through playing computer/arcade games – it was assumed that a participant who regularly plays these games would be able to adapt and become involved in the environment easier.

The second questionnaire was a measure of presence in the environment. By asking questions about the imagery and the control method, it was possible to relate different factors, such as task performance, involvement, immersion, naturalness etc. to the amount of presence felt. To clear up any misunderstanding about the terms used, definitions of important terms were placed at the top. The questions were again derived in part from the experiment by Witmer and Singer (1998), and in part from criteria tested here. The questionnaire was split into two parts, one assessing each variable. The imagery questions were set out to enable direct comparison between the two environments, the first two questions assessing the overall impressions of realism, interest and connectivity The next three measuring the involvement, ease of navigation, presence, and ease of task completion of each display. Further questions measured effects of the displays on cybersickness, lag time the importance of detail and realism. The second part of the questionnaire used a similar approach, comparing the two control methods, looking at general impressions of the control, and more specifically about immersion, presence and task completion. This questionnaire also contained certain questions asking the participants to assess how much the control method and the imagery contributed to task performance.

Results

The results were interesting for several reasons. As might be expected, Groups 1 and 3 who were predominantly made up of students who both knew the Campus and frequently played computer games, did significantly better than those in the tasks who did not know the Campus.

Almost unanimously, the bike was preferred as an interface. Not only was it found to be fun and interesting, but it gave users the best sense of belief in their surroundings, by portraying their movement in the most natural way. This also reduced the sensory conflict and cybersickness, experienced with the mouse. Apart from the awkwardness of the handlebars and the lack of resistance, the bike was found to be the preferred method of movement. Rather than complaining about the control, users tended to give positive feedback as to how it could be further developed. Use of the mouse when used with the large projected image caused many instances of disorientation which could be attributed to the high sensitivity (small movements) causing large movements in the projected image. A high proportion of the uncompleted tasks occurred when using the mouse on the less detailed model. In one case a member of group 3 (Spatially Unaware / Knows the University Campus) felt ill for up to 2 hours after doing the test. She also commented that she felt 'drawn into the screen', especially when using the mouse. From this, it can be summised that the control method must be individually suited to the environment it is interacting with. The bike, for example, is the best method of navigating this particular environment, but would not be an ideal interface for the inside of a building. An alternative interface to match a wider range of surroundings would be to 'walk' around an environment.

The preference of the bike ties in well with our expectations. It seems that in this environment, this method of control was more natural and familiar to most users. It also appears to agree with the Sensory Conflict theory, in that the whole body action induced by the bike mimics more closely the movement in the environment causing less internal conflict. The comments about mouse and sensitivity suggest that the speed of optical flow has to match expectations of the user when initiating movement. This was easy to correlate on the bike, because the sensitivity can match real time. With the mouse, however, it was hard to define the amount of distance covered in the model which should be initiated by a small arm movement.

Another considerable observation was to do with the difference between the imagery in the two environments: The difference in the statistical results was not as diverse as expected and many people noticed little difference in the detail between the two displays: this was shown in comments such as 'did not notice difference at first' and 'the more detailed model was slightly more consistent with reality'. Having said this, there was a general preference for the more detailed model, particularly in the case of aesthetics. There was particular enthusiasm for the environment in some of the written comments. Some said that it felt 'less lonely – more real and friendly', or 'colour and detail makes buildings easier to recognise and nicer to look at'. The issue about detail versus colour was raised frequently with many contradictions about which was more appropriate. One observation made stated that 'colours made association easier, but detail wasn't relevant at all', while another said that 'greater detail would be better than colour'.

When analysing the reaction to imagery, it was important to take into account which groups tended to prefer which variable. It was interesting to note that overall the use of colour was referred to more than detail as beneficial to the success of the model. Looking more closely at the groups, it could be seen that groups 3 and 4 especially, made comments such as 'Platinum trees don't stand out as trees' and 'grass on map related to grass on screen'. There was little emphasis from these groups on the level of detail and this was mostly highlighted by groups 1 and 2. Comments from these people included 'for association with facades, detail is important' and 'easier orientation and recognition with detail'. This evidence tends to correlate with expectations on spatial awareness. Those who place a greater emphasis on the visual representation system, rather than the kinesthetic or auditory systems have a higher spatial acuity and therefore find it easier to recognise objects quickly. Overall, groups 1 and 2 tended to give higher scores for ease of navigation, task completion and sense of presence.

With regards to the style of imagery, it was found that aesthetic primitives such as colour provided a more useable experience than detail, which focused more on spatial acuity. Incorporating more of these aesthetic primitives into the model, would plug into the hardwiring of the visual system to produce an environment which more users could associate with. Although these visual cues may not produce hyper-realism (and therefore presence) strived for in many VEs, we found that presence was not absolutely necessary for task completion, i.e. the imagery used was acceptable enough to navigate the environment with ease. The test showed that prior knowledge of the real environment being modeled mentally completed the lack of detail in the virtual environment. The series of experiments have produced a set of parameters that will directly inform modeling and form of the next phase of the University Campus model.

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