Travel techniques in VR and the degree to which they affect Simulator Sickness

Ryan Acton
Student Number: ACTRYA001
Cape Town, South Africa
University of Cape Town
ACTRYA001@myuct.ac.za

ABSTRACT

VR Travel techniques are the means by which users navigate and track their geographical progress in virtual environments. Moving a joystick, walking or even flying, all abstract user movements in virtual reality and they all affect the users in physical and psychological ways. This paper provides a brief insight into the implementations of the various travel techniques and the extent to which each affects simulator sickness.

The techniques will be compared and critiqued in their implementations in accordance with: their level of practicality, relevance and any simulator sickness that may have been experienced by the participants in these investigations. This paper concludes with a discussion of the shortcomings and successes of these implementations with the aim of outlining restrictions and goals for future work.

INTRODUCTION AND MOTIVATION

Moving and traveling in Virtual Reality is mandatory in a lot of programs: from practical training software to high-end game titles [1] [16] and while the outcomes of the various programs are different, the goal of achieving a feeling of user-immersion and control is shared. Considering the vastness of the field of research this review will focus on a few travel techniques, namely: walking, driving and teleportation [10]. Each of these techniques can be carried out by users at different levels of abstraction: from using a joystick or controller, to users physically manouvering and manipulating their bodies to yield change in the VR environment.

This paper presents the different VR travel techniques that are being used and the methods involved to implement them. They are classified by their relevance and their different implementations. The paper then compares the methods and findings, in an analysis section, with reference to what cannot be proven or tested, and the degree to which the various methods affect the users' simulator sickness.

For each technique there might be numerous implementations with varying simulation strategies and these all affect the users in separate ways. It is therefore important to consider multiple implementations of the same travel techniques. Context of the applications is important and this paper will review the limitations of the various travelling techniques as well as variation in simulator sickness derviations.

Initially this paper will present the multiple models of simulator sickness and explain the most commonly used metrics and methods for assessing the degree to which participants in experiments are affected by simulator sickness.

PRESENTATION

Simulator Sickness

Simulator sickness, otherwise known as cyber sickness, is sometimes experienced by people after participating in a VR program. The effects of it are well known and are akin to those of motion sickness, namely: nausea, disorientation and dizziness. The cause of this effect however, is not completely understood [18].

One of the earliest theories suggests that it is caused by a confusion of sensory inputs as a person tries to carry out a natural activity in an unnatural environment [21] - an adaptation of the sensory conflict theory [15]. The theory was further refined and focused to be the discrepancy between vestibular signals and visual, informational input [7] and from here the neural mismatch model was presented.

This outlined more specifically that sensor sickness was caused by a mismatch in sensory input and retrieved sensory memory [25]. In this sense it is related to motion sickness and with this model it is easier to quantitatively assess the degree to which someone is experiencing the sickness, considering the speed of the movement. For example in the case of a rotational environment it would be proportional to the angular velocity or the rate at which a user's head is moving.

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More recently, the studies have focused on physical characteristics of the users: in particular the postural sway theory - suggesting that the sickness affects people differently, based on the stability of their posture - and the theory of eye movements, which is focused more on visual stimuli [11] [26]. All of these theories compoundly suggest a link between what is perceived in a VR environment and a user not being able to completely adjust to it [5].

Quantifying Simulator Sickness

There are numerous ways of testing the degree of the effects of simulator sickness and, like the traveling techniques, whichever are best to implement will be determined by the context and situation of the testing. For instance if it is necessary to conduct tests with inactive or injured participants, it would not be advised or ethical to test balance [24], in accordance with the postural stability theory. An alternative test, should it meet the requirements of the experiment, is to monitor the participants' physiological systems, such as respiration and cardiovascular parameters [13].

Finally, a totally non-invasive approach to measuring effects is the Simulator Sickness Questionnaire [7]. This self-reflective approach allows the participants to answer to the best of their ability and is recognised as "the gold standard" [9] when it comes to measuring effects of simulator sickness.

TRAVEL TECHNIQUES

Walking

Walking in VR has many practical applications [2] and can be implemented in numerous ways. Research done at the University of North Carolina contributes a classification of some of these methods, namely: Real-Walking, Moving-Where-Looking and Moving-Where-Pointing [6].

Real-Walking, as the name suggests involves physically walking around an area, with their movements being mapped into the virtual environment. This offers a high-level of immersion for the user as they control themselves in the virtual space as they would in reality.

Similar implementations of this - walk-in-place - model have been shown to yield high levels of presence and immersion [20] and lower levels of simulator sickness. The justification for this was that a model where a person's legs moved in a walking motion was similar enough to the actual process of walking, that the users could more accurately control their movement and feel less sensor sickness as a result.

However, in some studies it was shown that in complex generated environments, people experienced more simulator sickness from the "Real Walking" as opposed to a "virtual technique" of gesturing or using a controller [2]. It was additionally found that once the participants had become accustomed to walking method, they collided less with the virtual environment variables.

Controller based movement has been tested for its effects, and showed in some cases to have a very minimal effect on simulator sickness [3]. However the experiment was also assessing user immersion and enjoyment and found that this motion style was not as immersive [14].

Driving

Driving in virtual reality can have numerous practical benefits and be extremely entertaining. With effective driving learning programs, users can get the appropriate context and feel of driving, without the danger [23]. They can rapidly drive around virtual racetracks and with the rate of VR advancement, these experiences are only getting better as the technology improves. The problem is that a lot of the tests being done induce simulator sickness in the participants, which hampers the development of software and the enjoyment of the users. [8]

Simulator sickness has however not been the main focus of this VR driving based research. Immersion and realism are the focuses, to enable highly realistic and practical driving simulations to be developed. Simulators are an aspect of this motion and they are available and accessible at a wide price range and level-of-complexity [17]. This is highly relevant to the investigation as the degree to which the simulator is able to create a believable environment will undoubtedly affect the immersion and realism of the experience.

Studies in this area have shown the effects of simulator sickness. In particular a study carried out by senior members of the IEEE, in which they attempted to mitigate effects of simulator sickness in an off-road driving simulation. While the participants acted as passengers, sensors applied tactile stimuli to create a more realistic simulation. It was found that large amounts of sensor sickness were felt by the participants without the effects of the tactile stimuli and, while still present, the effects were mitigated somewhat by the stimuli introduction [19].

Teleportation

The Point-and-Teleport technique is one that has been implemented [12] in which the participants pointed to a location, either using a controller or a hand-gesture and were teleported there. The study however, was conducted in an area with lots of obstructable objects and it was shown that participants frequently collided with environmental objects during the experiment.

Additionally it was found that in terms of the effects of simulator experience felt by the participants, the Point-and-Teleport model did not yield better results than the model where the participants physically walked in place, to move in the virtual environment.

Another implementation of teleportation, compared it to a redirected-walking and joystick technique [22]. The simulator sickness experienced in this example did not increase for the teleportation technique, from the redirected-walking technique. Additionally, the presence felt by the users was less for the teleportation method, as it did not feel as real as the other methods for the participants.

ANALYSIS

As has been shown, simulator sickness is by no means entirely predictable. While in certain instances and reports an attempt at inducing the effect has been successful, in particular when it comes to driving simulations [4], the degree to which people are affected varies greatly. This particular variance makes a review of all scenarios as a whole very difficult and thus warrants specific responses.

Simulator Sickness Classification

The multitude of possible specifications of the simulator sickness theories show that each must be considered specifically for separate experiments. Thus to test for it, it must be specified which theory is governing the particular investigation.

For instance, when it comes to the virtual driving software, it makes more sense to define the simulator sickness in terms of balance and posture in line with the postural sway theory.

I feel this was done fairly well in the work that is currently available, as papers go into much detail explaining their relevant versions of the simulator sickness theories and defining them to be appropriate for their tests. However, because of this categorisation of what is being tested, an element of unconscious bias is introduced. This is due to simulator sickness being classified specifically for the experiment. While this is important to yield results that are relevant it unconsciously takes away from other possible theories of simulator sickness in the process.

This is necessary in order to concretely outline what you are trying to accomplish in an experiment, however it makes it impossible to ever achieve total coverage in terms of what is meant by simulator sickness.

Measuring Techniques

Once again, because of the variance in the experiments, the metrics for observing the effects of simulator sickness must be relevant for the particular tests. However, measuring the effects of this are more straightforward them defining what you are measuring for. The symptoms experienced are fairly universal across the reviewed papers and thus evaluating them does not need to be as specific.

Physiological tests should be implemented in scenarios where the simulator sickness is defined by these factors and the goals of the experiment are to use this data to discover the severity of the effect. Alternatively, as mentioned, balance can be tested should the simulator sickness definition lie closer to the postural sway theory.

The Simulator Sickness Questionnaire, while non-invasive, is not conclusive in a medical sense. While people are to identify their state of being and health to a large extent, should the testers require more specificity, alternative methods of evaluation might be more appropriate. It is used in relevant experiments as mentioned to good effect and has the benefit of being less invasive and more comfortable for people to partake in.

Travel Techniques

Walking

Because of all the possibilities of implementations of walking in virtual reality, like simulator sickness, the analysis of the procedures must be case specific.

For these scenarios and, which is done in the majority of the reviewed articles accredited, the scope of the environment needs to be established. Walking especially, requires additional space if the model being implemented is an attempt at modelling “real-life-walking.” This might be because of an attempt at creating a more immersive environment - with the aim of minimising simulator sickness by making the program feel as real as possible.

In some reviewed studies, joystick-based movement proved to induce the least simulator sickness. This being said I would criticise the purpose of this investigation in particular, as it does not feel very realistic for the user to walk this way anyway. Maybe a more relevant comparison would have been using an alternative method of simulated walking, where the participant experiences a sensation that is closer to that of when they are walking in reality.

The relevance of walking in whichever program users are testing must also be considered. If the program does not require the users to navigate an environment, continuously, they will experience less simulator sickness and it will not matter how the traveling technique has been implemented.

Driving

The limitations on the testing that can be done in this area, are aligned with the simulators that can be used. As previously mentioned, immersion and a realistic environment are crucial to minimising simulator sickness and in this case, crucial for simulations that may have real-world consequences - realistic driving simulations.

There is a large variance in terms of equipment because of how the driving environment is simulated. Users could be fully immersed with a state of the art full simulator, equipped with: wheel, pedals and other apparatus or a joystick and in both cases, they could be in similar environments.

Thus an analysis and comparison of the equipment would fill a gap in the reviewed papers and possibly add explanation as to how relevant it is, in particular for mitigating simulator sickness by establishing a more believable scenario.

In this area a lot of what the simulated driving studies evaluated were motion sickness. While the symptoms are consistent with those of simulator sickness, the cause of motion sickness is much more concretely established. Many of the studies did refer and test for simulator sickness, but it felt like there was a lack of discrepancy between the two.

Teleportation

It has been shown that teleportation does not add immersion to the programs that have been reviewed. This is highly relevant because of the link between perceived and actual reality and the effect this has on the participants simulator sickness. In their environment, if the user can using either the PAT technique or something similar, they have a lot of control over the system but it can never align with their reality.

However, the software requirements would determine whether or not this is an issue. For example in the referenced teleportation example, the software required the users to map an area.

Considering this inherent goal, the ability for users to maneuver themselves quickly and get an overview of the geography is extremely beneficial. It does not mitigate simulator sickness, but it adds value to the program. This is an area in which I felt a lot of the comparisons fell short - where they failed to identify the value of some of the techniques, aside from the level to which they exerted discomfort (simulator sickness) on the users.

Additionally, using teleportation made it difficult for some of the users to ascertain distances and this resulted in the environment collisions. Once again this is relevant for specific cases as: it could influence simulator sickness it some kind of feedback is provided in this case, or create a non-immersive experience for the users.

Analysis for Scope of Future Work

Simulator sickness is a present hindrance and problem that needs to be dealt with, in order to allow for significant progression in the interactive virtual environment space. While various mitigation strategies exist outside the scope of this review, considering the vast distribution of people that are affected, across multiple travel techniques in VR, there is no solution that will address all the problems.

However, it has been found that the problems are very specific and the solution to them needs to be catered for the program that will be run. Simulator sickness must be appropriately defined at an early stage, to allow the mitigation strategy to be as focused as possible. While this does take away from other possible versions of simulator sickness research, it allows the current research to generate results that will contribute to the context of simulator sickness research in some capacity.

When identifying the travel techniques it is important to clarify the implementation of it and the degree to which the user will be put under physical or psychological stress. Equipment needs to be assessed for its relevance in the study and it must be critically considered for its role in the generation of simulator sickness. When testing various implementations of a travel technique, it is important to ensure that each implementations, continues to be useful in the context of the program and that they are not arbitrary inclusions.

Finally, testers must be aware of the scope of their solution and hypothesise the degree to which their research will affect the participants of the study.

CONCLUSIONS

This paper has reviewed relevant peer-reviewed articles and papers, to find a context from which further tangential research can draw upon. It has done so by explaining the relevant work in line with topic, presenting the methods and findings in an compact and readable manner.

The various definitions of simulator sickness have been addressed, with reference to scenarios in which they would each be relevant. The different testing strategies have also been explained and the situations in which they are appropriate have been shown. Different travel techniques have then been explained and in the process, have been categorised into: walking, driving and teleportation.

The paper has then illustrated the way in which in which they are implemented, to determine in what ways they influence simulator sickness and whether their role in the reviewed studies is relevant. The implementations are explained in order to highlight why they were included in the studies and criticised if their inclusions were arbitrary.

Following the same format as the presentation of the methods, the techniques and their implementations have been analysed to ascertain to what extent their effect on simulator sickness and relevance to the study contributes to the scope of future investigations. General analysis of considerations for future work, on the basis of the discoveries made in the review is contributed with the goal of outlining possible failings and necessary inclusions for the future.

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