Department of Electrical, Computer, and Software Engineering

Part IV Research Project

Literature Review and

Statement of Research Intent

Project Number: 62

Exploring Embodiment in Immersive XR

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Declaration of Originality

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1. Introduction

How do we become immersed in virtual environments? The world of XR presents exciting opportunities for pushing the boundaries of reality and creating unique experiences for users, but making users feel truly embodied and connected to those experiences can be difficult. This presents the unique opportunity to investigate whether it is possible to experience the same embodiment in a virtual environment as in a real life one.

The theory of what makes up embodiment and how we can quantify it within a virtual reality (VR) context has been extensively researched [1, 2, etc.]. Practical explorations of embodiment techniques in extra reality (XR) have also been documented, although there is a significant over representation of avatar based approaches.

Dance, a field heavily reliant on the sense of body experience and movement [3], provides a unique viewpoint to the study of embodiment in XR spaces. Existing XR dance projects do not focus heavily on immersion, and dancers' unique requirements may lead to new embodiment techniques unfound from a generic perspective.

By studying existing research projects, this literature review aims to expose gaps in the exploration of embodiment techniques in order to support the discovery of new approaches.

2. Body

2.1. Defining Embodiment

In multiple studies, the meaning of embodiment is broken down into distinct requirements necessary to produce a sense of “being there”. Without referencing each other, they all tend to come to similar conclusions about what these requirements are. Kilteni et al. [4] divide the sense of embodiment into three subcomponents: the sense of body-ownership, the sense of agency and the sense of self-location. Similarly, when identifying important categories of survey questions for measuring embodiment, Gonzalez-Franco & Peck [1] note body ownership, agency, and location of the body as significant factors towards embodiment. Additionally, Gonzalez-Franco & Peck suggest that users’ response to external simulated stimuli, such as objects flying at the user, provide insight into measuring embodiment whereas Kilteni

& Groten allow this to simply be a consequence of their three subcomponents being strong. In general, studies tend to refer to at least one of these subcomponents if not all of them when evaluating embodiment [3, 5, 6, 7 etc.].

This three subcomponent model has been contested and critiqued [4]. For example, body ownership has been argued to be unneccessary in the presence of tool embodiment [8]. Debate around dependencies between the subcomponents also exists. There is an argument that as a body that obeys one's intentions will probably be one's own body there is a correlation between agency and body ownership [4]. However Tsakiris et al. [9] state that body ownership does not imply a sense of agency as self generated movements are not necessary for ownership, disproving that dependency.

2.2. Measuring Embodiment

A method of quantifying embodiment is needed to compare immersion techniques. Gonzalez-Franco & Peck [1] propose a standardized questionnaire that can be used in virtual reality experiments to evaluate the degree of embodiment. Their questionnaire focuses on the same values of embodiment as the three subcomponent model, with an extension to include potential tactile sensations and visual appearances. The inclusion of visual appearance questions exposes their research bias towards avatar embodiment, rather than embodiment in general. This research bias is observable in many studies, and is discussed further on. The proposed questionnaire produces a numeric result intended to be easily analysed against other participants' results and similar studies. No independent studies were found that used the questionnaire to prove its measuring capabilities, however the researchers did validate their own questionnaire by conducting 9 studies with 400 samples [10].

Physiological measurements for embodiment have also been proposed. For example, through an electroencephalogram, it was shown that when an embodied virtual hand was stabbed with a virtual knife the same region of the brain that responds to a threat was activated [11]. This observable physical response could be used to determine whether embodiment has occurred [1], however it is rather limited in application.

2.2.1. Concrete Example: The Rubber Hand Experiment

The "Rubber Hand" experiment is a classical experiment in which researchers attempt to create a sense of body ownership for a rubber hand in a participant [4, 5]. Participants have a rubber hand on the table in front of them, with a blanket or other such object covering across their arm so that it could be conceived that the rubber hand is attached to them. The participant's hand is then given synchronous stimulation to the rubber hand, such as being brushed by the researcher. In

past experiments, this has led to participants feeling that the rubber hand was their own. This experiment has been recreated multiple times with different variations to investigate embodiment and ways of measuring it.

In 2008, Moseley et al. [6] hypothesized that there was a link between a sense of body ownership of a limb and its skin temperature. To investigate this, they induced the rubber hand illusion and measured the temperature of participants' limbs. They found that the skin temperature of the real hand decreases when a participant takes ownership of the artificial one, suggesting that physical temperature could be a viable physiological measurement for embodiment, at least when it comes to direct mapping of body parts to non real counterparts.

Bailey & Bailenson [5] investigated a variation of the rubber hand experiment specifically targeting virtual embodiment. Using VR, they created virtual limbs for the participant to control which either matched their physical hand or mirrored it. They then used their performance accomplishing a task as a measurement for embodiment. This measurement was meaningful for their study, but is not necessarily generalizable to future studies due to its specific nature.

2.3. Virtual Avatars and Embodiment

A large portion of embodiment studies frequently assume that to produce embodiment a virtual avatar is needed for the user to project upon. However, the studies quoted to justify this assumption only shallowly investigate the potential for avatarless embodiment. Instead, it usually comes down to a comparison of graphics quality or movement responsiveness. For example, *Simulating Virtual Environments Within Virtual Environments* [2] (which Kilteni et al. [4] claim as their reasoning for needing virtual avatars) asked participants to choose which simulation they felt most immersed in. The options the participants were presented with ranged from a no shadows and no virtual body scenario to a fully rendered environment with a synchronously moving motion captured body. Unsurprisingly, users picked the most graphically advanced option. However, this doesn't prove that virtual avatars are crucial to embodiment as Kilteni & Groten claim it does, as there wasn't fair investigation into avatarless embodiment.

2.4. Embodiment Beyond Visual Stimuli

As a lot of research centers around creating accurate virtual bodies to produce embodiment, they neglect to consider the potential contributions from non-visual stimuli. The focus on avatars is understandable considering the body ownership

component of embodiment implies a need for a body, however research shows it remains unclear whether a visual perspective is necessary for body ownership [4].

Regardless, it has been proven visual stimuli alone is not enough to fully immerse the user [5]. Bailey & Bailenson [5] showed that while participants were getting visual feedback as to how their virtual arm was moving, they were still feeling the movement of their physical arm. The visual stimuli was not enough to override their kinesthetic senses nor their body fluency (i.e. whether they were left or right handed), and as such true embodiment was not achieved.

The question then is, what sensory stimuli, alongside visual or not, can support embodiment? Kilteni et al. [4] suggest that synchronous sensory feedback, for example visual-tactile feedback (such as haptic feedback) helps to enhance the sense of body ownership. Dance specific studies, discussed below, also investigate non-visual stimuli.

2.4.1. Dance and Non-Visual Stimuli

Humans use their body positions to contribute to their thinking and by extension, their experience [5]. Studies in dance recognise how vital the kinesthetic sense is to this experience, as well as to performance and training for dance [3]. Blom and Chaplin [12] go as far as to describe kinesthetic awareness as a primary perception of the moving body.

Akerly's [13] 2015 study explores auditory stimuli and dance. The dancers used the sound as a body location method to judge proximity to ground and the world around them. One dancer described how the audio made visual stimuli defunct, noting it didn't matter what their eyes saw, because their body would respond to what they were hearing instead of what they were seeing.

2.5. Dance and XR

2.5.1. XR Dance Performances

Papers on performance pieces tend to have existing dance processes at the center of their design, in order to blend well with existing workflows. For instance, to combat how unfamiliar and unintuitive virtual spaces are to theatre practitioners, Farewell to Dawn [14] based their work on existing processes used in real physical theatre. They also state real time performance capture is essential, specifically because this is what is already familiar to the performers. Moura et al. [3] also show their commitment to existing dance practice by working closely with a contemporary dance company.

Performances aren't limited to just the VR avenue of XR, instead there are multiple examples of AR. Farewell to Dawn [14] expresses a preference for AR over immersive VR as AR allows the dancers to be aware of their physical

environment, as well as the virtual one they are performing in. Contrastingly, Golz & Shaw [15] use AR for the audience's experience, providing iPads which augment the performance with extra visual effects.

Primarily performances are focused on the audience experience over that of the dancer. Farewell to Dawn [14] purposely avoids the dancer to be fully immersed in the virtual world, but does discuss the possibilities for off-site audience immersion. Golz & Shaw's [15] iPad AR is only visible for the audience, not the performers. These decisions show their immersion priorities.

2.5.2. XR Dance Tools

Existing XR dance tools are used to promote experimentation and assist in education. The tools vary in their feedback methods. A Virtual Reality Dance Training System Using Motion Capture Technology [7], an educational tool, uses a visual avatar alongside numerical analysis to provide feedback to the dancer about their progress. Their detailed score breakdown allows students to identify their weaknesses, which the paper describes as vital for learning. Raheb [16] also uses visual feedback, but opts for a less literal avatar representation. Instead, Raheb utilizes particle systems and motion trails to provide a better understanding of the user's movement trajectories and motion through space. Akerly's [13] study leaves visual stimuli behind altogether and instead extensively uses audio feedback. Their system encourages movement experimentation by creating variations in sound when new movements are produced by the dancer. The system doubles as an educational tool, as dancers know that if a sound does not repeat itself when they reattempt the same action they are not executing an exact repetition.

3. Conclusion

Existing research into improving VR embodiment focuses too heavily on avatars and graphics, leaving gaps for exploration of other potential embodiment techniques. Combinations of different stimuli types, movement representation and exploring the importance of kinesthetic senses provide potential avenues for less superficial research, moving away from a best avatar based approach.

Current dance tools neglect embodiment in favour of more visual experiences. Farewell to Dawn [14] and Gol & Shaw's [15] performances primarily enhance the audience's experience through visual effects and don't even attempt to produce embodiment for the performers themselves. Chan [7] and Raheb's [16] tools for dancers also rely solely on visual stimuli,

which Bailey & Bailenson [5] state is not enough to produce embodiment. This leaves a gap in understanding how virtual embodiment might impact dance, as well an opportunity for an embodiment rich dance tool.

By defining embodiment as three components (body ownership, agency and self location) a logical methodology to improving immersion is to target each component. Measuring these improvements could be done via the physiological embodiment responses discussed, but considering all of these were done alongside qualitative methods with corresponding results, qualitative measurements will be sufficient. Additionally, Gonzalez-Franco & Peck [1, 10] have already done the work to develop a quality survey to measure embodiment in virtual avatars, which can be adapted to perform more generally.

In summary, this literature review has exposed the potential for researching new XR embodiment techniques with the purpose of creating a tool for dance. The level of embodiment can be measured qualitatively through a survey. By targeting improvements in the user's sense of body ownership, agency and self location an overall improvement to XR embodiment should be achieved.

4. Research Intent

We are interested in investigating what aspects of XR applications are conducive and compelling to embodied interaction.

As our project involves working with the dance department, we are interested in investigating this through the creation of a dance related tool. By targeting this specific audience we hope to uncover unique perspectives which will lead to new ideas for embodiment techniques.

To achieve results, we will run various workshops with both dancers and non-dancers investigating the strengths of both existing XR technology, and XR technology we create ourselves. From this feedback, we will go on to create a dance tool that utilizes what we have learned to produce embodied interaction.

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