Department of Electrical, Computer, and Software Engineering

Part IV Research Project

Literature Review and Statement of Research Intent

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Exploring Embodiment in Immersive XR

Author: Eva-Rae McLean

Project Partner: Hazel Williams

Supervisor: Danielle Lottridge

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Declaration of Originality

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Name: Eva-Rae McLean

1. Introduction

Advancements in extended reality (XR) technology have allowed for original and novel applications across many disciplines. There are some inherent challenges with integrating dance and virtual reality (VR) technology, as the feeling of embodiment during dance is so closely tied with the physical, often unencumbered, human body. Much of the existing research around VR, dance and embodiment uses motion capture technology to transform the dancer's body into a virtual avatar. However, this technology is expensive and time consuming to set up. The goal of this project is to provide a tool that can enhance the feeling of embodiment in VR using accessible technology without relying on an accurate avatar representation, and to explore how existing XR technologies can be applied in the context of dance. In this project we will explore what kinds of sensory feedback gives the dancer a sense of agency and embodiment in this digital world, and what new types of performance this technology could afford. We will conduct workshops with existing XR technologies to probe what elements of extended reality technology are compelling in a dance application, with the ultimate goal of prototyping a useful tool based on the insights gained from these workshops.

2. Exploratory Research

2.1 Embodiment in VR

Embodied cognition theory states that human cognition is shaped by how our bodies affect and interact with our environment [1]. This framework allows us to understand how XR can be used to affect our embodied cognitive experience by providing sensory input not present in typical body-environment interactions. Our brains contextualise experiences through sensory input, act through our bodies on that input, receive more input after the environment responds, and so on.

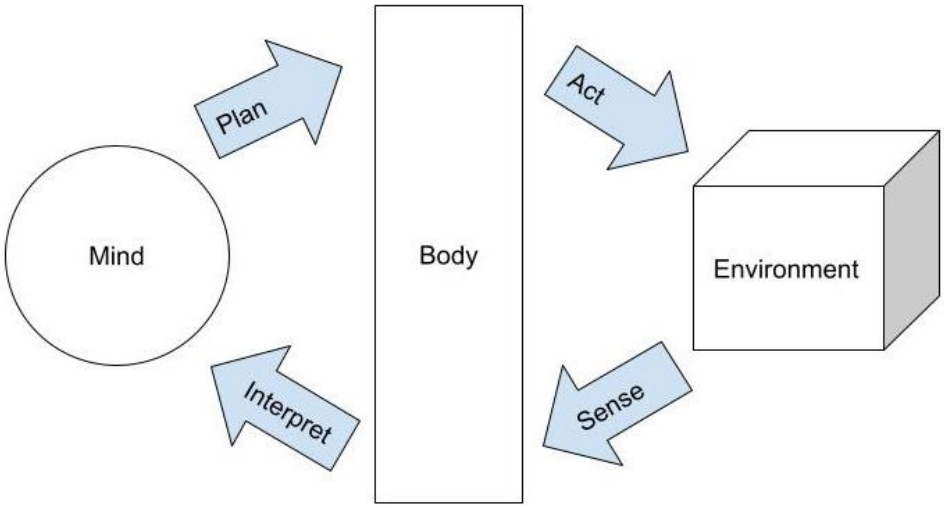

Fig 1: Diagram of body-environment feedback loop

For example: for sighted people, there is an expectation that the action of moving your body is reflected visually while your body is in your field of view. A large amount of research in embodiment in VR explores avatars as a way to give the user a virtual body, mimicking real life experience. The degree to which this virtual body mimics the user's real-life actions affects immersion in and plausibility of the virtual environment, as shown in [2]. Participants with avatars that closely followed their movements reported a heightened sense that their environment was real than those without avatars or static avatars. The experiment also demonstrated how realistic lighting can enhance immersion and believability; not only can we see the body move, but we can see the effect that movement has on the environment, i.e. casting a dynamic shadow. This research is valuable in that it demonstrates the obvious; the more similar we make a VR/XR world to the real world, the more real that virtual world feels.

While a lot of investment has gone into making VR environments and avatars mirror the embodied cognition feedback loop we are accustomed to in our day to day lives, VR can also be to intercept and alter the mapping between action and environmental changes artificially as demonstrated in [3]. By mapping a participant's physical right hand to their virtual left hand (and vice versa), researchers were able to alter how subjects felt towards their own handedness. Right handed subjects usually regard the right side as being "good", and the left as "bad". After participating in the VR handedness swap, right-handed participants were more likely to rate the left side as good, and right as bad.

This idea is expounded upon in [4], showing that not only can XR be used to modify the brain's mapping between our real bodies and our virtual ones, but that we can add entirely new elements to that mind-body mapping. This study demonstrated that participants can feel agency and ownership over a virtual tail that is controlled by their hip movements, and over a short period of time can learn to use this new virtual limb to solve puzzles. [4] and [3] demonstrate the power that VR has to create links between the body and sensory input (e.g. the mirrored mapping shown in the VR headset) that do not exist in our day to day environment, and that these links can have significant effects on cognition and embodiment.

2.2 Technology and Dance

Embodied cognition theory tells us that to create a feeling of embodiment in XR, the virtual environment should map closely to the body's movements. Dance is a discipline focused on movement of the body, and VR technology affords a variety of ways one could map dance to a virtual environment. For example, most VR controllers and headsets have accelerometers as well as a constant stream of relative spatial coordinates that can be extracted to dynamically calculate and render the virtual environment. Tsampounaris et. al [5] explore the use of particles and trail emitters and trails in a virtual space to create visualisations of movements over time. Some of these are linked to whether or not a body part is

moving (information is gathered using a motion capture suit), allowing the dancer some limited control over the rate of emission. This software can also be experienced in first person using a VR headset, allowing them to experience the scene from the avatar's perspective.

It is of note that all of the projects in the field of dance that used VR or AR have focussed on avatars. This seems like a natural consequence of translating a performing art that from an audience perspective, is almost wholly reliant on seeing the human figure as they dance. Chan et al [6] show that avatars in VR can be a great teaching tool for dance, as it allows the student to replay and study a motion pre-recorded by a teacher, who is virtually present in this environment as a pre-recorded avatar. The student also has a first person avatar representation, which they attempt to align with the teacher's. The student is both a performer and the audience, and in the audience member role they are able to take advantage of VR to pause, replay, and study in three dimensions the movements of another person. There are opportunities in dance and XR to situate the dancer in another body or context that would otherwise be impossible, as discussed above, one of these is the ability for two people to overlap in digital space. Choreomorphy [7], like previous research examples, uses avatars to map movement into the virtual environment. However, Choreomorphy is not a first person VR experience; the avatar appears on a screen in front of the dancer. Thus, participants felt that they were controlling the avatar, not that they *were* the avatar. The research emphasised that the appearance of the avatar had an affect on the dancer and their choice in movement, especially those which did not match the participants body type; "different avatars were seen as an augmented mirrored-self that allows the users to see their movement but at the same time to distance themselves from their own self, emerging thus as a new character or moving creature". A large part of a dance performance is the consideration of how the body looks in space, so affecting the body in drastic or surreal ways appears to be a promising method of promoting creativity as shown through this research.

2.2.1 Moving away from avatars

As discussed above, dance tools in XR rely on the avatar representation. However, there have been some projects that use technology in other ways to translate the dancer's motion into some novel sensory feedback. Bisig [8] uses a neural network to generate a figure that interprets and responds to a dancer's movements using motion capturing technology, for example by slightly altering movements or generating extra limb extensions based on the movement. This figure is projected into the physical space to be visible to both the dancer and the audience. Bisig notes that this approach "abstains from mimicking a human body and movement in favour of using more abstract systems". In doing so, they achieve the sense of a relationship to the digital object, without that object being a mimicry of the physical body. As with the research discussed above, this visual feedback affected the dancers: "Because they all perceived the system as a

response to them, they all played a game with it, responding to it, exploring all the possible responses to the different qualities they embodied, and even trying sometimes to find its limits".

Linking to the original discussion around embodied cognition, [9] shows that using technology to map a dancer's movements to their sensory input can have a significant effect on their embodiment and flow. By playing an audio tone that only changes when the dancer performs a new movement, Ackerly showed that over time participants could "tell through the sound how long they had been in stillness or in a repetitive cycle", and that this feedback prompted them to make "compositional choices to maintain, evolve, or dissolve an idea". Similarly to [3], over time, participants become more accustomed to the relationship between their own movement and some novel sensory input. In a VR context, there are many new sensory possibilities that could be linked to movement, and this is one area of research I would like to explore further in the research project.

2.2.2 XR Dance Performances

As we look to develop an XR tool, it is worth considering what possible perspectives exist for performers and audience members, and whether it should be a tool intended for a performance at all (or just private practise). As discussed in [10] there is a lot of unexplored potential for integrating the audience into an XR experience. An example given is a hypothetical dance performance where the audience can navigate in VR from the perspective of moving fireflies, illuminating the performers in the virtual space. In this way, XR could blur the line between participant and audience member. Whist [11] is an XR performance that does just that, placing audience members in the center of an interactive story. It uses pre-recorded footage from a 360 degree camera that is explored by audiences using VR headsets. This performance showcases the effectiveness of mixed reality, using physical objects in an art gallery as triggers for events in the VR world perceived by the audience, drawing on tactile sensory input and linking the physical world with the digital.

Farewell to Dawn [12] shows how a live performance can be shared by performers and audience members in the same digital environment: motion capture suits are used to project a live dance performance onto a virtual stage. Performers use augmented reality glasses (AR) to see what their avatars would see in the VR space, thus simultaneously occupying both the physical studio where the performance is taking place, but also the digital where it is being watched. The production was shown on one screen to a room of people. However, this seems like a missed opportunity to have audience members watching the performance live through VR headsets and moving through the space. As noted in the paper, a digital performance such as this can be recorded and replayed easily to audiences across the globe.

Whereas [11] and [12] situate the audience firmly within the virtual space, in [13] it is shown that simple, inexpensive techniques can be used to enhance the performance in using AR to augment a video stream when viewed through an iPad camera. Thus the audience is both aware of the unaltered dancer in front of them, and the parallel reality shown on the screen, where that dancer may be changing scale, being teleported, or be affected by any number of virtual effects. A common theme in these dance technologies is that it is very useful to composers, dancers, and audience members to have a recording of the performance; in some cases in a 3d representation that you could view from any angle. As Chan et al show, this is very useful for a dance student, and could have a lot of potential for choreographers.

3. Conclusion and Research Intent

This preliminary literature review shows that technology can be used to alter and enhance the experience of a dancer and so push them to move in creative ways. It also shows the power that VR can have in mapping motion to novel visual environments, and how this feedback loop can enhance the sense of embodiment in users.

Existing literature and tools for the field of dance do not explore fully the possibilities allowed by a virtual world. Farewell to Dawn [12] does situate dancers in a virtual environment to accelerate the passage of time, however with the technology available to create essentially any environment (or stage) imaginable there is a lot to explore. Choreomorphy [6] has some limited exploration into having avatars interact with physical objects using collision detection. This could be investigated further as interaction with physical objects in VR may improve the feeling of embodiment when viewed as another form of sensory feedback in the embodied cognition loop.

There is a clear gap in research around embodiment in VR without relying on an avatar or representation of the user. In our research we would like to explore the idea of embodiment without an avatar, and the different ways we could manipulate the embodied cognition feedback loop using XR. As Ackerly linked movement to audio, we could potentially use VR to link movement to a variety of visual sensory input. For example, linking movement speed to colour, scale, light, or visual filters, could promote creativity in dance practitioners.

Part of our research process will be probing XR technology that is not intended for a dance application and exploring what experiences or technologies are meaningful for an embodied experience in dance. As the field of XR and dance is fairly young, exploring how XR has been used in the creative arts, gaming and other areas should provide some original applications of these ideas. We will conduct several exploratory workshops with dance practitioners to see what aspects of XR excite and encourage spontaneity in a dance setting and create a sense of embodiment. We will select a range of applications that affect the embodied-cognition feedback loop in different ways, for example; those with/without

avatars, music, physics engines, trails and particle effects, 360 video, etc. We will use participants from a range of backgrounds (both dancers and non-dancers) to gauge the successes and shortcomings of these technologies through interviews and debriefing discussions. We will then prototype based on the insights from these workshops, with the goal of creating an XR tool that facilitates embodied interaction, and acts as a creative catalyst.

Our prototype tool should:

- Create an experience that inspires creativity in dance practitioners
- Draw on ideas in XR that are yet to be applied to a dance context
- Explore the sense of embodiment in XR without reliance on avatars
- Provide an experience that is only possible in XR
- Have real value to dance practitioners

In the process of continued research and development we hope to answer the question: “ How can we facilitate embodied interaction with XR applications?”. Throughout the process, we will draw on the knowledge and expertise of post-graduate dance students to provide ongoing feedback and drive the direction and further scoping of the project.

4. References

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