Parasitic Body: Exploring Perspective Dependency in a Shared Body with a Third Arm

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ABSTRACT

With advancements in robotics, systems featuring wearable robotic arms teleoperated by a third party are appearing. An important aspect of these systems is the visual feedback provided to the third party operator. This can be achieved by placing a wearable camera on the robotic arm's "host," or Main Body Operator (MBO), but such a setup makes the visual feedback dependant on the movements of the main body. Here we introduce a VR system called Parasitic Body to explore a VR shared body concept representative of the wearable robotic arms "host" (the MBO) and of the teleoperator (here called the Parasite Body Operator (PBO)). 2 users jointly operate a shared virtual body with a third arm: The MBO controls the main body and the PBO controls a third arm sticking out from the left shoulder of the main body. We focused here on the perspective dependency of the PBO (indeed, the PBO view is dependant of the movement of the MBO) in a "finding and reaching" task.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Shared body; Supernumerary Limbs; Third Arm

1 INTRODUCTION

A new future for robotics is emerging in the area of the humanmachine hybrid. Recent work has explored the possibility of "robotic augmentation" [5] with AI-based technology placed on or worn by the human body to augment human ability or allow teleoperation. One form that this vision has taken is a robotic body augmentation system worn by one person but controlled by 1+ teleoperators (e.g. to assist the host remotely). For instance, the Fusion system [7] features 2 robotic limbs controlled by a teleoperator while a robotic camera "head" attached to the surrogate provides visual feedback. The teleoperator and the surrogate can thus "share a body" and collaborate remotely. Our work builds on these explorations by combining a wearable robotics third arm with a shared body in VR.

1.1 Shared Body

Shared body systems in VR are premised on the Homonculus Flexibility [8]. The Homonculus Flexibility allows VR embodiment in a different body (e.g. a body with supernumery limbs) thanks to the human brain's flexibility to remap the embodiment scheme. Studies have showed that the "different body's fake limbs" (e.g. arms, fingers, tail) can be mastered in less than 10 minutes and that their visuomotor synchrony increased the user's agency and body ownership [4]. However, when using a shared body, the users do not have full control over all of their limbs, thus partially breaking any visuomotor synchrony.

1.2 Perspective and Self-Location

Self-location (i.e. the experience of where "I" am in space [2]) is an important aspect of VR embodiment. For instance, Aymerich-Franch et al. [1] showed that by observing a main body in 3rd view (from a teleoperated robot), it was possible to feel bi-located, i.e. being in 2 bodies at the same time. Depending of the type of task (e.g. if the MBO moves a lot), the motion of the MBO can make it difficult for the PBO to have a good understanding of its spatial location, or of its self-location, which might lead to confusion.

We want to investigate the possible impacts when the PBO is dependant of someone else over what s/he is seeing. The interests of this work are: (i) investigating the effects of different perspectives on performance, VR embodiment and workload; (ii) using VR to explore teleoperator design problems in robotics (c.f. the Fusion [7]); and (iii) exploring a novel concept of VR body sharing.

2 SYSTEM OVERVIEW

Here we describe the parasitic body system in detail, as well as present the experimental setup for the feasibility pilot and the task description for the shared body activity.

2.1 Avatar

The main body (c.f. Fig. 1) is the dummy model delivered in the FinalIK Unity package[1], but any avatar, as long as it can meet the usual avatar rigging requirements (i.e. having a root and a skeleton rig) will work (even if the dummy is not a very realistic body, a realistic body is not actually necessary to produce high level of VR embodiment [6]). The parasite body (c.f. Fig. 1) is comprised of 2 meshes: (A) a generated mesh continuously updated and following a Bézier curve with the MBO shoulder, the PBO upper arm, and lower arm as control points; and (B) an arm similar to the left arm of the main body's model. Since (A) and (B) intersect, the parasite body gives an illusion of continuity. This approach lets the PBO move freely in the scene, while still being "visually linked" to the main body. Moreover the parasite body's default "head position" (the head is invisible) is 40cm above the left shoulder of the main body. Its virtual head rotation rotates naturally, but the virtual head position moves at a much lower distance (i.e. 20%) than the real head position, to stay near the MBO [2].

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[1] http://www.root-motion.com/final-ik.html

[2] Having an arm moving freely in space is beyond the current research in robotics, yet we decided to do it in VR to force the participant to have more control regarding his/her actions and his/her point of view

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Figure 1: Left: The main body and the parasite body as seen from a spectator. The camera widget is the parasite body's head position. Right: View from the parasite body.

2.2 Setup

Tracking was performed with 10 Optitrack Prime 13[3] cameras and 6 Optitrack Prime 17W[4] cameras in a $10.6m^2$ ($4.4m \times 2.4m$) space. The users' head, hands, waist, and feet were tracked with passive markers while the rest of the body was resolved using inverse kinematics (using the FinalIK Unity package). We developed the Parasitic Body application with Unity 2018, and it was deployed on 2 laptops able to run it smoothly. Both HMDs were the Oculus CV1.

2.3 Task Design

The Virtual Environment (VE) was a room matching the dimensions of the tracking area. Both the MBO and the PBO could move and communicate freely in it. The MBO was an actor instructed to walk slowly around the room, and to help the PBO if asked. The PBO was a participant and was instructed to: (a) Walk around the room for 1 minute; (b) After 1 minute, try to catch as many balloons as possible in 4 minutes. Only one balloon was visible at a time in the VE. Each time the PBO touched the balloon with his/her virtual hand, the balloon disappeared and randomly reappeared somewhere else in the room; (c) After 4 minutes, the PBO removed his/her HMD, took a break, filled out a questionnaire about his/her VR embodiment (inspired from Gonzalez-Franco et al. [3]) and workload (the NASA-TLX). The perspective condition then changed, and the participant started again from (a). After all the 3 conditions were completed, there was an interview session with the participant.

The 3 perspective conditions are as follows. The parasite body head rotation/position is only dependant on: (C1) the participant's real head rotation/position; (C2) the rotation/position of the main body shoulder AND of the participant's real head rotation/position; or (C3) the rotation/position of the main body's shoulder AND of the participant's real head rotation (*only the rotation*).

3 Observations

Three participants completed the procedure. Because of the small number of participants, we do not present a statistical analysis, but our overall impressions based on the results and the interview discussions we had with participants.

Regarding the number of balls touched, C1 generated the best results, then C2, then C3. In terms of overall workload, C1 was easiest, then C3, then C2 (except for one participant, where C2 was easier than C3). Overall, C1 provided the best VR embodiment experience, then C3, then C2. ◯ Participant P1 mentioned that he had motion sickness in C2 and C3 (some motion sickness was expected, even when keeping the time in the VE relatively short and even when the actor avoids sudden movements). He also felt disoriented in C2 and C3 and had difficulty knowing where he was and where the targets were. He preferred C1 because it felt more natural. ◯ Participant P2 mentioned that he especially disliked C2 because it was hard to see the VE and the arm (i.e. the parasite body). He liked that the main body was only affecting the length of the parasite body (as opposed to the parasite body position being dependant on the main body), because it was easier to use. Overall, he mentioned several times that it was the other user (i.e. the main body) which made it difficult (an observation hinting at researching shared action and empathy). ◯ Participant P3 mentioned that each condition changed the VR immersion, especially that it was difficult to understand that the parasite body was "away" from the head. He said that the differences in conditions considerably affected the task difficulty, and that, overall, it was difficult to know where he was moving at any given time.

4 Conclusion

Overall, C1 was well received and can be used as a baseline for further comparison. C3 performed better than C2, which is unexpected given that the PBO had less control over his/her visual perspective. It might be because C3 was easier to understand. The change of visual perspective seems to have an impact on VR embodiment (and according to a P3, on immersion as well). The interviews provided further contextual and explanatory evidence for these results. The motion sickness of P1 is an issue that we need to tackle. The disorientation felt by P1 and P3 suggest that we also need to further investigate a way to display "what is going on" in the scene in C2 and C3. P2 hinted towards low feelings of empathy for the main body, which could generate further issues when the tasks are shared. Overall, the parasite body was well received. In the future, we will study shared or join action tasks and their potential effect on performance and empathy.

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