ACE-VR : Avatar Control with Eye-Tracking in Virtual Reality for Accessibility

Structure:

- City: Nantes (France). Host institution: École Centrale de Nantes. Laboratory: LS2N (team PACCE)

Supervisors:

- Rebecca FRIBOURG, Associate Professor, École Centrale de Nantes, LS2N (PACCE)
- Jean-Marie NORMAND, Professor, École Centrale de Nantes, LS2N (PACCE)
- Geoffrey GORISSE, Associate Professor, École Nationale Supérieure d'Arts et Métiers (Laval, France)

Context:

Virtual Reality allows users to be immersed in Virtual Environments (VEs) while being able to interact with their content (e.g. virtual objects or other users). In particular, with the increased interest and economical investment in the metaverse lately, the amount of shared VEs is likely to increase in the near future, enabling multiple users to interact and collaborate. In shared VEs, users are commonly represented in the VE by a virtual body, also called an avatar, which is animated according to their own movements in real time. This can be done by using motion capture suits or specific sensors (e.g., head, hands and feet sensors) used to estimate body movements with inverse kinematics algorithms [1]. However, this assumes that users are in the capacity to move which is not always possible as users might suffer from e.g., paraplegia, tetraplegia or other impairments and therefore cannot move parts or their whole body. **Aiming for an inclusive metaverse, we believe it is of high importance to develop accessible collaborative platforms in which avatars can be embodied by users with limited movement capacities. Using alternative interaction metaphors, our ambition is to provide these impaired users with a similar level of control over the virtual body compared to what is normally achieved with tracking technologies.**

A significant core of research explored the implementation of hands-free interaction in VR [2], for instance for surgery training in which surgeon hands should remain free for patient manipulation in order to remain close to a real scenario. Yet, in comparison a very small amount of studies explored how such interaction metaphors could be used to make VR experiences more accessible to people with specific motor disabilities. Some works explored the potential of Brain-Computer-Interfaces (BCI) combined with head gesture for hands-free interaction in VR [3], while other works investigated the potential of voice command compared to button press for this mean [4]. Yet, these studies did not involve avatars although those are known to greatly improve immersion [5] and the sense of presence [6] in VEs. On the other hand, having a Sense of Agency (SoA) - “feeling of control towards the avatar” is important when using avatars [7], but is highly challenging to achieve with hands-free control as compared to a normal mapping between users and avatars’ movements. While some works showed that it is possible to experience a limited SoA towards an animated avatar with no control (e.g., walking [8] or moving legs [9]), the level of agency remains limited and reinvigorates the need to investigate innovative methods of agency elicitation towards avatars with hands-free control. As far as we know, only one study investigated the use of BCI for the control of an avatar in immersive VR [10], showing a positive impact on the SoA. Yet, the use of such systems raises a lot of technical challenges, requires training and is time consuming to install. The use of eye-tracking for interaction in VR on the other hand is technically less demanding but while greatly explored for various interactions in VR [11], it has never been explored for avatar control in VR.

The aim of this PhD is therefore to explore new control capacities over an avatar in VR that involves extremely little or no movement at all of the physical body of users. In particular, we are willing to explore the use of eye tracking, potentially combined with other inputs (e.g., voice, button or electromyography

sensor) to control an avatar in VR. The goal of the PhD student will be to develop an immersive environment in Unity 3D and implement different control methods over an avatar involving eye tracking. Several user studies will be conducted in order to compare different control methods and how they might impact different dimensions of the user experience (users' SoA, the ease-of-use, the performance of the method on a specific task, etc.). Because of the preliminary nature of this research, all user studies will be conducted on healthy subjects.

Preliminary planning:

T0-T12: Literature review, development of the VR environment and different eye-tracking interaction metaphors. A first user-study will be conducted as a proof-of-concept of our implementation. In particular, for one task (manipulation), several multimodal combinations will be tested to improve our system (e.g., vocal + eye-tracking vs EMG + eye-tracking) in user-studies.

T12-T18: We aim to explore other classical VR tasks with user studies (e.g., navigation, complex full-body motions, etc.).

T18-T30: Finally, we want to study our eye-tracking methods for avatar control in a collaborative VR application. In particular, we are interested in how users will perceive one's own avatar as well as how other users' avatars will be perceived depending on the level of control over the avatar.

T30-T36: the student will focus on writing the thesis manuscript and finalizing papers.

References:

[1] D. Roth, J. Lugrin, J. Büser, G. Bente, A. Fuhrmann, and M. E. Latoschik, "A simplified inverse kinematic approach for embodied VR applications," in *2016 IEEE Virtual Reality (VR)*, Mar. 2016, pp. 275–276.

[2] P. Monteiro, G. Gonçalves, H. Coelho, M. Melo, and M. Bessa, "Hands-free interaction in immersive virtual reality: A systematic review," *IEEE Trans. Vis. Comput. Graph.*, vol. 27, no. 5, pp. 2702–2713, May 2021

[3] R. Grichnik, M. Benda, and I. Volosyak, "A VR-Based Hybrid BCI Using SSVEP and Gesture Input," in *Advances in Computational Intelligence*, I. Rojas, G. Joya, and A. Catala, Eds., in Lecture Notes in Computer Science. Cham: Springer International Publishing, 2019, pp. 418–429.

[4] P. Winkler, P. Stiens, N. Rauh, T. Franke, and J. Krems, "How latency, action modality and display modality influence the sense of agency: a virtual reality study," *Virtual Real.*, vol. 24, no. 3, pp. 411–422, Sep. 2020

[5] B. J. Mohler, S. H. Creem-Regehr, W. B. Thompson, and H. H. Bülthoff, "The Effect of Viewing a Self-avatar on Distance Judgments in an Hmd-based Virtual Environment," *Presence Teleoper Virtual Env.*, vol. 19, no. 3, pp. 230–242, 2010.

[6] K. L. Nowak and F. Biocca, "The Effect of the Agency and Anthropomorphism on Users' Sense of Telepresence, Copresence, and Social Presence in Virtual Environments," *Presence Teleoperators Virtual Environ.*, vol. 12, no. 5, pp. 481–494, 2003.

[7] K. Kilteni, R. Groten, and M. Slater, "The Sense of Embodiment in Virtual Reality," *Presence Teleoperators Virtual Env.*, vol. 21, no. 4, pp. 373–387, 2012.

[8] J. Saint-Aubert, M. Cogne, I. Bonan, Y. Launey, and A. Lecuyer, "Influence of user posture and virtual exercise on impression of locomotion during VR observation," *IEEE Trans. Vis. Comput. Graph.*, pp. 1–1, 2022

[9] E. Kokkinara, K. Kilteni, K. Blom, and M. Slater, "First Person Perspective of Seated Participants Over a Walking Virtual Body Leads to Illusory Agency Over the Walking," *Sci. Rep.*, vol. 6, p. 28879, Jul. 2016

[10] B. Nierula, B. Spanlang, M. Martini, M. Borrell, V. V. Nikulin, and M. V. Sanchez-Vives, "Agency and responsibility over virtual movements controlled through different paradigms of brain–computer interface." bioRxiv, p. 735548, Aug. 15, 2019.

[11] I. B. Adhanom, P. MacNeilage, and E. Folmer, "Eye Tracking in Virtual Reality: a Broad Review of Applications and Challenges," *Virtual Real.*, Jan. 2023