Scaled User Embodied Representations in Virtual and Augmented Reality

Zubin Choudhary, Gerd Bruder, Gregory Welch
{zubin.choudhary,bruder,welch}@ucf.edu
University of Central Florida
Orlando, Florida, USA

ABSTRACT

Embodied user representations are important for a wide range of application domains involving human social interactions. While traditionally, human appearances were defined by the physics of the real world, we now have the means to go beyond such limitations with virtual, mixed, and augmented reality (VR/MR/AR) technologies. Different human appearances can have an impact on their perception and behavior with other users in social or collaborative environments. There is a growing literature about the impact of different user representations and behaviors on perception; however, investigating the impact of visual scaling of human body parts has so far received less attention from the research community.

In this paper, we present and discuss our position that scaled user embodied representations in VR/MR/AR could lead to significant improvements for a range of use cases. We present our previous work on this topic, including the *Big Head* technique, through which virtual human heads can be scaled up or down. We motivate how it can improve the visibility of facial information, such as facial expressions and eye gaze, over long distances. Even when a human would be barely visible at a distance in the real world, this technique can recover lost embodied cues. We discuss perceptual effects of scaling human body parts and outline future research.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**;
• **Computing methodologies → Mixed / augmented reality**.

KEYWORDS

Virtual, mixed, and augmented reality, human body representations, scaled body parts, visual magnification.

1 INTRODUCTION

Human vision allows us to perceive the surrounding real or virtual environment via light in the visible spectrum, e.g., reflected off objects in the environment. However, our visual acuity is naturally limited by the density of rods and cones on the retina, or through the resolution of a virtual, mixed, and augmented reality (VR/MR/AR) display. If the size of a physical object's projection on the retina/display falls below a perception threshold, we are unable to perceive it or its details visually. For instance, a person walking away from us causes their retinal size to shrink, which means that they are gradually perceived with fewer and fewer details until they become indistinguishable from the background at a threshold distance. This is particularly evident in current low-resolution consumer VR displays and Social VR environments, where the facial features of a virtual avatar/agent become difficult to perceive at only three meters distance [2].

In previous research on this topic, we have introduced different methods for visual enhancements by scaling human body parts, which have much promise to recover lost visual cues. We analyzed approaches for static and dynamic scaling of human embodied cues, based on perceptual limitations and detection thresholds. With recent advances in VR/MR/AR technologies and techniques, it becomes feasible to pursue and employ these methods for a wide range of practical applications.

In this position paper, we first provide background information and our own previous research, then outline our general research approach and present concluding remarks.

2 BACKGROUND

Speech-based and textual communication are integral to human social interaction, but visual aspects of communication, such as appearance, gestures, or facial expressions, also play an important role, by themselves and in addition to speech or text. In VR/MR/AR environments, users can implicitly recognize the importance of these visual characteristics of their own and other peoples' avatars or agents. With recent improvements in the visual quality of virtual humans, as well as means of avatar customization in consumer environments, e.g., social VR platforms like *VR Chat* or *Altspace VR*, such visual aspects are becoming more and more relevant and noticeable to users [3]. VR/MR/AR technologies are capable of replicating spatial appearances of humans in the real world, and they further provide the opportunity to go beyond realism [4, 13] and potentially enhance a user's perception of real or virtual entities by making them easier to see, such as by making them, in their entirety or in part, appear larger. We discuss our approach and past work on scaling spatial appearances of humans in VR/MR/AR in the following sections.

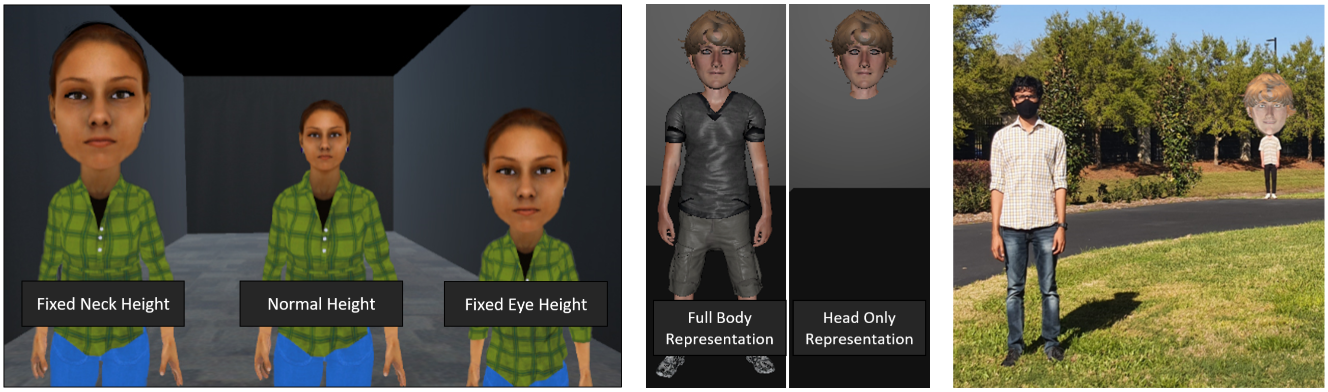
3 PREVIOUS RESEARCH

In previous work, we concentrated on a body scaling method, which we call the *"Big Head"* technique. We introduced and investigated the approach.

We first examined how magnifications can be used to enhance the visual perception of virtual human avatars/agents over different distances in VR [2]. We presented a scaled-up head of the virtual

Mensch und Computer 2021, Workshopband, 3rd Workshop on User-Embodied Interaction in Virtual Reality (UIVR)

https://doi.org/10.18420/muc2021-mci-ws16-361



(a) (b) (c)

Figure 1: Illustrations of the *"Big Head"* technique with different mechanics and in different environments: (a) Comparison of two scaling methods: The method on the left side scales the virtual human's head from the neck up but maintains the scale of the rest of the body; the method on the right maintains the eye height of the virtual human when the head is up-scaled by down-scaling the torso and legs [2]. (b) Comparison of scaled heads and their effects on distance perception for two social VR body representations with a full body or a head-only avatar [1]. (c) The big head technique applied in outdoor AR using a HoloLens to scale body parts of a distant social interlocutor.

human and investigated two different head scaling methods, one that maintained a fixed eye height of the virtual human and one that maintained a fixed neck height of the virtual human (see Figure 1a). We found that the fixed eye height based scaling method was slightly preferred by participants in the context of detecting facial features and when participants had to rate their sense of comfort when seeing a scaled human representation. We also found that participants were surprisingly tolerant of even large disproportional head scaling in terms of comfort levels and their sense of "uncanniness" [14].

In a follow-up study, we investigated the effects of the *Big Head* technique on distance perception in VR [1]. We tested the technique on two body representations, a full body representation and a head-only representation (see Figure 1b). The study revealed a significant effect of big head scaling on distance judgments—but only if the scaled heads were presented as floating objects in VR, but *not* when they were spatially anchored and attached to a human body at true scale. From this we can say that not only visual facial perception but other perceptions like distances can be affected by scaled heads on virtual humans.

4 GENERAL RESEARCH APPROACH

Our research is situated and contextualized in the field of collaborative VR/MR/AR environments and aims to facilitate effective communication with new methods to introduce and accentuate embodied cues [5–8, 10–12, 15–18, 20, 21]. Our contributions are made in the convergence research field at the nexus of VR/MR/AR computer graphics and perceptual and cognitive psychology, which inspires and guides our developments.

Since our previous work on the *Big Head* technique has shown that humans are surprisingly tolerant to even large disproportionate changes in human head scales, we believe that scaled heads and bodies will become more widely used in the future. For instance, Facebook is already leveraging it in their Social VR environments [24], and Piumsomboom et al. [19] presented Mini-Me as a tool for enhancing MR collaboration between AR and VR. It is our position that more research is needed to understand the effects of such scaling on social interactions, proxemics and avoidance behavior [22], multi-scale representations [9], etc. While our previous research so far was concentrated on head scaling, we investigate scaling techniques for other body parts, tools, and other representations with the potential to provide benefits in a wide range of collaborative and social environments. These methods will likely show an impact on users' perception of and behavior towards other users [23]. It may even effect their perception of themselves in line with the *Proteus* effect in VR/MR/AR [25]. Further research is needed to investigate localized scaling approaches on different body parts from the head down, including the hands, feet or torso. Scaling may occur individually, involve a combination of different body parts, or the entire representation as a whole. Similar to Figure 1b, these manipulations can also be realized for different real/virtual body representations. The scope for this research approach is wide, so far largely underexplored, and we believe that it can be developed into an effective tool for future multi-user collaborative environments.

5 CONCLUSION

Embodied scaling methods like these outlined in this position paper have a lot of potential to make positive contributions to the way we perceive other humans and our environment, be that the real world via AR/MR display technologies, or be that a social virtual environment by using VR displays. Subtle scaling approaches that make relevant body parts bigger or smaller in an observer's visual field can provide more visual cues when needed (e.g., using just-in-time mechanics) or prove useful to different parts of our population, such as people with limited visual acuity. We believe that this research direction is highly interesting both from a *basic research* perspective due to the various interactions with human perceptual and cognitive processes, but also for *applied research* as multiple application domains could benefit from such methods. More research is needed to explore the design space and investigate these fields.

ACKNOWLEDGMENTS

This material includes work supported in part by the Office of Naval Research under Award Numbers N00014-17-1-2927 and N00014-21-1-2578 (Dr. Peter Squire, Code 34) and the Advent Health Endowed Chair in Healthcare Simulation (Prof. Welch).

REFERENCES

[1] Zubin Choudhary, Matthew Gottsacker, Kangsoo Kim, Ryan Schubert, Jeanine Stefanucci, Gerd Bruder, and Gregory F Welch. 2021. Revisiting Distance Perception with Scaled Embodied Cues in Social Virtual Reality. In *2021 IEEE Virtual Reality and 3D User Interfaces (VR)*. IEEE, 788–797.

[2] Zubin Choudhary, Kangsoo Kim, Ryan Schubert, Gerd Bruder, and Gregory F Welch. 2020. Virtual big heads: analysis of human perception and comfort of head scales in social virtual reality. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, 425–433.

[3] Nicolas Ducheneaut, Ming-Hui Wen, Nicholas Yee, and Greg Wadley. 2009. Body and mind: a study of avatar personalization in three virtual worlds. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 1151–1160.

[4] Austin Erickson, Kangsoo Kim, Gerd Bruder, and Greg Welch. 2020. A Review of Visual Perception Research in Optical See-Through Augmented Reality. In *In Proceedings of the International Conference on Artificial Reality and Telexistence & Eurographics Symposium on Virtual Environments*. 8.

[5] Kangsoo Kim, Celso M. de Melo, Nahal Norouzi, Gerd Bruder, and Gregory F. Welch. 2020. Reducing Task Load with an Embodied Intelligent Virtual Assistant for Improved Performance in Collaborative Decision Making. In *Proceedings of the IEEE Conference on Virtual Reality and 3D User Interfaces (IEEE VR)*. Atlanta, Georgia, 529–538.

[6] Kangsoo Kim, Nahal Norouzi, Tiffany Losekamp, Gerd Bruder, Mindi Anderson, and Gregory Welch. 2019. Effects of Patient Care Assistant Embodiment and Computer Mediation on User Experience. In *Proceedings of the IEEE International Conference on Artificial Intelligence & Virtual Reality (AIVR)*. 17–24.

[7] Kangsoo Kim, Ryan Schubert, Jason Hochreiter, Gerd Bruder, and Gregory Welch. 2019. Blowing in the Wind: Increasing Social Presence with a Virtual Human via Environmental Airflow Interaction in Mixed Reality. *Elsevier Computers and Graphics* 83 (2019), 23–32.

[8] Kiyoshi Kiyokawa, Haruo Takemura, and Naokazu Yokoya. 1999. A collaboration support technique by integrating a shared virtual reality and a shared augmented reality. In *IEEE International Conference on Systems, Man, and Cybernetics*, Vol. 6. 48–53.

[9] Eike Langbehn, Gerd Bruder, and Frank Steinicke. 2016. Scale matters! Analysis of dominant scale estimation in the presence of conflicting cues in multi-scale collaborative virtual environments. In *Proceedings of the IEEE Symposium on 3D User Interfaces (3DUI)*. 211–220.

[10] Marc Erich Latoschik, Daniel Roth, Dominik Gall, Jascha Achenbach, Thomas Waltemate, and Mario Botsch. 2017. The effect of avatar realism in immersive social virtual realities. In *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology*. 1–10.

[11] Myungho Lee, Nahal Norouzi, Gerd Bruder, Pamela Wisniewski, and Greg Welch. 2019. Mixed reality tabletop gameplay: Social interaction with a virtual human capable of physical influence. *IEEE transactions on visualization and computer graphics* (2019).

[12] Myungho Lee, Nahal Norouzi, Gerd Bruder, Pamela J. Wisniewski, and Gregory F. Welch. 2019. Mixed Reality Tabletop Gameplay: Social Interaction with a Virtual Human Capable of Physical Influence. *IEEE Transactions on Visualization and Computer Graphics* 24, 8 (2019), 1–12.

[13] Rachel McDonnell, Martin Breidt, and Heinrich H Bülthoff. 2012. Render me real? Investigating the effect of render style on the perception of animated virtual humans. *ACM Transactions on Graphics (TOG)* 31, 4 (2012), 1–11.

[14] Masahiro Mori, Karl F MacDorman, and Norri Kageki. 2012. The uncanny valley [from the field]. *IEEE Robotics & Automation Magazine* 19, 2 (2012), 98–100.

[15] Nahal Norouzi, Gerd Bruder, Brandon Belna, Stefanie Mutter, Damla Turgut, and Greg Welch. 2019. A systematic review of the convergence of augmented reality, intelligent virtual agents, and the internet of things. *Artificial intelligence in IoT* (2019), 1–24.

[16] Nahal Norouzi*, Austin Erickson*, Kangsoo Kim, Ryan Schubert, Joseph LaViola, Gerd Bruder, and Greg Welch. 2019. Effects of shared gaze parameters on visual target identification task performance in augmented reality. In *Symposium on Spatial User Interaction*. 1–11.

[17] Nahal Norouzi, Kangsoo Kim, Gerd Bruder, Austin Erickson, Zubin Choudhary, Yifan Li, and Greg Welch. 2020. A Systematic Literature Review of Embodied Augmented Reality Agents in Head-Mounted Display Environments. (2020).

[18] Thammathip Piumsomboon, Arindam Day, Barrett Ens, Youngho Lee, Gun Lee, and Mark Billinghurst. 2017. Exploring enhancements for remote mixed reality collaboration. In *SIGGRAPH Asia 2017 Mobile Graphics & Interactive Applications*. 1–5.

[19] Thammathip Piumsomboon, Gun A Lee, Jonathon D Hart, Barrett Ens, Robert W Lindeman, Bruce H Thomas, and Mark Billinghurst. 2018. Mini-me: An adaptive avatar for mixed reality remote collaboration. In *Proceedings of the 2018 CHI conference on human factors in computing systems*. 1–13.

[20] Thammathip Piumsomboon, Youngho Lee, Gun A Lee, Arindam Dey, and Mark Billinghurst. 2017. Empathic mixed reality: Sharing what you feel and interacting with what you see. In *2017 International Symposium on Ubiquitous Virtual Reality (ISUVR)*. IEEE, 38–41.

[21] Daniel Roth and Marc Erich Latoschik. 2019. Construction of a validated virtual embodiment questionnaire. *arXiv preprint arXiv:1911.10176* (2019).

[22] Ferran Argelaguet Sanz, Anne-Helene Olivier, Gerd Bruder, Julien Pettre, and Anatole Lecuyer. 2015. Virtual Proxemics: Locomotion in the presence of obstacles in large immersive projection environments. In *Proceedings of IEEE Virtual Reality (VR)*. 75–80.

[23] Thomas Waltemate, Dominik Gall, Daniel Roth, Mario Botsch, and Marc Erich Latoschik. 2018. The impact of avatar personalization and immersion on virtual body ownership, presence, and emotional response. *IEEE transactions on visualization and computer graphics* 24, 4 (2018), 1643–1652.

[24] Will Cherry. Sep 25, 2019. Oculus Connect 6, All In This Together - Live Blog. https://noproscenium.com/oculus-connect-6-all-in-this-together-1ad86529e62b.

[25] Nick Yee and Jeremy Bailenson. 2007. The Proteus effect: The effect of transformed self-representation on behavior. *Human communication research* 33, 3 (2007), 271–290.