RESEARCH STATEMENT

MAURICIO SOUSA

My interests are in Human-Computer Interaction – at the intersection of Computer-supported Collaborative Work, 3D User Interfaces, and Mixed Reality. Through prototyping and user studies, I seek to contribute new research focused on making it easier for people to interact with each other and their environment (physical, virtual, or a mix of both). I am also motivated to be part of the scientific community exploring new ways to bring remote people together as if they were in the same physical space. I firmly believe that for academia to create new impactful interactive technologies, it is vital to consider human factors and natural implicit and explicit communication.

My research aims to seamlessly bring together geographically distant people as if they share the same physical space. Physical distance should not be a contending factor prohibiting people from being together, sharing experiences, and transferring knowledge. I aim to contribute to a future where remote people can meet, experience each other's presence and environments, as well as use natural communication to socialize, collaborate, share resources, and help each other.

Current predominant computing technologies are effective in establishing communication channels between people. Still, they add unproductive protocol layers to the flow of communication between remote people, rendering interactions far from seamless. Although widely adopted, traditional video conferencing approaches still uphold partial viewing or down-scaled representations of remote people that curb the sense of "being there." Modern advances in Mixed Reality technologies have ignited hope of bringing remote people closer together. Yet, people are resistant to adopting these technologies compared to others, such as videoconferencing on smartphones or desktop computers. I believe there are three reasons for this. First, Mixed Reality's benefits do not significantly improve communication over conventional technologies. Current approaches promise remote encounters in immersive virtual realities that detach people from their reality and environment. For virtual encounters to be practical, we must embrace how people naturally interact in their physical world. Second, technology is still cumbersome and requires people always to wear head-mounted displays. We must look for solutions to equip the physical environment with augmentations instead of solely resorting to user instrumentation. Lastly, the Metaverse promises virtual encounters in a separate alternative reality that requires an overwhelming disconnection from actual reality. Despite the benefits of entertainment and escapism, people want to be aware of their surroundings and who surrounds them in most scenarios.

To achieve this vision, I create software and hardware technologies that unite people by leveraging their context and natural communication. And I focus on improving how people communicate and collaborate, perceive each other's actions, and have a tangible impact on remote physical environments.

Research Contributions

My research follows these four related areas: 1) studying perception manipulation techniques to improve remote interactions, 2) improving user interactions within immersive environments, 3) contributing novel medical interfaces for rehabilitation, medical imaging, and surgery, and 4) advanced technology for learning physical skills.

Perception Manipulation to Improve Remote Collaboration

I hypothesized that perception manipulations could increase workspace awareness and improve remote face-to-face collaborative work in shared 3D workspaces. By perception manipulations, I mean to purposefully change the properties of how a workspace and remote people are presented to a local observer using geometrical transformations, reshaping gestures, and warping and repositioning devices. I focused on leveraging the sense of "being there" using full-body virtual representations of people and enhancing the visibility of nonverbal communication.

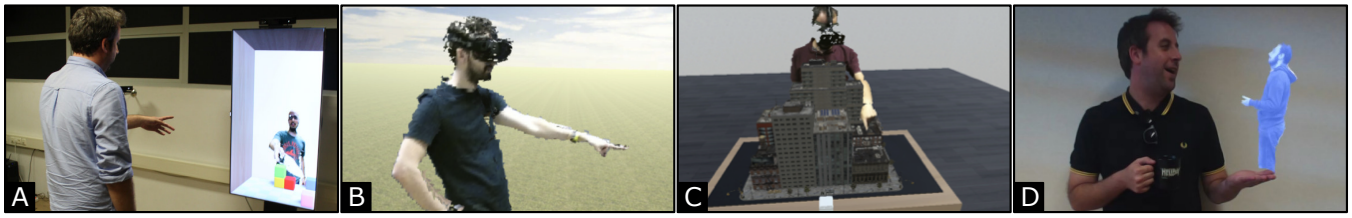

Figure 1: I proposed four concepts to improve remote telepresence and collaboration.

I contributed the open-source Creepy Tracker Toolkit [11], a set of tools for rapid-prototyping context-aware applications that incorporates body tracking, interactive surfaces, and point-cloud representation of people. The Creepy Tracker toolkit served as the technological foundation for all my prototypes related to body representation and remote telepresence.

I designed an assessment of different manipulation techniques to improve workspace awareness in a face-to-face remote collaborative 3D. And I proposed a new shared virtual workspace, called Negative Space [10] (Figure 1A), connecting two remote physical spaces while providing a sandbox for interacting with 3D content. From this research, I found that Mixed Reality technologies interfere with the ability of people to perceive deictic gestures. Therefore, I proposed Warping Deixis [9] (Figure 1B), a novel body warping technique to improve how deictic gestures to distance targets are interpreted in mixed-reality environments. Warping Deixis can significantly reduce misunderstandings when people collaborate in immersive environments. Finally, I contributed Altered Presence (Figure 1C), an interactive approach that uses body warping to ensure that opposing participants share the same understanding of the workspace.

Related to this topic, I realized that interacting with full-size representations of people may not be desirable. Using miniature versions of remote people can create an eye-gaze matching problem that hinders communication. Therefore, I collaborated to realize a design space [1] (Figure 1D) for interacting with volumetric representations of people and presented an approach for dynamically manipulating scale, orientation, and the position of holograms to improve communication.

Improving Interactions in Mixed Reality Environments

I also contributed to improving the user experience in immersive and semi-immersive environments. One of the current drawbacks of current technologies and approaches is the still existing gap between the interaction techniques and the natural way people interact with the physical world. Therefore, I collaborated and contributed to several techniques for selection [7, 16], manipulation [8], perception of virtual objects [6], and interactive surfaces [15]. Furthermore, immersive technologies isolate users entirely from the outside world and can place them in unsafe situations. Two this end, I was invested in creating methods to make virtual reality users aware of their surroundings [5] and investigating ways to safely warn bystanders if they invade dangerous situations near users engage in virtual reality experiences [14]

3D User Interfaces for Rehabilitation, Medical Imaging, and Surgery

I believe that Mixed Reality technologies are reaching a level of maturity that can positively impact healthcare. In the future, Mixed Reality could provide patients and medical practitioners with lifesaving information. Indeed, the U.S. Food and Drug Administration Federal Agency approved the first augmented reality app for surgical use not long ago.

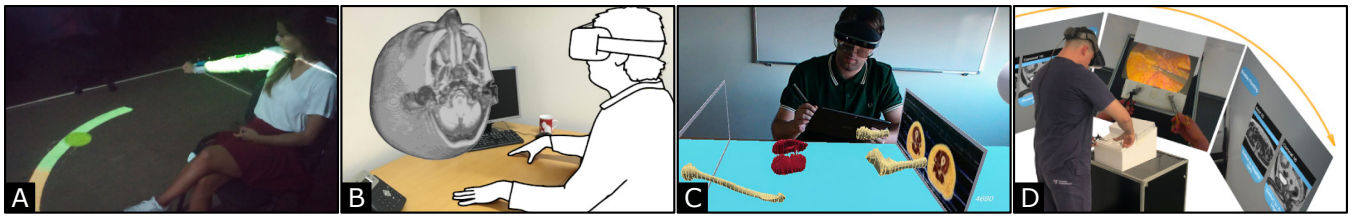

Figure 2: Contributions to Rehabilitation, Medical Imaging, and Surgery.

In this space, I proposed SleeveAR [13] (see Figure 2A), a projected Mixed Reality user interface that allows people to perform rehabilitation exercises by themselves under the offline supervision of a therapist. SleeveAR showed a robust approach to guiding people through prescribed exercises and demonstrated performance improvements between consecutive exercise executions. I proposed VRRRRoom [12] (Figure 2B), an interactive visualization approach to help radiologists analyze and interpret medical images in hopes of avoiding severe diagnostic errors. And I collaborated in a collaborative 3D reconstruction approach for anatomists, called Anatomy Studio [17] (Figure 2B). Yet, my significant contribution to this area is a collaboration that enabled the steps for Mixed Reality to be used in minimally invasive laparoscopic surgery [18]. In this work, I contributed to the design of a method that improves surgeons' comfort by keeping the laparoscopic video in their viewing area regardless of neck posture and an interface that makes it possible to access patient imaging data without interrupting the operation.

Physical Skills Demonstration and Remote Teaching

Online synchronous and asynchronous tutoring with an instructor is a powerful method for people to learn new physical skills. However, online videos and telepresence approaches do not allow adequate spatial awareness or viewpoint control

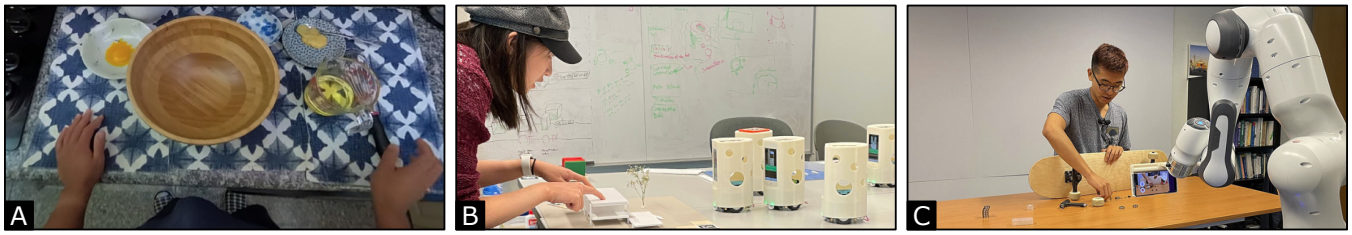

Figure 3: I proposed three approaches for learning technical skills by demonstration.

of the demonstration activities scattered across a physical workspace. Even online synchronous tutoring using video conferencing, instructors are not sufficiently aware of the audience's progress and understanding. I believe that online tutoring and remote teaching can bring direct knowledge to those who need it. And help people who do not have access to formal education in the subjects they need. As a mentor and scientific advisor, I have been engaged in research to improve physical skills demonstration and remote teaching.

I contributed to presenting immersivePOV [2] (Figure 3A), an approach to create how-to videos from an immersive first-person perspective using a head-mounted 360° action camera. We found that our approach reduces perceived cognitive load and facilitates task learning. Also, I contributed Asteroids [3] (Figure 3B), a novel approach for tangible robotic telepresence, to enable workbench-scale physical embodiments of remote people and tangible interactions by the instructor. With Asteroids, the audience can actively control a swarm of mini-telepresence robots, change camera positions, and switch to other robots' viewpoints for a better sense of presence and understanding. Finally, more recently, I contributed Stargazer [4] (Figure 3C), a novel approach for assisting with tutorial content creation with a camera robot that autonomously tracks regions of interest based on instructor actions. Instructors can fluidly control camera behaviors by integrating subtle nonverbal communication into instructional activities.

Future Research Agenda

I choose an academic career to pursue my vision and contribute meaningful and impactful research. Below, I describe some of the challenges I hope to study:

Tangible Remote Telepresence – In 1998, Scott Brave, Hiroshi Ishii, and Andrew Dahley proposed the concept of real-time, distributed, collaboration-based Tangible User Interfaces. While there is a large body of work on collaborative methods and tangible interactions, little is known about how remote collaborators can manipulate local physical environments. This challenge is also aggravated by the lack of research on how local people can have sufficient awareness of the remote person's actions. I believe this line of research is important and can lead to advances in remote assistance and teaching. I aim to focus on technology that allows remote influence on physical objects and study spatial, social, and workspace awareness techniques to improve collaboration in this space.

Cross-reality Remote Collaboration – I helped organize the first workshop on *Enhancing cross-reality applications and user experiences* (AVI 2022). Our objective was to discuss the benefits and challenges of interacting in cross-reality environments. In cross-reality, people transition between different points on the reality-virtuality continuum according to their context and the technology they can access at any given time. However, it is challenging to maintain awareness and communicate when everyone has varying degrees of presence and different abilities to interact. My goal is to perform studies on awareness and explore ways to improve an equal standing between all collaborators.

Remote Expert Assistance – I want to continue my research on physical skills demonstration and remote teaching. I believe that having access to knowledge is a matter of human rights. And I believe that the contribution of an experienced instructor or expert can make a difference in the learning process. There are significant opportunities to explore how remote experts can use novel technologies to guide and coordinate physical actions and collaborate in real time. There is also an opportunity to allow remote medical specialists to be called into a surgical room to guide and perform assistance anywhere and anytime. I aim to develop technologies further and study new approaches to democratize access to knowledge, focusing on communication, demonstration, and interaction with the audience.

I believe these challenges are exciting, and to research them will require lessons from various disciplines of Human-computer Interaction, computer graphics, computer science, and cognitive psychology. I look forward to collaborating inside and outside the department to further my research.

References

[1] Rafael Kuffner dos Anjos, Maurício Sousa, Daniel Mendes, Daniel Medeiros, Mark Billinghurst, Craig Anslow, and Joaquim Jorge. Adventures in hologram space: exploring the design space of eye-to-eye volumetric telepresence. In *25th ACM Symposium on Virtual Reality Software and Technology*, pages 1–5, 2019.

[2] Kevin Huang, Jiannan Li, Mauricio Sousa, and Tovi Grossman. immersivepov: Filming how-to videos with a head-mounted 360 action camera. In *CHI Conference on Human Factors in Computing Systems*, pages 1–13, 2022.

[3] Jiannan Li, Maurício Sousa, Chu Li, Jessie Liu, Yan Chen, Ravin Balakrishnan, and Tovi Grossman. Asteroids: Exploring swarms of mini-telepresence robots for physical skill demonstration. In *CHI Conference on Human Factors in Computing Systems*, pages 1–14, 2022.

[4] Jiannan Li, Mauricio Sousa, Karthik Mahadevan, Brian Wang, Paula Aoyagui, Nicole Yu, Angela Yang, Ravin Balakrishnan, Anthony Tang, and Tovi Grossman. Stargazer: An interactive camera robot for capturing how-to videos based on subtle instructor cues. Article in peer review.

[5] Daniel Medeiros, Rafael Dos Anjos, Nadia Pantidi, Kun Huang, Maurício Sousa, Craig Anslow, and Joaquim Jorge. Promoting reality awareness in virtual reality through proxemics. In *2021 IEEE Virtual Reality and 3D User Interfaces (VR)*, pages 21–30. IEEE, 2021.

[6] Daniel Medeiros, Maurício Sousa, Daniel Mendes, Alberto Raposo, and Joaquim Jorge. Perceiving depth: optical versus video see-through. In *Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology*, pages 237–240, 2016.

[7] Daniel Mendes, Daniel Medeiros, Eduardo Cordeiro, Maurício Sousa, Alfredo Ferreira, and Joaquim Jorge. Precious! out-of-reach selection using iterative refinement in vr. In *2017 IEEE Symposium on 3D User Interfaces (3DUI)*, pages 237–238. IEEE, 2017.

[8] Daniel Mendes, Maurício Sousa, Rodrigo Lorena, Alfredo Ferreira, and Joaquim Jorge. Using custom transformation axes for mid-air manipulation of 3d virtual objects. In *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology*, pages 1–8, 2017.

[9] Maurício Sousa, Rafael Kufner dos Anjos, Daniel Mendes, Mark Billinghurst, and Joaquim Jorge. Warping deixis: distorting gestures to enhance collaboration. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–12, 2019.

[10] Maurício Sousa, Daniel Mendes, Rafael K dos Anjos, Daniel Simões Lopes, and Joaquim Jorge. Negative space: Workspace awareness in 3d face-to-face remote collaboration. In *The 17th International Conference on Virtual-Reality Continuum and its Applications in Industry*, pages 1–2, 2019.

[11] Maurício Sousa, Daniel Mendes, Rafael Kuffner Dos Anjos, Daniel Medeiros, Alfredo Ferreira, Alberto Raposo, João Madeiras Pereira, and Joaquim Jorge. Creepy tracker toolkit for context-aware interfaces. In *Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces*, pages 191–200, 2017.

[12] Maurício Sousa, Daniel Mendes, Soraia Paulo, Nuno Matela, Joaquim Jorge, and Daniel Simões Lopes. Vrrrroom: Virtual reality for radiologists in the reading room. In *Proceedings of the 2017 CHI conference on human factors in computing systems*, pages 4057–4062, 2017.

[13] Maurício Sousa, João Vieira, Daniel Medeiros, Artur Arsenio, and Joaquim Jorge. Sleevear: Augmented reality for rehabilitation using realtime feedback. In *Proceedings of the 21st international conference on intelligent user interfaces*, pages 175–185, 2016.

[14] Sixuan Wu, Jiannan Li, Mauricio Sousa, and Tovi Grossman. Investigating guardian awareness techniques to promote safety in virtual reality. Article in peer review.

[15] Fengyuan Zhu, Zhuoyue Lyu, Mauricio Sousa, and Tovi Grossman. Touching the droid: Understanding and improving touch precision with mobile devices in virtual reality. In *IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, 2022.

[16] Fengyuan Zhu, Mauricio Sousa, and Tovi Grossman. Bubble pinch: Applying spatial magnification and motion dampening for precise target selection in virtual reality. Article in peer review.

[17] Ezequiel R Zorzal, Maurício Sousa, Daniel Mendes, Rafael Kuffner dos Anjos, Daniel Medeiros, Soraia Figueiredo Paulo, Pedro Rodrigues, José João Mendes, Vincent Delmas, Jean-Francois Uhl, et al. Anatomy studio: a tool for virtual dissection through augmented 3d reconstruction. *Computers & Graphics*, 85:74–84, 2019.

[18] Ezequiel Roberto Zorzal, José Miguel Campos Gomes, Maurício Sousa, Pedro Belchior, Pedro Garcia da Silva, Nuno Figueiredo, Daniel Simões Lopes, and Joaquim Jorge. Laparoscopy with augmented reality adaptations. *Journal of biomedical informatics*, 107:103463, 2020.