Virtual Reality for Telecommuting

Yaying Zhang
Microsoft Vancouver
yayzhang@microsoft.com

Brennan Jones
Department of Computer Science
University of Calgary
bdgjones@ucalgary.ca

Abstract
The COVID-19 outbreak resulted in a large scale prevention action of quarantine, which made many people and companies unable to conduct normal work activities for weeks. This triggered vast discussions in the improvement of telecommuting technologies. Although telecommuting is beneficial, it is currently not widely accepted, especially in traditional industries like farming, retail, and manufacturing. One reason is that it cannot completely replace the experience of working locally yet. One key requirement is for technologies to provide a "feeling of presence," so that remote users feel as if they are *there* with colleagues, and to be able to manipulate machines remotely as easy as (or better than) when they are on-site. This is a major challenge that virtual reality (VR) can play a role in solving. This paper discusses current VR technologies for connecting humans to humans and humans to things in telecommuting, as well as the gaps and potential directions VR practitioners can work toward addressing.

Introduction
In late 2019 and early 2020, a novel coronavirus outbreak, COVID-19, struck Wuhan, China around Lunar New Year, when hundreds of millions of people were travelling for family gatherings. Infections rose sharply from tens to hundreds to thousands. On January 23, the Chinese government enforced a lockdown of Wuhan, with the goal of slowing the spread of the virus [16]. Later, the government extended the

Figure 1: Floating emojis in AltspaceVR [1].

Figure 2: In AltspaceVR [1] 101 Events, a host teaches the audience how to use AltspaceVR's functionalities with slides and microphone speech.

Figure 3: Bigscreen's [19] remote-desktop feature.

Social VR: A New Medium for Remote Communication and Collaboration Workshop at ACM CHI 2020, Honolulu, HI, USA
https://www.socialvr-ws.com/

Figure 4: In Mini-Me [13], remote (VR) user (up, right) enters a 3D modeled world (bottom) that maps to the real space of the local (AR) user (up, left).

Figure 5: In the Giant-Miniature system [14], the remote (VR) user sees through a 360° camera held in the local user's hand. Bottom image shows the remote (VR) user's view.

New-Year holiday and requested companies to extend employees' holidays. Cities and towns also requested people to self-quarantine at home [17]. This caused huge pressure on Chinese businesses and workplaces, especially those that rely on their employees to work on-site. Small businesses faced bankruptcy because their employees could not come in. Thus, China's overall economic activity declined during the crisis.

If more employees can work from home, many of these issues can be reduced. However, remote work is still a challenge for some types of jobs, in particular: factory work, farming, and health. For other jobs (e.g., teachers, office workers), while remote work is possible, lack of social cues and inability to have ad-hoc conversations make it less productive than co-located work, and thus fewer people take part in remote work.

In our view, after this crisis, telecommuting will receive great attention. Telecommuting increases people's freedom to work where, when, and how they want, including under quarantine. It also lets people work with others from around the world, thus allowing employers to hire global talents and seek global opportunities. Furthermore, telecommuting reduces the need for long-distance travel, saving transportation costs, time, and reducing carbon emissions.

Virtual Reality's Role in Telecommuting

The essential difference between working remotely and locally is whether *manpower* and *material resources* need to be gathered in one place. Telecommuting can help remote workers do two things: (1) connect people with each other, and (2) connect people with things (equipment, machines, data, etc.). No matter what kind of connection it is, in order to provide the remote user an experience that is close to or better than working locally, one thing needed is a *feeling of presence*, so that remote workers feel as if they are *there*, either *with* their colleagues (social presence [3,10]), *in* the space (spatial presence [9,11]), or *in* the space *with* their colleagues (co-presence [6]). The experience does not necessarily have to mimic local presence, but rather it could instead provide a meaningful experience that goes 'beyond being there' [5].

Presence is something that virtual reality (VR) can help users attain. It enables users to be in one place, but to interact with and immerse themselves in another world as if they are there. This paper discusses existing VR technologies for telecommuting, as well as the gaps and potential directions VR practitioners can pursue.

Existing VR Technologies for Telecommuting

Meeting in a Virtual World. Multiplayer online social applications can unite people in a virtual space. This kind of application is usually popular for entertainment purposes (e.g. Rec Room [18], VRChat [7]), but recently we have been seeing more of them expand to work scenarios. These applications usually allow users to make their own avatar and provide premade or customizable virtual meeting spaces. Users communicate with each other using voice and expressions such as floating emojis (e.g., AltspaceVR [1], Figure 1) or grabbing/throwing simple objects.

One example is AltspaceVR [1]. In this app, users can host any event, such as a work meeting, lecture, seminar, talk-show performance, or even a religious congregation (e.g., Sunday church service [2]). Events can be private or public. Hosts can speak to others and show presentation slides (Figure 2). Another example is

Figure 6: A remote user operating a VR telepresence-robot interface (top), immersing themself in a distant outdoor location (bottom). From [4].

Figure 7: In the VROOM system [8], the remote (VR) user has a 360° camera view of the local space, as well as ability to use hand gestures (top). Bottom image shows the remote user's avatar in the local (AR) user's view.

Bigscreen [19], which allows users to share large-screen contents (movies, games, etc.) with other users in a virtual cinema space. It also provides a remote-desktop feature (Figure 3), so that users can connect their computers to the cinema screen. Furthermore, it provides color markers, allowing co-workers to draw 3D annotations. Bigscreen provides a vision of a future in which we can share multiple resizable screens for our applications and content in VR, and use those to share work with our colleagues.

Bring Me Over to You. Another type of technology brings the remote user to the space of the local user using mixed reality (MR). In the remote space, a remote user wears a VR headset to immerse themselves into the local space, which is presented or reconstructed in VR using 3D modeling, camera streaming, or a combination of the two. In the local space, the local user sees the remote user through an augmented-reality (AR) device such as HoloLens.

An example of this is Mini-Me [13], an MR system for remote collaboration. The local user, wearing a HoloLens, sees the remote user's avatar in her space. The remote user, wearing VR headset, sees the local user's avatar in a 3D modeled space that exactly maps to the local space (Figure 4). The two users can see each other's head orientations and hand gestures. To enable the local (HoloLens) user to see the remote user through the small field-of-view of the device, a mini avatar of the remote user appears when the real-size avatar is out of view.

The Mini-Me system requires a virtual room that exactly maps the local room. To remove this limit, Piumsomboon et al. proposed another system [14] that allows a remote (VR) user to see through a 360° camera held in the local user's hand. From local user's view, the remote user is represented by a mini avatar on the local's hand (superimposed over the 360° camera), and the local user essentially 'carries the remote user around' to see places (Figure 5).

While this provides an immersive telepresence experience, the remote user still loses some autonomy because they rely on the local user to 'carry them around.' Another kind of design resolves this issue by adding wheels and locomotion to the viewpoint. Heshmat et al. [4] proposed attaching the 360° camera to a telepresence robot (Figure 6). We proposed taking this further by also adding an AR avatar of the remote user superimposed over the telepresence robot, thus allowing the local user to see the remote's head gaze and hand gestures [8](Figure 7).

The above systems allow the remote user to see the local space, but they do not allow the remote user to touch and manipulate the real objects in the space, which is needed in scenarios such as remote surgery, factory work, or a handshake. There are systems that combine VR with robotic arm control, such as Sarcos Guardian GT [20] and Disney's haptic telepresence robot [15] (Figure 8). For these, the remote user wears a VR headset and sees from two cameras (one for each eye) attached to the robot.

Potential Directions

Although many promising systems exist, our VR telecommuting technologies are still far from our dream: *to allow anyone to stay at home, step into VR, and remotely complete all tasks that they would normally perform on-site*. A telecommuting experience that can replace local work should provide users with: (1) a private workstation, (2) remote meetings, and (3) opportunities to communicate ad-hoc, or randomly.

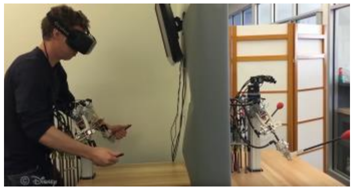

Figure 8: Disney's haptic telepresence robot [15].

Figure 9: Users working together in a VR office space in Bigscreen [19].

Figure 10: 'Bullet comments,' or floating comments from other users at the current moment, making the users feel like they are watching a video with people from around the world.

Connecting Humans to Humans

More Expressive Communication. When people communicate face-to-face, a lot of information is revealed through non-verbal expressions such as posture, gestures, eye contact, and dress. When two people are far away, especially when using virtual avatars, the simulation precision of our facial expressions, hand gestures, and body language is far from enough. On the one hand, we should think about how to enrich expressions without triggering the uncanny-valley [12] effect. On the other hand, we should also create novel digital expressions that are unique to online systems (e.g., floating emojis).

Random Moments of Interactions. The steps involved in arranging a meeting (deciding a time/place, inviting people, etc.) require effort. Whereas when working locally, we have more opportunities to interact randomly and ad-hoc. E.g., we might turn around and start to discuss things with a colleague next to us, or when we say something interesting, it might attract the attention of everyone in the office. Although it seems trivial, this ability to interact with others randomly is powerful, and it might be the turning point for telecommuting from 'an experience that can be used when there is no alternative' to 'an experience that works the same as or better than working locally.' One potential solution is demonstrated by Bigscreen: users can sit side-by-side in VR with their screens. One user can see another's screen with a glance, like in a real office (Figure 9). "Bullet comments" from 2D video streaming (e.g., Figure 10) is another idea that can be introduced to VR telecommuting to stimulate passive communication that's easy to receive (for users to notice random thoughts from co-workers without having to enter a chat).

Connecting Humans to Things

Greater Object-Manipulation Precision. We can manipulate objects in VR (e.g., grabbing, dropping, poking, throwing), but not precisely enough. For example, typing in any VR experience is frustrating: we have to poke the key one by one, and it is easy to miss keys. We need to improve the precision of our movements, especially for hands. Potential directions can be to have better hand tracking, to improve indirect pointer control (stabilize, smart select), or use more interface elements such as buttons.

Greater Connection with Real Objects. VR is good at giving users "magical powers" to interact with virtual things, but has not yet been powerful in allowing users to interact with real objects. Commercial applications for connecting people with on-site equipment is hardly seen, though VR-controlled robotic arms are a good example. There are other explorations on mapping real things into VR (e.g., [21]). Designers can also explore ways to connect VR experiences with IoT devices (e.g., allowing a worker to explore and manipulate switches in a virtual power plant, which then map to physical switches in a real power plant).

Conclusion

In this position paper, we explored existing VR technologies that enable telecommuting, and we outlined the challenges that, in our view, need to be addressed in order to facilitate more people working remotely. These include the ability to communicate through social cues (such as non-verbal behaviors that exist in the real world, as well as new expression mechanisms that VR provides), ability to communicate ad-hoc, and ability to physically manipulate objects and/or digitally interact with devices through IoT.

References

[1] AltspaceVR. Be there, together. *AltspaceVR Inc*. Retrieved February 18, 2020 from https://altvr.com/.

[2] AltspaceVR. Virtual Reality Church. *AltspaceVR*. Retrieved February 24, 2020 from https://account.altvr.com/channels/VRChurch.

[3] Frank Biocca. 1997. The Cyborg's Dilemma: Progressive Embodiment in Virtual Environments. *Journal of Computer-Mediated Communication* 3, 2.

[4] Yasamin Heshmat, Brennan Jones, Xiaoxuan Xiong, et al. 2018. Geocaching with a Beam: Shared Outdoor Activities Through a Telepresence Robot with 360 Degree Viewing. *Proceedings of the 2018 ACM Conference on Human Factors in Computing Systems*, ACM, 359:1–359:13.

[5] Jim Hollan and Scott Stornetta. 1992. Beyond Being There. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 119–125.

[6] Wijnand A. IJsselsteijn, Jonathan Freeman, and Huib De Ridder. 2001. *Presence: Where are we?* Mary Ann Liebert, Inc.

[7] VRChat Inc. VRChat. Retrieved February 18, 2020 from https://www.vrchat.com/.

[8] Brennan Jones, Yaying Zhang, Priscilla N. Y. Wong, and Sean Rintel. 2020. VROOM: Virtual Robot Overlay for Online Meetings. *Extended Abstracts of the 2020 ACM Conference on Human Factors in Computing Systems*, ACM.

[9] Kwan Min Lee. 2004. Presence, Explicated. *Communication Theory* 14, 1: 27–50.

[10] Matthew Lombard and Theresa Ditton. 1997. At the Heart of It All: The Concept of Presence. *Journal of Computer-Mediated Communication* 3, 2.

[11] Marvin Minsky. 1980. Telepresence. .

[12] Masahiro Mori. 1970. The uncanny valley. *Energy* 7, 4: 33–35.

[13] Thammathip Piumsomboon, Gun A. Lee, Jonathon D. Hart, et al. 2018. Mini-Me: An Adaptive Avatar for Mixed Reality Remote Collaboration. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ACM, 46:1–46:13.

[14] Thammathip Piumsomboon, Gun A. Lee, Andrew Irlitti, Barrett Ens, Bruce H. Thomas, and Mark Billinghurst. 2019. On the Shoulder of the Giant: A Multi-Scale Mixed Reality Collaboration with 360 Video Sharing and Tangible Interaction. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, ACM, 228:1–228:17.

[15] John P. Whitney, Tianyao Chen, John Mars, and Jessica K. Hodgins. 2016. A hybrid hydrostatic transmission and human-safe haptic telepresence robot. *2016 IEEE International Conference on Robotics and Automation (ICRA)*, 690–695.

[16] 2020. 2019–20 coronavirus outbreak. *Wikipedia*. Retrieved February 23, 2020 from https://en.wikipedia.org/w/index.php?title=2019%E2%80%9320_coronavirus_outbreak&oldid=942314057.

[17] 2020. Mainland China during the 2019–20 coronavirus outbreak. *Wikipedia*. Retrieved February 23, 2020 from https://en.wikipedia.org/w/index.php?title=Mainland_China_during_the_2019%E2%80%9320_coronavirus_outbreak&oldid=942291411.

[18] Rec Room. *Rec Room*. Retrieved February 18, 2020 from https://recroom.com.

[19] Bigscreen. Retrieved February 23, 2020 from https://www.bigscreenvr.com/.

[20] Industrial Dual-Armed Robot for Mining, Welding & More - GuardianTM GT. *Sarcos Robotics*.

Retrieved February 23, 2020 from https://www.sarcos.com/products/guardian-gt/.

[21] This is what happens when your VR and real life apartment match : BeAmazed. Retrieved February 23, 2020 from https://www.reddit.com/r/BeAmazed/comments/eq92cr/this_is_what_happens_when_your_vr_and_real_life/.