Towards Virtual Co-location and Telepresence based on Augmented Reality

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Abstract
Augmented reality (AR) allows users to see the real world, with virtual objects superimposed on the real world. AR systems can be used to establish the experience of being practically co-located by means of simulated presence. AR systems have, e.g., been used to allow experts to spatially collaborate with others at any other place in the world without traveling and thereby creating the experience of being virtually co-located. Along the vision of science fiction authors, this position paper outlines a research agenda for future telepresence technologies.

Author Keywords
Augmented Reality; virtual co-location; telepresence technologies; presence

ACM Classification Keywords
H.5.3 Group and Organization Interfaces; H.5.1 Artificial, augmented, and virtual realities

Introduction
Tad Williams describes in his saga Otherland [19–22] a future world with a widespread availability of full-immersion virtual reality [11] installations. These installations allow people to access an online world,

called simply 'the Net'. Within the Net, a group of people aims to achieve immortality. In his novel Rainbows End [18] Vernor Vinge describes how the main character Robert Gu is slowly recovering from Alzheimer's disease due to medical advances in the future. While recovering, former technophobe Robert adapts to a changed world in which almost every object is networked and the use of augmented reality [1, 2] is normal. Humans interact within augmented reality by wearing smart clothes and contact lenses that can overlay the physical environment with computer graphics. In Rainbows End [18], augmented reality is used for various purposes, e.g., large-scale commercial gaming areas, supporting maintenance workers with blueprints of machines or buildings, communication with virtual avatars and diagnostic purposes in medical settings.

Science Fiction authors Tad Williams and Vernor Vinge forecast a vision for the future that current research on telepresence technologies is addressing. Several years from now, telepresence technologies will provide an infrastructure for physical and virtual connectivity just as described by Vernor Vinge in his novel Rainbows End. Everyday objects will be connected and able to provide and exchange information. Instead of only overlaying the physical environment with computer graphics and thereby focusing on human vision, future cyber-physical systems will address all human senses, i.e. sound, smell, taste and touch, as envisioned in the saga Otherland by Tad Williams. They will mature into holistic embodied experiences, which are seen as a prerequisite for social cognition, with interaction as a crucial element [9]. The use and the interaction within augmented reality environments will become as natural as in Vernor Vinge's novel Rainbows End.

Background

First steps towards a combined vision of Tad Williams and Vernor Vinge have already been taken. There has been quite some research on introducing smell into movie theaters and television [10] and even more research on haptic feedback [16]. One of the most difficult aspects to reproduce, however, is a realistic interaction with other (real or virtual) humans. Olson and Olson [12, 13] analysed technology support for virtual co-location. They come to the conclusion that distance matters and that the analysed technology is not mature enough to enable virtual co-location. Olson and Olson state that even future technology will struggle to enable virtual co-location. In their opinion, providing awareness among co-workers and enabling co-reference as well as spatial referencing will remain a challenge. Here, Gaver [8] stresses the importance of supporting awareness information to help actors shifting from working alone to working together.

Considering current groupware technology, this forecast is still correct. Complex problem solving still requires a team of experts to physically meet and interact with each other. Then, the identification of the problem and the creation of a shared understanding are major challenges for efficiently solving a problem [14]. Typical scenarios are e.g.: solving complex construction problems, training the usage of complex machinery, analysing complex situations in emergency services or diagnosing complex medical situations. Unfortunately, it is not always possible to bring a team together to handle a complex situation. This is due to experts' availability, critical timing issues or accessibility of a location. While in the novel Rainbows End [18], such situations are supported with augmented reality technology, current technology is not yet there.

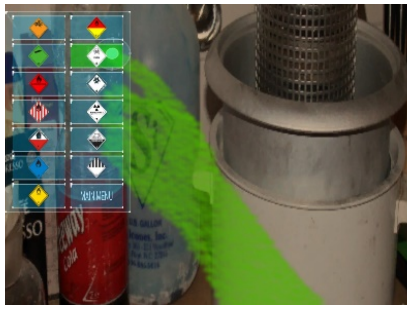

Figure 1 Simulation of the user interface for a fireman

Figure 2 User interacting with AR content

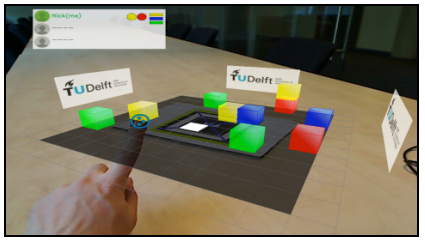

Figure 3 Collaborative tower game interaction

Recent research has shown, however, that virtual co-location is in fact possible. We used AR to allow experts to spatially collaborate with others at any other place in the world without traveling and thereby creating the experience of being virtually co-located. In the field of crime scene investigation [15], a remote expert guides and collaborates with a colleague on a crime scene to collect evidence. In this setting, the remote colleague wears a head-mounted device incl. a camera and shares the local view with the remote colleague, while both can annotate what they see with virtual objects. In a further project in the security domain (see Fig. 1 and 2), we used AR to establish virtual co-location and thus telepresence of a remote colleague for police investigations, work of firemen or reconnaissance teams [5, 6]. These projects showed that AR can in principle enable virtual co-location and allow experts at a distance to interact with local users to perform collaborative spatial tasks.

However, the evaluation revealed several issues with regard to presence and awareness, e.g. remote experts connected via augmented reality reported that they still would like to see the location with their own eyes. On the other side, the local investigator was not always totally aware of the remote expert's activities leading to the interaction in augmented reality is still cumbersome.

With a game on jointly building a tower out of virtual blocks [3, 4], we mimicked the above settings of collaborative spatial tasks (see Fig. 3). Within experiments, we could on the one hand confirm that virtual co-location can be established but on the other hand several issues still remain.

Research agenda

To address the above issues, future research on telepresence technologies will have to focus on how to design virtual co-location environments to enhance sensations of presence and (situational) awareness. Starting from proven concepts of, e.g., fidelity, human-computer interaction or visualisation models for traditional desktop collaboration situations, research will have to go beyond current augmented reality systems that only address human vision and research the effect of olfactory or gustatory senses on the perception of presence and situational awareness.

Dubois et al. [7] distinguish interaction paradigms ranging from graphical user interfaces towards tangible user interfaces to interact within augment reality. For future telepresence technologies, it has to researched which interaction paradigms are more effective. I To enable real telepresence as envisioned by Tadd Williams and Vernor Vinge, it further needs to be how interaction between virtual and real objects can be enabled. Schraffenberger and Van der Heide [17] have performed first experiments in this direction. Finally, it needs to be explored how such distributed users can be empowered to interact with the environment and with each other.

Summarising, to create an environment for virtual co-location based on telepresence technologies research needs to design for (situational) awareness and sensations of presence by making use of all human senses, new interaction paradigms that enable users and objects of the real and virtual world to interact with each other, and new interaction tools empowering users to solve complex problems and take decisions

within the novel interaction space created by virtual co-location.

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