Title: Inexpensive and mobile tele-immersive environments for everybody (TEEVE)
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Focus area: To identify open problems and fundamental challenges that must be addressed to enable deployment of pervasive computing systems at massive scale.

What are Tele-immersive environments for everybody (TEEVE)?: In general, tele-immersion systems provide a way for users in distributed geographical locations to collaborate with each other in a shared virtual space. Such systems consist of imaging hardware, networking, displays, human-computer-interface (HCI) technologies, and computational resources to run it all. The functional summary of tele-immersive systems can be described as an environment enabling real-time cloning of three-dimensional (3D) objects in physical spaces, placing them into virtual spaces and then supporting interactions in virtual spaces. The idea of TEEVE is to develop such a system at a relatively low cost so as to allow them to be deployed in households everywhere.

The Internet and the World Wide Web: The key in achieving TEEVE is the Internet and the World Wide Web with all its services. Ideally TEEVE would connect every household (and possibly every wireless handheld device). Animated 3D+time streams would become part of search engines like Google. While the computations needed to recover 3D information in real time would be likely embedded with the sensors, additional computations supporting search, classification and modeling would be executed using cloud computing. New file formats will have to be considered to store and distribute such data (including new compression methods to deal with this added dimension of depth). The use of the Internet infrastructure by TEEVE systems creates new job opportunities as the business and private use of such technology has a broad spectrum of users.

Evolving Foundations: The TEEVE technology advances the long term preservation of information, improves education, and enables distributed art in mixed virtual and physical environments. We can provide concrete examples as the current users of TEEVE at UIUC, UCB, NCSA, UPENN or commercial prototypes at HP, Microsoft, Polycom, Teliris, AT&T come from the domains of artists, citizens with disabilities, social scientists, and businesses. Providing 3D+time information to everybody would forge another evolution of cyber-infrastructure technologies.

The Transformation of the Sciences via Computation: While supercomputers, fast networks, and wide coverage of networks have been used for transformative research, it is the dynamic information content, availability of authentic representation of our physical spaces, and the methods for fast delivery of information that make the actual impact in end applications. Tele-immersive systems bring together the end applications in physical spaces with the theoretical knowledge in synthetic (virtual) spaces that enable interactions of objects from physical and virtual spaces with standard hand held devices. The applications include any type of communication, unprecedented preservation of activities, or specific types of applications from medical or engineering fields just to name a couple.

Computing Everywhere: With advancements in sensing and imaging the tele-immersive systems are ready to change the world by aiming at the holodeck as imagined in the Star Trek: The Next Generation. The stereo imaging and 3D reconstruction technologies are commercially available to deliver information that can be integrated and distributed to any networked location. With sensing everywhere and on every portable device, pixels being acquired everywhere, and computing available everywhere, the TEEVE systems can revolutionize the way we communicate, learn or relax.

Open Problems and Fundamental Challenges to Enable Deployment of TEEVE at Massive Scale: The aspects of TEEVE deployment of TEEVE involve real-time sensing of depth and color, configuration of sensing devices, integration of information, networking to exchange information streams, delivery of 3D+time streams, and support of interactions. While each aspect of the deployment poses various technical challenges leading to open research and development problems, the underlying fundamental challenge is to understand the application and task specific requirements (a) on quality of 3D+time content, (b) on connectivity of sensing devices and TEEVE sites, and (c) on media delivering 3D+time information and supporting interactivity with the content.

We foresee the deployment of TEEVE at massive scale over time with the reduced cost of depth plus color cameras, the improved Internet-based connectivity, and the advancements in 3D displays. However, the massive scale deployment will be enabled only if basic standards for representation of acquired and integrated data, networking, rendering and interactions are put in place with reference engineering implementations of the standards. TEEVE components need to become interoperable due to the system complexity. Furthermore, the massive scale deployment needs research and development investments into scalability since going from solutions with a less than ten sensing devices to several tens and hundreds of sensing devices, or connecting more than two TEEVE sites, or rendering 3D+time content on tens and hundreds of 3D display devices are not trivial problems as proven by Google in the past. Finally, the massive scale deployment would benefit tremendously from human-computer interface (HCI) research and development because the TEEVE configuration and operation need to be user friendly and intuitive. As illustrated by the introduction of Microsoft Kinect sensor, HCI has shifted from device-based to voice- and gesture-based interfaces which would be the same in the case of TEEVE deployment.

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