Wenjun Zeng
University of Missouri, zengw@missouri.edu

Immersive Environment: An Emerging Future of Telecommunications

Ameer Abbasi and Uthman Baroudi
King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

Over the past few years, various research groups, industry leaders, and entrepreneurs have come together to exchange knowledge and define the future of immersive environment networks and telecommunications. Immersive virtual environments are more than just faster videoconferencing techniques. They offer practical advantages and benefits over many traditional telecommunication applications.

Immersive refers to the act of immersing a human or an object in a digitally constructed environment.[1] An *immersive digital environment* is an artificial, interactive, computer-generated scene or "world" within which users can immerse themselves.[2] Immersive digital environments could be thought of as synonymous with virtual reality (VR), but without the implication that they are actually simulating reality. Thus, an immersive digital environment could be a model of reality or a fantasy user interface or abstraction. Although the definition of immersion is wide and variable, here we mean simply that users feel like they are part of the simulated world.

The success with which an immersive digital environment can actually immerse the user depends on many factors such as believable 3D computer graphics, surround sound, and interactive user-input as well as other factors such as simplicity, functionality, and the potential for enjoyment. New technologies are currently under development that claim to bring realistic environmental effects to the players' environment such as wind, seat vibrations, and ambient lighting. Based on exciting new ideas and active research in immersive environment networks, it seems certain that the home and work environments of the future will be significantly enhanced by immersive presence, including applications in entertainment, education, VR, and collaboration activities.

Immersive environments also enable a natural experience and virtual interaction between people, objects, places, and databases even if they are geographically distributed.[1,3] Thus, immersion has several practical applications. It can serve as an aid to engineering applications as well as help users understand and aid the disabled. Other example applications include computer games, from simple arcade games to massively multiplayer online games, and training programs such as flight and driving simulators. In addition, entertainment environments such as motion simulators immerse the riders/players in a virtual digital environment enhanced by motion, visual, and aural cues. For example, there are motion simulators that take users to the Virunga Mountains in Rwanda to meet a tribe of Mountain Gorillas (www.pulseworks.com) and that take a journey through the arteries and heart to show the buildup of plaque and teach about cholesterol and health (www.usagainstathero.com). All these environments produce large amounts of data for transmission and storage, however, so data types

Editor's Note

In the future, we can envision home and work environments significantly enhanced by the presence of an artificial, interactive, computer-created "world" filled with realistic environmental effects. Users will be able to immerse themselves within these environments. Applications are limited only by the imagination. This article surveys immersive communication environments and their applications in entertainment, business and society, and simulated learning and education.

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such as images, audio, video, and text are an integral part of immersive environments.[1]

Previous publications have discussed challenges and recent advances in immersive communication, focusing on the state of the art in signal processing for immersive communication environments.[3] This article, however, surveys immersive communication environments and focuses on high-level related issues. We depict a holistic picture of this advanced and complex field. In doing so, we classify the immersive computing environments into three major categories: entertainment, business and society, and simulated learning and education.

Entertainment

Art, entertainment, and multimedia have always served as unique and demanding laboratories for information science and ubiquitous computing research. This section overviews research activities and projects that are being conducted to improve the human multimedia interaction, experience, and perception with the help of immersive environments.

Immersive Gaming

Paul Bourke and Dalai Felinto discussed a cost-effective immersive gaming environment and its implementation in an open source game engine called Blender.[4] They claim that they extended the traditional approaches to immersive gaming that tend to concentrate on multiple flat screens, sometimes surrounding the player, or cylindrical displays.[5] These former techniques cause unnatural gaps between each display due to screen framing; they rarely cover the 180 horizontal degree field of view and are even less likely to cover the vertical field of view required to fully engage the human visual system. Bourke and Felinto introduced a solution that concentrates on seamless hemispherical displays, planetariums in general and the iDome in particular (see Figure 1).[6] The authors argue that their methodology is equally appropriate to other real-time 3D environments available in source code or have a suitably powerful means of modifying the rendering pipeline.

Figure 1. iDome and car racing game example. Although the warped image sent to the data projector appears distorted, the imagery is correct on the dome surface.[4]

Immersive Multimedia and Wireless Sensor Networking

Wireless sensor networks have attracted much interest in recent years. WSNs monitor the physical world by means of a densely distributed network of wireless sensor nodes. With this technology, it will soon become more feasible to deploy substantial numbers of inexpensive devices (sensor nodes) to observe large ground surfaces, underwater regions, and areas in the atmosphere. A typical WSN consists of a larger set of miniaturized sensor nodes integrated with a miniature power supply, multiple modality sensors, on-board processors, and radio communication modules. They probe their surroundings and report the data to a base station.

WSN offers an opportunity to develop a broad spectrum of applications and new capabilities in various disciplines. For example, researchers can use WSNs to develop applications for environmental monitoring, industrial sensing and diagnostics, infrastructure integrity, and art entertainment and education, enabling exciting virtual and immersive digital spaces. Integrating WSNs with the immersive environment (audio, video, graphics, and so on) is a new research area that pushes their boundaries. The idea is to use a sensor network to capture the targeted environment data (such as a sound environment) in real time and transfer it to a remote user using low-bandwidth channels such as the current Internet infrastructure or wireless channels.[7] This would give the use an *immersive presence* in the targeted environment. Figure 2 illustrates a scenario such

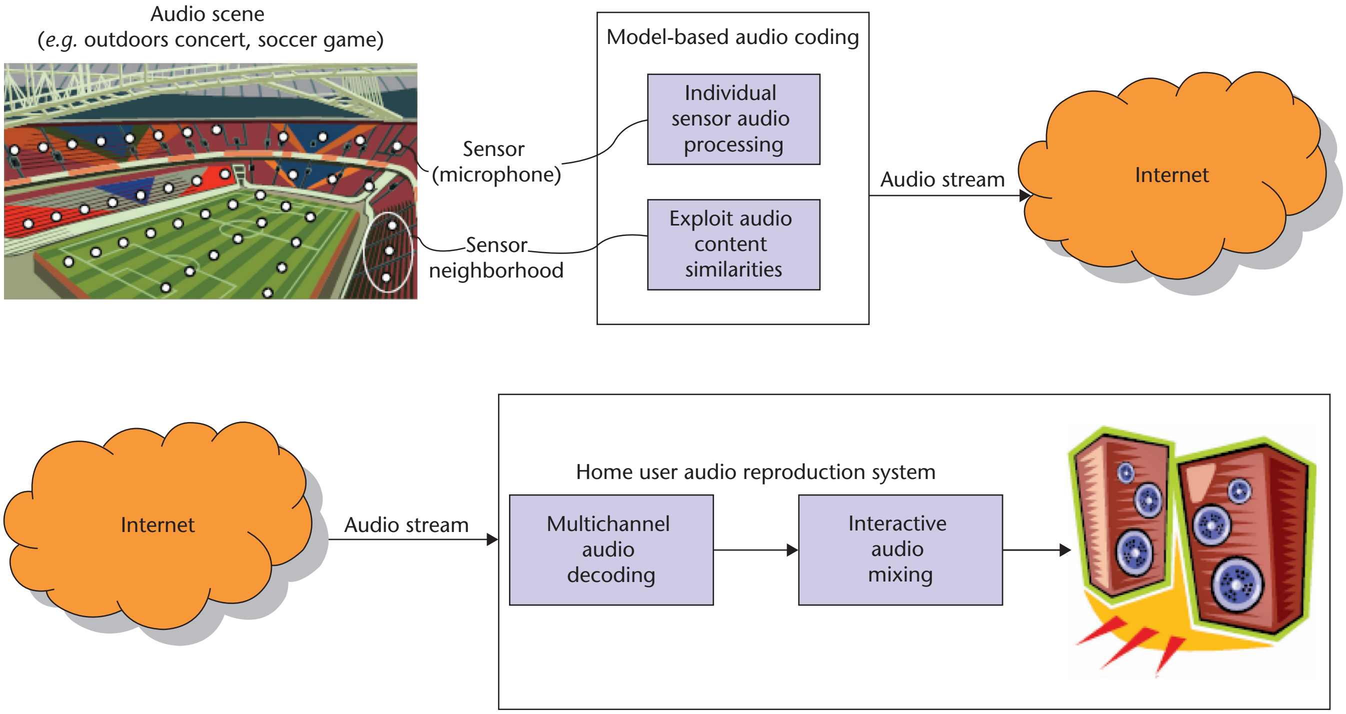

Figure 2. Immersive audio scenario. Because immersive specialized sound and user-controlled interactivity depend on enhanced audio content, the ability to efficiently capture, process, transmit, and render multiple recordings containing numerous sound sources is of crucial importance.[7]

as a soccer game or outdoor concert where audio is of interest.

If successfully integrated, WSNs could have a major impact on society. By approaching traditional, entrenched problems from innovative new angles, the research and projects are breaking through the wireless-sensor-node glass ceiling. Currently, several funded research projects such as the Aspire project[8] are in progress to bring this concept to reality.

In their paper on the Aspire project,[8] Athanasios Mouchtaris and Panagiotis Tsakalides presents several exciting new ideas to be implemented in the future. For example, a user's immersive presence in a concert hall performance in real time implies interaction with the environment, such as being able to move around in the hall and appreciate the hall acoustics; virtual music performances, where the musicians are located all around the world; and collaborative environments for the production of music.

Locomotion Interfaces of Virtual Environments

Virtual environments provide the sensory experience of being in a computer-generated, simulated space. They have potential uses in applications ranging from education and training to design and prototyping. The utility of current generation virtual environments is limited by a lack of veridical perception of simulated spaces and an associated lack of realism in interacting with the simulated spaces. Much of current work is based on the thesis that effectively combining motor and visual information helps optimize performance when people interact with virtual environments. Locomotion interfaces are energy-extractive devices that, in a confined space, simulate unrestrained human mobility such as walking and running for VR. Locomotion interfaces overcome the limitations of using joysticks for maneuvering or whole-body motion platforms, in which the user is seated and does not expend energy, and of room environments, where only short distances can be traversed. Their use yields realistic navigation and engagement in modeled worlds and an enhanced sense of spatial layout.

J.H. Hollerbach provided information about the Sarcos Treadport experimental platform, a unique locomotion interface that consists of a large tilting treadmill, an active mechanical tether, and a CAVE-like visual display.[9] Hollerbach mentioned that highly interdisciplinary teams of investigators seek to make the locomotion experience as realistic as possible through two broad research thrusts: mechanical aspects of locomotion interfaces and perceptual aspects of locomotion interfaces.

Business and Society

Over the last several years, many of the business activities at the product and team levels have become increasingly geographically distributed for both economical and technical reasons. Without collocation, communication and collaboration problems increase with the number of people working at regional facilities, the number of regional facilities involved, and the size of the geographic area over which they are distributed. To overcome these issues, researchers in immersive telecommunications are working hard to provide solution systems that can help team members feel as if they are working side by side, despite being geographically distant.

Immersive Telecommunication and Videoconference Systems

Immersive telecommunications refers to the process of transmitting objects and their status over a distance to a remote entity. This definition leaves the door open to what the remote entity might be; it can be a digital world, a real world, or a combination. In comparison, *telepresence* refers to the process of interacting with a remote real world, while *immersive VR* refers to the process of interacting with a digital world.

An example of an immersive telecommunications system is an enriched videoconferencing system where participants collaborate to design a new building or device.[1] The participants have both a virtual or digital design and a realistic design, and all the participants can interact with both designs. Such an application is not new but nowadays we are closer than ever in realizing such a vision. This is motivated by the recent advances in a number of related areas such as pervasive computing, imaging technologies, video and 3D coding and transmission, displays, WSNs, broadband access, graphics processing units (GPUs), and processors and hardware.

Oliver Schreer and his colleagues presented an overall concept of the European FP7 3D Presence project,[10] which will develop a multiparty, high-end 3D videoconferencing concept that will tackle the problem of transmitting the feeling of physical presence in real time to multiple, remote locations in a transparent and natural way (see Figure 3). Their work included the geometrical design of the whole prototype demonstrator, the arrangement of the cameras and displays, and the general multiview video analysis chain. The driving force behind the design strategy was to fulfill the requirements of a novel 3D immersive videoconferencing system, including directional eye gaze and gesture awareness.

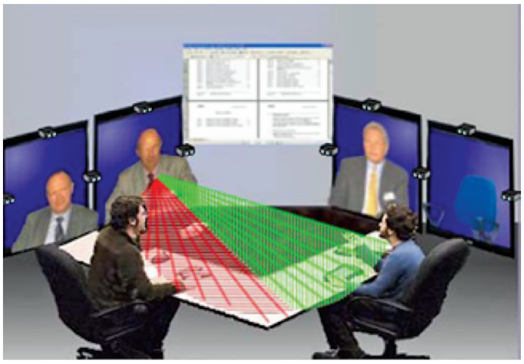

Figure 3. 3D Presence multiparty videoconferencing concept.[10] The goal of the European FP7 3D Presence project is develop a multiparty, high-end 3D videoconferencing concept that transmits the feeling of physical presence in real time to multiple, remote locations.

Peter Eisert also presented challenges, concepts, and implementations for immersive 3D videoconferencing.[11] Eisert's system is based on the principle of a shared virtual table environment that guarantees correct eye contact and gesture reproduction and enhances the quality of human-centered communication. He claimed that the MPEG-4-modeled virtual environment allows the seamless integration of explicit 3D head models for a low-bandwidth connection to mobile users. To achieve this, instead of video streams, the systems transmit facial expression and motion information, achieving a low bit rate. Each participant receives a bit rate of a few kilobit per second. The author stated that the model-based approach also enables new possibilities for image enhancements such as digital make-up, digital dressing, or modification of scene lighting.

Based on a polyhedral visual hull algorithm, Chi Wa Leong, Yue Xing, and Nicolas

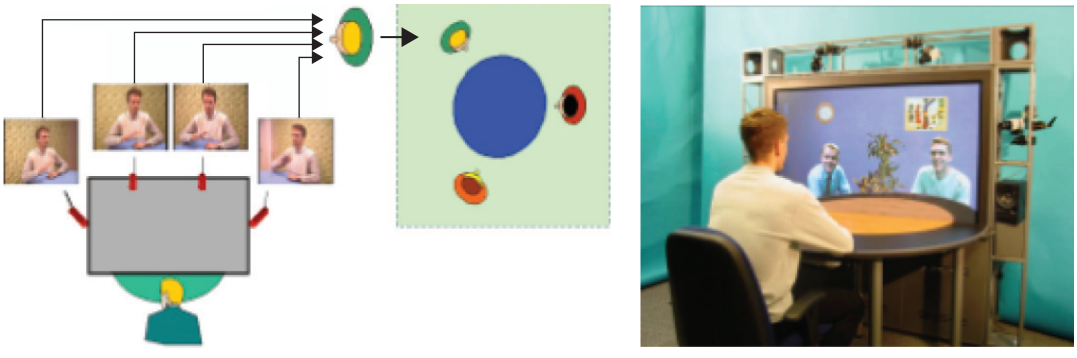

Figure 4. Immersive 3D videoconferencing example.[11] (a) Setup for a three-party conference, (b) Virtual Team User Environments (VIRTUE) system setup.

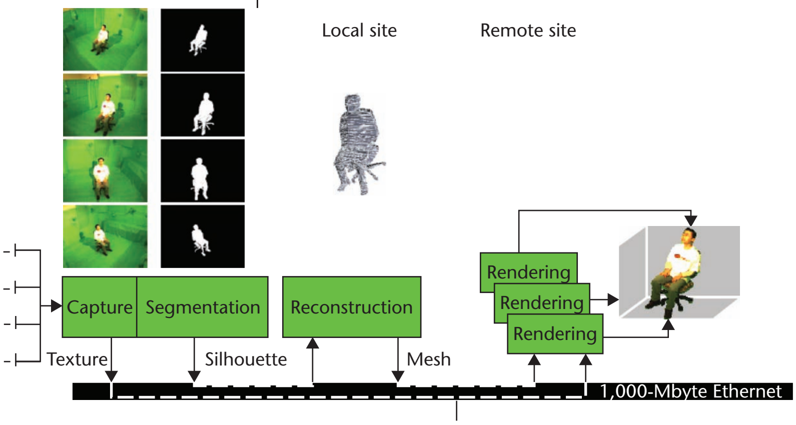

Figure 5. Experimental framework of teleimmersive system.[12]

Georganas presented an experimental framework of a teleimmersive system.[12] Their system is divided into local and remote sites. At the local site, participant images are taken from a set of synchronized cameras. The polyhedral visual hull algorithm is then used to reconstruct the 3D mesh. The texture information together with the mesh model is then sent to the remote site for rendering on immersive walls. Their paper described in details each system component, including segmentation, post process filtering, visual hull reconstruction at the local site, and view dependent texture mapping at the remote site.

Globally Distributed Software Development

Business pressures today drive development projects toward global development in which the systems and software development team are distributed over two or more geographical locations. Redge Bartholomew described an ongoing corporate experiment that aims to improve collaborative software development.[13] That experiment has become so popular that it has spread to more than four continents, seven countries, and 20 regional facilities. It involves the use of an immersive networked virtual environment (NVE) for the development of aviation electronics. Bartholomew claimed that collocation allows improved communication, confidence, familiarity, and trust that facilitate rapid information sharing, mentoring, problem resolution, and so on. Pointing to previous observations made by the research community, his paper stated that to improve the speed and cost of software development while distributing it across a global team requires remediation such as the acquisition and deployment of collaboration technology.

Behavioral Finance and Immersive Games

Gill Clough, Graínne Conole, and Eileen Scanlon explained the development of a design and evaluation framework that aims to help stakeholders of an interdisciplinary research project developing a shared understanding of project goals and methods by pooling their knowledge of research approaches and methodologies.[14] The Excellence in Decision-making through Enhanced Learning in Immersive Applications (xDelia) project is a three-year pan-European project that uses wearable sensors and gaming to investigate how people's behavioral habits and emotional states affect their financial decision making. The paper explained that the project combines research skills and expertise of European partners from different methodological traditions (experimental, economic, and field research) that will work together to achieve the project goals. According to the paper, the design and evaluation framework will provide a working collaborative model to capitalize on the different approaches, using ongoing participatory evaluation to ensure the development of an integrated set of research questions, optimum use of research instruments, and effective collaboration between the different disciplines.

Simulated Learning

In the learning and education field, several underrepresented regions lack support for the hands-on experience that is crucial in the learning process. Using remote science laboratories and videoconferencing systems, remote instructors could teach a science lab and interact with students located in various geographical locations. Example applications of immersive telecommunications in this area are numerous, and all of them fit the 21st century goal of green technology. For example, a surgical training system could benefit from immersive telecommunications technologies where existing VR-based surgery training systems are combined with remote-access technologies for remote supervision and instruction by experienced surgeons.[15] Activities in this area span many fields, including health, legal, and military training.

Health Training Systems

A work by Lars Lünenburger and his colleagues described the design and implementation of an immersive virtual environment for robot-assisted gait training that delivers feedback and increases motivation.[16] Subjects can navigate through exchangeable virtual environments by modulating their performance of the left and right leg. Preliminary tests show usability with control subjects. However, clinical tests are still required to show applicability in the clinical routine and to test for therapeutic efficacy. An interactive VR system has been implemented for a gait-rehabilitation robot such that subjects can control their virtual movement in a computer-generated environment. In a usability test, able-bodied subjects were able to use the system and reported high motivation. Before clinical tests with patients during neurological rehabilitation, areas that necessitate improvements include the temporal feedback resolution, the presently limited variety of scenarios, and the magnitude of the used technology. With these adaptations to the clinical setting, the combination of VR and rehabilitation robotics can be expected to enhance patient performance and the quality of rehabilitation.

The immersive computing environments and applications surveyed here represent a qualitative advancement over earlier technologies.

The main purpose of the research presented by Matthias Harders and his colleagues was to develop a generic surgical training simulator for hysteroscopy.[17] A key target is to go beyond rehearsal of basic manipulative skills and enable training of procedural skills such as decision making and problem solving. According to their paper, the sense of presence plays an important role in the achievable training effect. To enable user immersion into the training environment, the surrounding and interaction metaphors should be the same as during the real intervention. Thus, they replicate virtually an operating room lab, provide standard hysteroscopic tools for interaction, and generate a new virtual scene for every session. In this setting, the training starts as soon as the trainees enter the OR lab and ends when they leave the room.

Law/Court Training

Jim Blascovich and Jeremy Bailenson explore the possibilities and implications of employing virtual environments for courtroom training and practice.[18] They claim that the immersive and interactive reality created by these tools significantly enhances courtroom practice. The obvious boundaries between the real and virtual enhance the attractiveness of these tools because technologies of rhetorical persuasion that can be used to demonstrate subjective perspective, strengthen or impeach witness credibility, and provide the judge or jury with a better understanding of each side's perception of the facts at issue. In addition, the paper discussed in detail how the immersive technology would be applied to the court system and suggested how to improve the current procedures.

In this article, we presented a survey of immersive computing environments and applications. Although they offer practical advantages, they also represent a qualitative advancement over earlier technologies. Unlike prior tools used for recreation and simulations, these are both immersive and interactive. Although several research issues and open problems must be addressed, we believe that immersive virtual technology is mature enough to be used to serve human societies. **MM**

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Ameer Abbasi is a PhD student in the Computer Engineering Department at the King Fahd University of Petroleum and Minerals, Saudi Arabia. Contact him at ameer_abbasi@kfupm.edu.sa.

Uthman Baroudi is an assistant professor in the Computer Engineering Department at the King Fahd University of Petroleum and Minerals, Saudi Arabia. Contact him at ubaroudi@kfupm.edu.sa.