EDUCATION AND MANUFACTURING IN THE NEXT MILLENNIUM

E. McShane, K. Shenai, T. DeFanti, and A. Johnson

University of Illinois at Chicago, Department of Electrical Engineering and Computer Science
Chicago, IL 60607

Abstract

The vitality of the Internet has demonstrated the economic and scientific potential of a world-wide multimedia communications network. When issues such as network bandwidth and real-time sequencing of transmitted data are overcome a new wave of virtual reality (VR) and electronic visualization (EV) applications will soon appear. These technologies have the potential to significantly impact global manufacturing, commerce, education, and medicine. Similar applications will appear in aerospace research and exploration. This paper describes our work in the fields of EV/VR and the underlying electronics necessary to support these systems.

Our research includes investigation of low-power wireless communications technologies and EV/VR technologies for remote visualization, immersive collaboration, and tele-presence. By combining these thrusts we are developing a visualization technology that is tailored for access via wireless communications, but which still retains the capability for integration with existing global wired communications. A key element of this work is defining the EV/VR requirements of a space exploration and manufacturing program, and creating the necessary infrastructure to support EV/VR access by terrestrial researchers, industry personnel, and students. It makes use of existing Internet/WWW networks for global distribution, but proposes a distributed microsatellite network for near- and deep-space connectivity.

Introduction

Electronic visualization and virtual reality (EV/VR) applications to date have focused on data mining, advanced prototyping, art, and the modeling and visualization of extremely complex systems. Some derivative applications have included virtual teleconferencing and immersive collaboration in a synthetic environment. These applications are a valuable proof-of-concept and serve as the foundation of future implementations for distance learning, tele-medicine, and virtual exploration. For aerospace settings in particular EV/VR will be the basis of training environments, remote medical consultations, reconstruction of distant landscapes, and tele-presence to space-based manufacturing and exploration spacecraft.

Recent results of the NASA/Jet Propulsion Laboratory Mars rover have shown that remote virtual environments can form a valuable tool in navigation and manipulation of distant landscapes. A further development of data recording and reconstruction will aid in establishing virtual worlds. As a preparatory step to manned interplanetary missions or colonization these virtual worlds will be requisite for training and validation of mission concepts and objectives. They also permit a more natural exploration of terrains that are too harsh for human presence.

Our initial work has been performed to construct a real-time, immersive, collaborative virtual environment for education (as shown in Fig. 1) [1]. In this setting children cooperate in tending a virtual garden. Full stereo audio/visual communication is supported. Other projects have included environmental simulation and prototyping for the automotive and heavy equipment industries. These virtual prototypes allow rapid evaluation of physical designs without resorting to physical manufacturing.

Fig. 1 A collaborative, fully-immersive virtual world for accessing a shared environment.

Similar work has also been performed in developing collaborative environments for manufacturing and medicine that permit multiple simultaneous users to participate in the same virtual environment.

The underlying electronics of EV/VR systems are dominated by the need for high-bandwidth communications and fast memory accesses. We are investigating embedded memory systems in which memory accesses are speeded by an order of magnitude over conventional multi-chip sets [2].

The partitioning work considers the optimal segmentation of memory for best access rates and also the best power efficiency. This effort is part of our larger effort to develop VLSI integrated circuits combining a central processing unit with high-bandwidth memory, and communications circuits for distributed modeling and collaborative global engineering [3]. In addition, to provide data flow from extraterrestrial observation sources, a wireless communications network is necessary. To accommodate this network we are developing compact electronics that include computing and communications and are suitable for inclusion in a microsatellite cluster. Such clusters, distributed throughout the solar system, would provide a network of repeater stations suitable for establishing a wireless infrastructure.

Intended applications of our work span tele-medicine and -education, immersive virtual environments, and realistic simulation environments. Establishment of virtual worlds can proceed simultaneously with unmanned space missions, using the recovered data to refine the model and enhance the verisimilitude. The electronics development is intended to support multi-gigabyte per second data transfer to permit real-time manipulation of large data sets typical of graphics images.

High-Bandwidth Wireless Communications

Our research into new technologies to support these applications encompasses low-power communications and computing architectures and variable-bandwidth virtual environments. These technologies will profoundly impact space exploration and settlement by providing immersive visualization of distant terrain, realistic simulated environments of space vehicles and habitats, and remote presence for medicine and education. Three research objectives are now being pursued for space-based applications: 1) development of high-bandwidth radio electronics for near- and deep-space communications, 2) creation of a tele-presence environment for distance interaction and exploration, and 3) the definition of a space-based infrastructure for linking and distributing communications between remote observers via tele-presence.

We have developed two RF transceiver architectures that are amenable to a monolithic CMOS implementation with an intended application to providing a primarily uni-directional communication capability to a computational core for embedded control, telemetry, or scientific/medical data transfer. The first type (see Fig. 2) is based on a direct-conversion topology and assumes an ASK modulated baseband signal. The second (see Fig. 3) is more aggressive and explores a direct digital broadcast by signal synthesis and recovery directly at RF broadcast frequencies using high-speed analog signal processing [4,5].

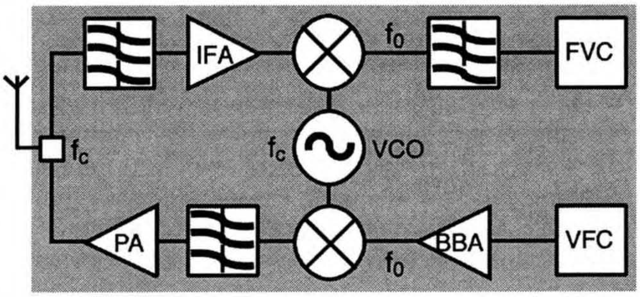

Fig. 2 Compact direct conversion transceiver.

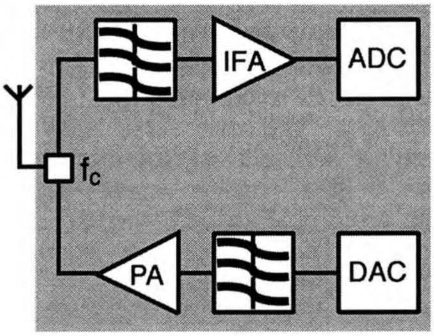

Fig. 3 Direct synthesizing transceiver employing a very high sample-rate ADC and DAC combination.

The first architecture has been included in previous designs we have performed in the field of spacecraft microavionics (that also include computing, communications, and sensing).

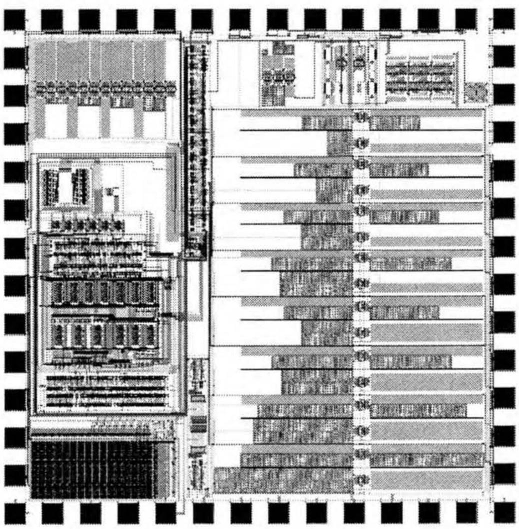

Fig. 4 An SOI CMOS microchip that includes a version of our wireless transceiver.

Two generations have been designed and fabricated (a 0.25-micron SOI CMOS version is shown in Fig. 4), the most recent in collaboration with the Jet Propulsion Laboratory as part of their ongoing research into compact, low-power spacecraft microelectronics [6].

EV/VR and Remote Access

Our objective in space-based tele-presence environments is directed toward the development of the necessary infrastructure of a planetary communication network for high-bandwidth transmission of EV/VR data. Terrestrial interfaces through Internet/WWW access will provide public and commercial access to remote sites for education and manufacturing purposes. Communication nodes, implemented as microsatellites, will provide wide interplanetary coverage. Each microsatellite will act as a repeater station and will include low-power, high-bandwidth communications with signal processing for data compression, encoding, and error recovery. We will also investigate VR environments for habitat simulation, remote terrain exploration, and tele-presence that balance bandwidth requirements with visual verisimilitude. These objectives complement our existing research and are a realizable technology.

A key result of this work is the accessibility of space-based exploration and manufacturing facilities to terrestrial observers, scientists, industry personnel, and students. We have already addressed several key applications, and these are being adapted for space implementation.

In medicine, technologies have been developed for visualizing internal physical features and for sharing data among physicians in different locations. For future space health concerns this will provide a valuable means of consulting a broad base of experts. Figure 5, for example, shows an EV/VR representation of an inner ear.

Fig. 5. A virtual reality application for telemedicine (inner ear shown) and collaborative synthetic environments.

In addition to medicine, space based manufacturing is expected to become a major resource, particularly for the pharmaceutical and semiconductor industries, both of which benefit from ultra-clean, contaminant-free environments. Costs, though, of maintaining and controlling such facilities may preclude the physical presence of a large support staff, resulting in a need for remote control and observation. We have worked with numerous computer-aided design companies in semiconductor design in the development of visualization and equipment control software [7]. As a result we can combine immersive virtual environments with equipment control software to provide a remote tele-presence that allows maintenance and monitoring from a remote site. Two applications are shown in Fig. 6 in which EV/VR access to manufacturing can be used to monitor semiconductor processing. This visualization is now supported in many computing systems, so integration with a space-based facility can be accomplished through the Internet.

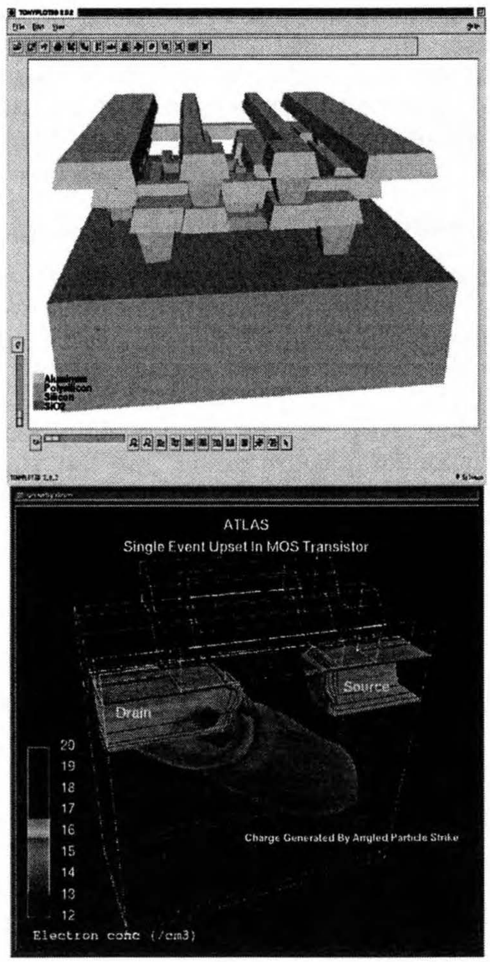

Fig. 6 Electronic visualization for distributed modeling and distance engineering.

Applications

The described EV/VR technologies were initially conceived to support terrestrial collaborative environments for education, research, and manufacturing. The described electronics have a heritage of portable computing and wireless communications. But their synthesis will enable a new generation of applications for remote visualization and exploration based on EV/VR data obtained from extraterrestrial sources, distributed down to terrestrial observers, scientists, industry personnel, and students. The proposed integrated technologies will enhance the exploration of extraterrestrial environments, support virtual reality for tele-medicine and science applications, provide immersive access to space-based manufacturing facilities, and heighten public awareness and interest in space exploration and settlement.

By combining these remote visualization technologies with terrestrial communications and Internet/WWW access, a power tool is envisioned for providing access to remote facilities. Figure 7 shows an example in which an Internet/WWW format environment can be used to introduce space-exploration and remote-communication into a classroom for curriculum enhancement. This type of remote access to space will allow many of the benefits of space-based research and manufacturing to be shared among many more customers than would be possible using proprietary terrestrial facilities.

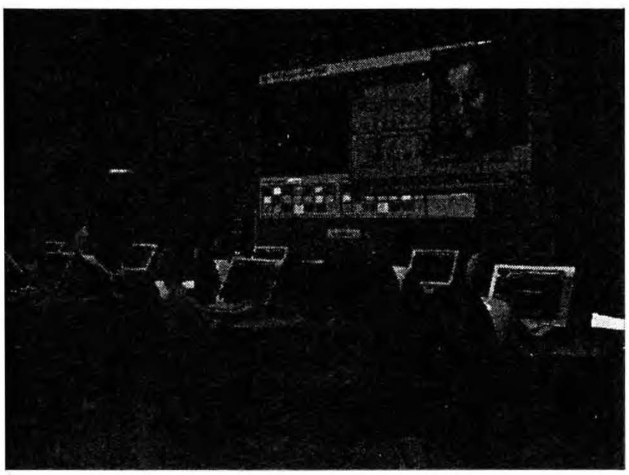

Fig. 7 A multimedia classroom for distance learning and remote collaboration.

Conclusions

We have developed several technologies for terrestrial commercial and research purposes that have led to several innovations in their respective fields. The technologies can also be combined to provide a powerful tool for improving the methods by which future space exploration and manufacturing will be conducted, and the manner in which the visualization and control of these efforts will be performed by terrestrial users.

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