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Artificial Reality in Robotics and A/E/C Firms

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ABSTRACT

Artificial Reality (AR) in a new computer interface technology which is expected to have a major impact on A/E/C firms. The system works as an interactive animation system which allows advance simulation modeling in 3-D. Artificial Reality is a display and control technology that can surround a person in an interactive computer-generated environment. The objective is to put user into a non-existent, or virtual, world and let him interact with that world much as he would with the real world. The objectives of this paper are: 1) To describe artificial reality, and 2) Present its application in: Construction, architectural engineering, training and education, telepresence and telerobotics, construction planning and scheduling, information management, and telecommunication. The goal is to provide new ideas for testing application of robotics in various construction activities without having to set up expensive physical testing facilities. With more and more competitive emphasis on reducing the design/construction cost of prototype robots, at the same time, also improve constructability, technology such as AR will be viewed as a tool for productivity improvement.

1. INTRODUCTION

Artificial Reality (AR) is a display and control technology that can surround a person in an interactive computer-generated environment. The word artificial or virtual is referred to what appears to be present but is not real. The objective is to put user into a non-existent, or virtual, world and let him interact with that world much as he would with the real world.

Artificial reality which is also known as virtual reality, virtual environment, virtual space, or cyberspace might be considered as an information world, superimposed on the physical world. It is a new kind of computer interface that enables users to move through computer-generated images in three dimensions[1-3]. AR is an interactive animation system. In AR the real world is blocked out, everything is computer-generated, including the image of a hand that mimics the motion of a real hand as the user moves it in front of his eyes. An AR system might include a head-mounted monitor with a position and orientation sensor, gloves that track hand and finger movements and a microphone wired for voice recognition transport the user to a computer-generated reality. The user issues instruction to the computer by pointing, talking, gesturing, and actually handling graphics images.

AR is still in the basic research stage, however commercial interest among the large Architectural/Engineering/Construction (A/E/C) firms is starting to develop. The research possibilities of this emerging technology are enormously great in the construction industry. The objectives of this paper are to describe artificial reality, and present its application in A/E/C firms.

As the processing power and graphics frame rate on microcomputers quickly increases, portable, personal AR systems will also become available. It appears that the possibilities of AR are as limitless as the possibilities of reality. It provides an advance simulation system to A/E/C firms to interact with objects in the simulated world. Advances in both computing and imaging technology will make this system affordable enough for commercial use.

With more and more competitive emphasis on reducing the design/construction cost while, at the same time, also improve product quality, technology such as AR will be viewed as a tool for productivity improvement.

2. BACKGROUND

In 1965, scientist Ivan Sutherland[4] was the first to theorize a virtual-reality system as a means of solving the interface barrier. His first step toward that virtual world was to develop the head-mounted display (HMD), a device that uses two display screens to create the image of a three-dimensional world. Four years later, Tom Furness[5], then with the Air Force, and his team at Wright-Patterson Air Force Base in Ohio began developing similar display systems for use in aircraft. Their aim: to simplify the pilot's interactions with his plane. In 1982, Furness unveiled the most advanced version of the HMD.

By that time, the prototype for a new interactive device, DataGlove, was in existence. Invented by electrical engineer Thomas Zimmerman in 1981, the DataGlove is an ordinary lycra glove fitted with fiber-optic cable that senses whether the fingers are being flexed. With simple finger motions, you can tell the computer what to do[6].

The scientists at NASA's Ames Research Center combined the two devices - DataGlove and an HMD - to generated a computer-created world. In this artificial world, by turning head, view of the world changes. Using simple commands, user can move around. The user can reach out and pick up virtual objects by hands. The NASA's interactive system is called Virtual Interface Environment Workstation (VIEW), which uses a wide-angle, head-mounted, stereoscopic display system allowing the operator's voice, position, and gestures control. This system enables 360 degrees exploration of a virtual environment and interact with it in various ways [7-8].

Researchers at the University of North Carolina at Chapel Hill[9] are building virtual molecules for use in medical research. MIT, and University of Washington are also very active in AR research. The Human Interface Technology (HIT) Laboratory was established in 1989 at the University of Washington in Seattle. The HIT Laboratory's purpose is to develop a new generation of human-machine interfaces for AR and to transform virtual-world research into practical, economically viable technology products.

Companies like VPL Research Inc., Sense8 Corp., and Autodesk Inc. are working on AR system which combines goggles, gloves, and computers to produce virtual worlds[10-12]. Extensive research is conducted in Japan in area of tele-existence and 3-D virtual world[13-21].

3. COMPUTER INTERACTION

Interaction with an artificial reality is similar to a human interaction with the three-dimensional world: by moving, pointing and picking up, talking and observing from many different angles.

Therefore, it is natural that interaction devices are developed based on: touch, gestures, speech and even a kind of eye contact. In addition to more realistic graphics displays, the next generation of computers may feature hands on manipulation of computer-generated images along with tactile sensations and force feedback. Sensors will measure the position of a user's head and track the movements of his eyes; voice-recognition programs will allow computers to interpret spoken language. The next section describes some of these interaction devices.

3.1 Data Gloves

One type of interaction with AR system is tactile interaction. In this case the user wears lightweight glove-like devices that transmit data-records of arm, hand and finger shape and position to a host computer. DataGlove as an interaction device translates hand and finger movements into electrical signals carried by small fiber-optic cables in each finger of the glove. The cables are treated so that light escapes when a finger flexes, and phototransistors convert the light received into electrical signals. Some companies such as VPL has gone beyond the glove and designed a full body suit that would allow all sorts of body movements.

However, there are some limitations to glove-like sensors. Currently, these devices use a cable to transmit data from the glove to the workstation, making casual use difficult. Another problem with glove-like sensors is that all users need their own gloves. A workstation supporting the device must have multiple gloves available to support left- and right-handed persons with varying hand sizes. A different approach to the problem of sensing multi-finger gestures involves the use of vision-based systems. Computer-vision systems that analyze complex real-world scans in real time.

3.2 Speech Recognition

Speech recognition allows the user to give system commands in a natural, conversational format that can not be achieved with highly constrained discrete word recognition systems or through keyboard input. Typical speech mediated interactions are requests for display/report of system status, instructions for supervisory control tasks, and verbal commands to change interface mode or configuration.

Different interface technologies should be combined where appropriate. By mixing various systems, the user has a more powerful tool. For example, simple disconnected speech is good at selecting one of many operations from a menu, especially a large menu. However, gestures are more appropriate for quantifying many parameters in parallel and for spatially constraining the scope of an operation.

4. APPLICATIONS

Although AR is still in its infancy, however its applications will prove valuable to A/E/C firms in a few years. The following section describes the current as well as possible future application areas of the AR systems.

4.1 Architectural Engineering:

Architects are expected to be among the first and biggest AR users. AR programs can offer a highly realistic view of both the inside and outside of a building from different perspectives and allow changes to be made in the plans.

Much of the motivation for architects to implement AR system comes from the potential to increase productivity. The AR systems will cut design time. Learning time will also be shortened, and customization will be easier in relation to productivity.

Transferring spatial knowledge from an architect to computers has been an intractable bottleneck in CAD applications, possibly because today's formal computer languages represent that knowledge inappropriately. By gaining the ability to capture human expression, computers can provide a better alternative to traditional manual methods of design. As AR technology improves, the system input will permit architects to perform design functions in a more natural and intuitive manner.

Using AR system, an architect can walk through a house to review the design. Architect can then examine each room with a critical eye. Would the room look better with a higher ceiling, a wider hallway, or a larger window? Architect can make these changes in an instant, with no construction crews and no tools. It is expected that AR system will replace paper and on-screen reports as the method for viewing and exchanging the wide variety of building data.

An architects could use AR system to tour a client to a building under design. Therefore, AR can be used as a marketing tool by A/E/C firms. A client can view the building from any angle, before a physical structure is built. Building inspectors and others wanting a more realistic look at a structure before construction begins may find AR a useful tool.

AR system provides an excellent tool to those clients who can not understand and read a plan, they can explore every corner of the designed building, even zooming in on light fixtures and cabinet door. Expectation of clients has increased in recent years, they like to see and tour the building before contractor builds it. They also expect to view building model plugged into a city model for planners and neighbors to review the impact.

The Japanese appear to have hit upon the first marketplace application. Matsushita Electric Works has developed a virtual kitchen which uses headsets and data gloves so that prospective buyers of the company's custom-built kitchens can experience what the kitchens would look like. The customer provides dimensions of the kitchen and the type of appliances and cabinets. Then, the customer puts on the headgear and the data glove, and the kitchen appears in 3D. Using the system it is possible to move around the room, getting a feel for what working in it would be like. The doors of the virtual appliances and cabinets can be opened to make sure that they are unobstructed.

Other architectural related application areas of AR are in interior space-making, urban design, and landscape design. For example, interior designers can use AR systems to show their customers how the interior of a building is going to look like. The AR system provides interior designers with the power to experience a conceptual model - one visualized entirely within a computer - which can be used by a customer for moving freely within office spaces in three dimensions. This creates more realistic and lifelike virtual environment that may incorporate hardwood floors, marbles, carpet, plants, and trees.

One feature which makes the AR system very attractive is the ability to modify building models by grabbing elements like walls, doors and fixtures, then moving, stretching or deleting them. In a virtual model, architect could change anything by grabbing it or pointing to it, and then simulating the final results. This new technology is an interesting new tool that's going to have a major impact on design firms, and it would be a mistake for them to ignore it.

The VIEW system developed by NASA also may be a viable interface for several commercial applications in space design/construction. The system has been used to develop architectural simulations that enable the architect to design a small 3D model of a space, and then, using a glove gesture, scale the model to life size allowing the architect to walk around in the designed space.

At University of North Carolina, a computer scientist has designed a program that allows architects to design a building. If the client wants larger windows in his office, the architect simply grabs the window with his electrically gloved hand and enlarges it. Several design/construction companies have implemented AR systems on a limited basis for their architectural work.

4.2 Training and Education:

The impact of AR on education or experiential learning could be enormous. For the first time AR will bring simulations thoroughly alive for students. AR generated a computer environment that can simulate real-world work problems. Developments relevant to training include devices that let students aim themselves in the direction they wish to move through a design.

Another application of AR is to teach students how to operate construction equipment by allowing them to work in a virtual construction site at slow speed, and then gradually modifying the virtual environment until it matches the performance of a professional construction equipment operator in the real world. In this case the students can literally explore situations that would be dangerous to encounter in the real world. The AR system can be used in such a way that students can look through the eyes of a skillful operator and see the way he is doing a particular work. Caterpillar is working on virtual reality models of its earthmovers to improve performance and driver visibility.

AR system would apply to training when more of a sense of reality is needed, where either cost or safety considerations preclude training of students on the job site, or when a facility is still under construction. Basically AR provides a higher fidelity simulation which is an extremely useful tool for teaching. Some observers are pointing to AR as the ultimate training device.

Students in structural or material engineering can use this system to better understand a stress analysis by apply the stress with their hands. Graphic displays of 3D force fields provide a better understanding of the stress analysis, because not only they can see the force vectors but also feel them.

Educational application of this technology could be developed through this ability to simulate a wide range of real construction site environments with almost infinite possibilities of scale and extent. The AR systems' capabilities for providing a highly graphical, uniform interface for varying task environments and level of interaction may reduce students workload and training time and increase productivity.

4.3 Telepresence

Telepresence involves the remote control of robots by human operators using AR system. The operator can remotely command a robot in hostile environments by seeing the world from the robot's perspective, and controlling robot movements with position-sensing body suits. As a person's head moves in the helmet, television cameras on the robot would respond accordingly, allowing the person to see images of where the robot was. As the person's hand moved, the robot's hand would respond accordingly.

Telepresence has two important advantages over conventional remote-control systems. Using this system the operator would feel through the AR system, as if he were actually at the site when in reality he could be thousands of miles away. Another benefit of this system is that the operator would not have to be trained to control the robot since he would act as if he were working on a given task himself.

Telepresence can be applied to construction works that are considered too hazardous or delicate to be done by human hands. Another application is in construction of space facilities. Astronauts could assemble the space facilities from the relative comfort and safety of their space shuttle. The technology can be used also to allow an astronaut inside the proposed space station to operate a robot making repairs outside. Another application of telepresence is when a robot can work on repairing a leaking cooling pipe in nuclear power station in total darkness.

The virtual environment display system is currently used to interact with a simulated telerobotic task environment. The system operator can call up multiple images of the remote task environment that represent different viewpoints. Three-dimensional sound cues give distance and direction information for proximate objects and events. Switching to telepresence control mode, the operator's wide-angle, stereoscopic display is directly linked to the telerobot 3D camera system for precise viewpoint control. Using the tactile input glove technology and speech commands, the operator directly controls the robot arm which correspond to his own arm. Although the long term goal of construction automation is virtually autonomous operation, it is generally recognized that human operators should continue to monitor and supervise the systems under normal operations and to intervene under unusual modes.

4.4 Scheduling

AR system can be applied in construction planning and scheduling. No longer a scheduler will look at lists of construction activities but review a project's progress through a 3-D simulation of the building process. Contractor as well as subcontractor's crew can really understand and see how a project is put together, what the sequence of activities are, whether the pieces fit together smoothly, and if there are ways to implement value engineering or expedite portions of the construction work.

4.5 Information Management

Much of the focus in virtual reality today is on modeling real-world systems, but advances in scientific visualization are likely to lead to techniques for representing abstract data as 3D structures that can be directly manipulated by engineers in an information space. By pointing at the screen, you would be able to flip through a spreadsheet as if it were a stack of papers.

Advanced information management concepts can be developed by AR systems. Current investigations include use of the system to create a display environment in which data manipulation and system monitoring tasks are organized in virtual display space around the operator. Through speech and gesture interaction with the virtual display, the operator can rapidly call up or delete information and reposition. Three-dimensional sound cues and speech-synthesis technologies might be used to enhance the operators overall awareness of the virtual data environment.

4.6 Telecommunication

One goal of AR system in telecommunication is to develop connects at least between two users. The two users will participate and interact in a shared virtual environment but each will view it from their relative, spatially disparate viewpoint. The objective is to provide a collaborative workspace in which remotely located participants can virtually interact in a face-to-face meeting while also having access to their personal dataspace facility. This could enable valuable interaction between scientists collaborating from different locations across the country. With full body tracking capability, it will also be possible for each user to be represented in this space by a life size virtual representation of themselves in whatever form they choose - a kind of electronic person.

4.7 Construction Robotics

Developing a prototype construction robot is extremely expensive. Experiences gained from development of construction robots in the past ten years has been very costly. Even large construction companies can no longer afford to develop these expensive hardware without careful investigation.

Artificial reality provides an excellent tool for investigating various construction techniques and robots. The system allows researchers to review the automation process and make any necessary changes to improve productivity. Different construction scenarios can be developed, and automation system can be simulated to measure productivity.

5. SUMMARY AND CONCLUSIONS

Artificial realities allow the user to interact with the computer in an intuitive and direct format and to increase the number of interactions. The ultimate objective of AR research is to develop a simulated environment that seems as real as the reality.

Artificial realities will fundamentally change the way A/E/C firms work with computers, allowing them to interact in an intuitive and direct format. Currently, AR systems are in their infancy, still further research is needed for real applications, but now is the time that A/E/C firms should start thinking about this new technology and its application.

AR system can be implemented in such areas as: Architectural engineering, training and education, telepresence and telerobotics, construction planning and scheduling, information management, telecommunication, structural analysis, and construction robotics. AR also shows promise as a tool for material engineering and testing that goes far beyond current CAD systems. Concurrent engineering will be another area which can vastly benefit from this new technology. Some of these areas such as the ability to conduct repairs in hostile environments or to train people without having to set up expensive physical training facilities should seriously be considered by university, industry, and government researchers.

Application of AR systems in A/E/C firms is inevitable. Because AR gets its power from the fact that people comprehend images much faster. The Human's eye-brain system is incredibly advanced, therefore AR is the most natural way of all for people to understand and manipulate computerized data in three dimensions.

Of course, artificial realities hold more promise for some problems than for others. For example it is hard to imagine how a secretary who is typing a construction contract document would benefit from 3D representation. On the other hand, many scientific and engineering problems, particularly those that can be represented in three dimensions such is architectural design and education can benefit from this new technology.

At current time, a fundamental obstacle in AR application and development is the processing power of computer technology necessary to create virtual worlds. It is only a matter of time before computers become powerful enough to generate more realistic images. Another obstacle is that AR systems at the present time are expensive and require exotic hardware. However it is expected that over time, the technology becomes more economical and affordable to A/E/C firms and university researchers.

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