Visualization Tool Applications of Artificial Reality

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1. Introduction

In the early stages of the history of computer development, information processing capabilities of computers were not very large, and only very limited capabilities such as text handling were assigned for peripheral I/O devices. Since then, efforts to make computers more powerful and intelligent have been continually progressing. As a result, a new and serious problem has arisen as to how to interact with the advanced computational results. Namely, I/O or peripheral devices have become the "bottle necks" of information processing. Thus recently, the need for communication channel with wider band widths between the human operator and the computer has arisen.

For example, in the near future, continuous media such as live video or audio, will become dominant in information processing, rather than discrete media such as text consist of Ascii codes. Artificial reality research is aiming in the same direction, to give computers a greater capability of displaying information vividly and provide communication channels with very wide band widths between the human operator and the computer. Consequently, visualization is one of the most important application fields of artificial reality.

Several artificial reality research projects focused on visualization are being conducted in the Systems Engineering Laboratory at University of Tokyo. In this paper, the major projects are introduced. First, research to develop a novel I/O device for interacting with virtual 3D space generated by computer are introduced. Second, as one application, software visualization research is introduced. The key point of this research is how to give shape in virtual space to software which has logical characteristics but originally no spatial shape. Third, the capability of experiencing non-existent environments through artificial reality is discussed. For example, world with very low light speed wherein Einstein effect is visible can be demonstrated. Finally, the importance of artificial reality in the field of visualization is re-emphasized.

2. Artificial Reality as Advanced Computer Peripherals

(1) See Through Helmet Mounted Display (STHMD)

The STHMD is developed as a display device which can optically superimpose virtual 3D object onto real environments. (Fig.-1) The STHMD consists of Sony view finders, a lens systems and half mirrors. The image displayed on the view finder screen is focused about 1.0 m before the eyeball by using the lens system and the half mirror. The field of view is about 20 degrees which is very narrow. This value was determined because we wanted to display character information which requires a high resolution display. In the case of conventional HMDs, such narrow fields of view can cause a serious loss of sense of spatial direction. However, in the case of the STHMD, the user never loses his sense of spatial direction on behalf of the real world visible through the half mirror.

This display device is expected to be used in many application fields of artificial reality. For example, medical Magnetic Resonance Imaging(MRI) superimposed onto the real patient will be very helpful in surgical operations. Or, displaying invisible information such as underground or embedded piping will be helpful for construction work and building management.

To develop a better STHMD, several technical problems need to be solved in order for the virtual 3D space to fit the real 3D space. The first problem is to develop a small display with high resolution. The second is to develop a better 3D space sensor with less sensing distortion and a smaller response delay. The third is to develop an easy way of calibrating the sensor. In addition, for outdoor use, the display should have a high contrast, and the 3D sensor should have a much larger sensing range.

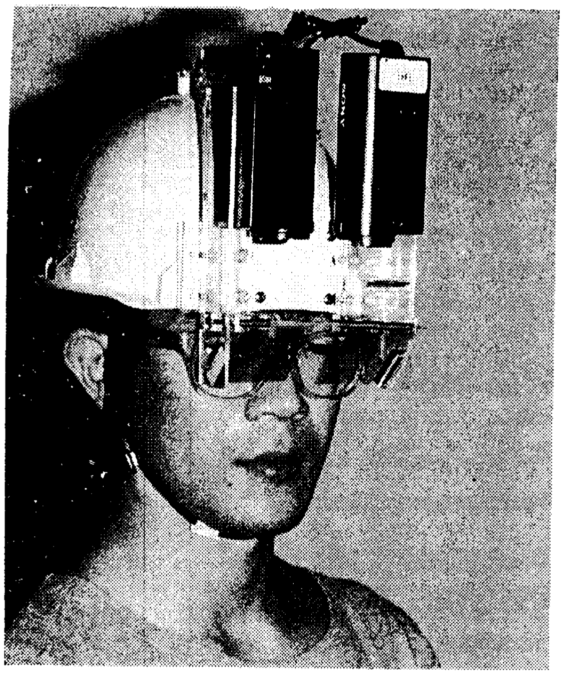

Fig.-1 See Trough Helmet Mounted Display

(2) Light Weight Helmet Mounted Display (LWHMD)

An ideal HMD would be "small" and "light weight" much like eye glass wear. Development of recent LCD technology promises realization of the ideal HMD in the near future. Currently, very small color LCD panels have already been developed for view finders for VCR cameras. By using such LCD panels, we developed the world's smallest HMD (Fig.-2). The LCD panel mounted on the lens frame is separated from the driving circuit which converts NTSC signals to LCD drive signals and is about 5.0cm by 7.5cm . The total weight of the HMD is 170gw except for the driving circuit. Specifications of the HMD are summarized as follows;

field of view : 50 degrees
focus : about 1m before eye ball
panel: EPSON color 0.7"LCD
resolution : 200(V) x 300(H)
Input signal: NTSC
weight: 170gw (including cables except for the driving circuit)

Fig.-2 Light Weighted Helmet Mounted Display

(3)Virtual Holography

A virtual environment without the use of HMDs or DataGloves is being developed. Since the current HMD has very poor resolution, we can not use it for the application which requires high definition display such as CAD. We substituted the HMD with a conventional stereo CRT which generates stereo images by using LC shutters, and has a resolution comparable to that used in conventional CAD systems. Unlike the conventional stereo CRT, by controlling the image rendering using a 3D head tracker, we can generate an effect similar to a holographic 3D image. That is the reason why we call the system "Virtual Holography".
Although the virtual holography cannot generate very large virtual 3D spaces as in HMDs, it can generate very sophisticated 3D space with high resolution (Fig.-3).

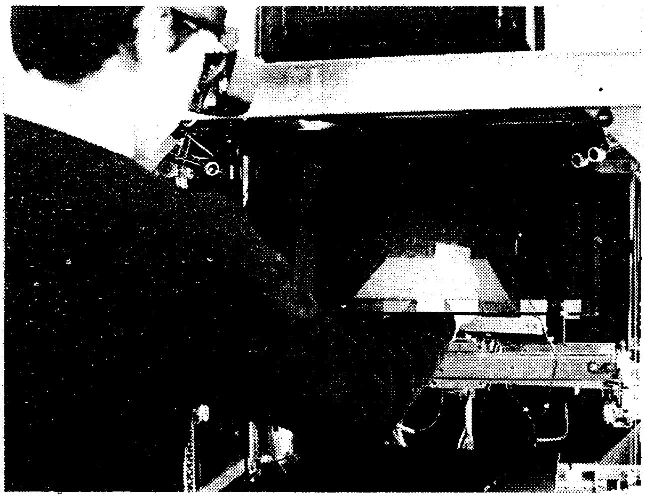

Fig.-3 Virtual Holography

In addition to the high resolution, we also have added to the system a "force display" which is a kind of mechanical arm to generate virtual force sensation. As shown in Fig.-4, four magnetic sensors located on the force feedback head measure the location of the finger wearing the magnetic ring. As long as the finger is not intersecting the displayed virtual object, the force feedback head is controlled not to touch the finger. However, once the finger intersects the virtual object, motion normal to the object's surface is disabled by locking the force feed back head. This means that physical constraints to the finger movement is synthesized in the virtual work space. By using the virtual holography, we can look around the mechanical parts which have yet to be manufactured, and even touch it.

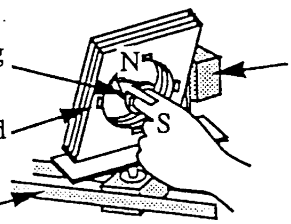

Fig.-4 Mechanism of Force Feedback Head

Under several situations, force feedback is very important. For example, when drawing characters, existence of the surface of the blackboard is very important. Only when the movement of the finger is restricted over the surface of the blackboard, the finger can draw beautiful characters very quickly. Otherwise, we have to pay large attention to not letting the finger tip go down into the black board, and never get beautiful results. Another application example is in the assembly of virtual objects. Existence of force feedback will be needed for quick execution of simple assembly such as inserting a cube into a corresponding square hall. By feeling force, we can get far more easy and intuitive understanding about the possibility of assembling in comparison with the case in which only visual feedback indicating intersecting between objects is available.

3. Software Visualization

3D visual environments can be used to develop and create large and complex software such as a network control software. Conventional text oriented environments are useful in programming individual processors. However, they are obviously insufficient in programming a large and complex system which includes large numbers of computers connected to each other. Two basic types of problems associated with the different levels can be considered. One type of problem is :"How do I program each computer?"(This is called "programming in the small"). Another might be: "How can I coordinate many networked computers?"(This is called "programming in the large"). As a solution for the programming in the large problem, a graphic programming environment is developed wherein one can visualize complicated software in a virtual 3D world.

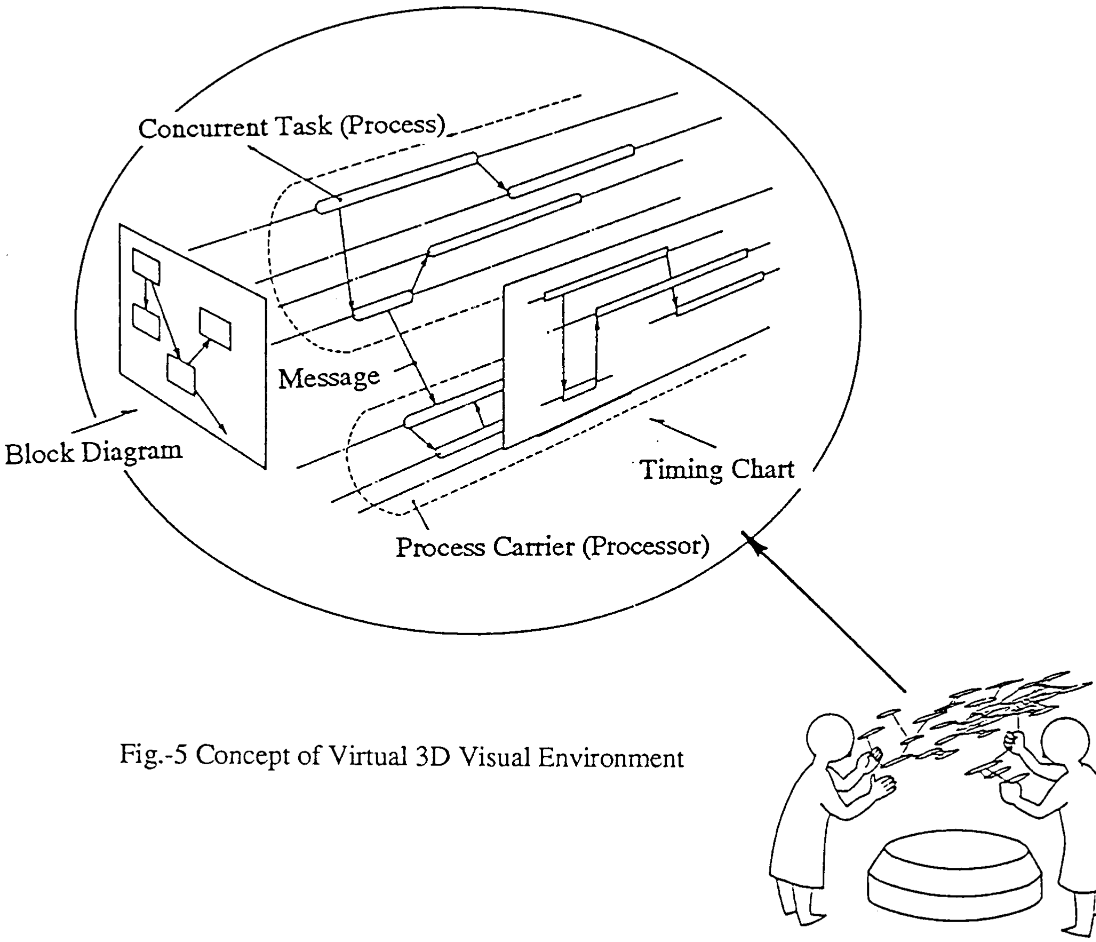

Fig.-5 Concept of Virtual 3D Visual Environment

One of the major features of the environment is the 3D representation of concurrent software process. 3D representation is used to supply both network-wide inter process programming capability and real-time capability. Often, a network diagram is given as a 2D representation, known as block diagram. However, if the description of a real-time control program is required, such as in the synchronization of several control processes, the time dimension should also be taken into consideration. Namely the idea is to fuse both the block diagram and the time chart into a single virtual 3D space. (Fig.-5) If we observe the representation along the x axis, it will be a conventional block diagram. the axis normal to the x axis is a time chart. The 3D representation gives us the capability for direct and intuitive planning or understanding of complicated relationships among many concurrent processes.

To realize the 3D representation, a technology to enable easy handling of virtual 3D object is definitely necessary. A prototype of the virtual environment is being developed using a Ikegami 80" 120 Hz stereo projector with CrystalEyes LC glasses which generates a vivid 3D virtual work space and a VPL DataGlove through which the programmer can easily handle the virtual objects in the virtual 3D space. The environment is controlled by Iris 4D 210 VGX graphic workstation for generating the virtual 3D image and handling I/O signal and SUN Sparc Station for text information handling. In the future, the virtual holography technology will be used in order to increase the sensation of handling in virtual "3D" space.

The function of the 3D programming environment is divided into two major functions, Visual Analysis (VA), and Visual Design (VD). VA is a function for displaying or visualizing already existing software codes in the virtual 3D space. VA is very useful in the phase of software management or maintenance. For example, by using VA, we can understand the global structure of very large scale softwares. Fig.-6 shows an execution record of power network control software visualized within the environment. In the example, the complicated portion indicates the portion where large numbers of process switching are included. Because of the complicated structure, it is easily expected that most bugs will be concentrated in that portion, and we can concentrate the debugging effort.

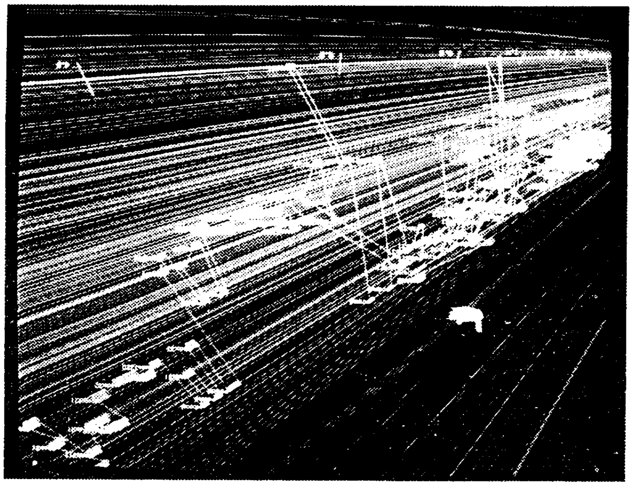

Fig.-6 Visualized Software in Virtual 3D Environment

The key point of the VA technology is to provide shape in the 3D virtual space to software which has logical characteristics, and consequently does not have a spatial shape in a conventional sense. To further advance the technology, more research should be done find ways for displaying complex information to fit the eye. Of course, visual information is not the only means. Other senses such as audio or tactile cues can be used to perceive software more intuitively.

VD is a function for developing software from the beginning or modifying the existing software in the 3D visual environment. For that purpose, several software tools are implemented.

+ Virtual Editor -- Tool to define, modify and delete processes and message passing among processes. VA data can also be modified by this tool.
+ Virtual Measure/Ruler -- Tool to measure the exact synchronization of processes

+ Critical Path Finder -- Tool to find and display the critical path which determines the total network throughput for a given network.
+ Network Simulator -- Tool to simulate message passing and data processing on each computer.

According to preliminary assessments of VD, 50% reduction of programming effort is achieved by using the virtual environment. Thus, artificial reality technology has considerable potential in the field of software engineering.

4. Virtual Physical Space Simulator

Visualization technology is also very useful in educational applications. The basic software framework for virtual physical space is implemented by using artificial reality technology. In this virtual environment, the motion of a virtual object is defined by world physical laws.We made two virtual environments, the first one is the simulated physical world as we know it. In this world, there are a floor, a table, 4 cubes, and 3 control levers. By using a virtual hand which is controlled by the user's hand wearing the data glove, we can pick up cubes and throw it away. Every object's behavior in the environment is dependent on world physical laws defined by Newton's equation which is implemented in the software working behind the system. Since collisions between objects are also implemented, cubes can be bounced on the surface of the table and the floor. By using the control lever, we can control the values of physical equation constants which are used to define the world physical law such as gravity, air viscosity and elasticity of objects.

That environment was originally implemented on HP 9000-340 SRX as a wire frame world which can be experienced by the HMD and the Data Glove. The refresh rate is about 8 frames per second which is believed to be the minimum requirement for getting a realistic sensation of the movement. (Fig.7) Recently the environment was ported to an Iris 4D 210 VGX workstation maintaining the same refresh rate as before but using solid model representations.

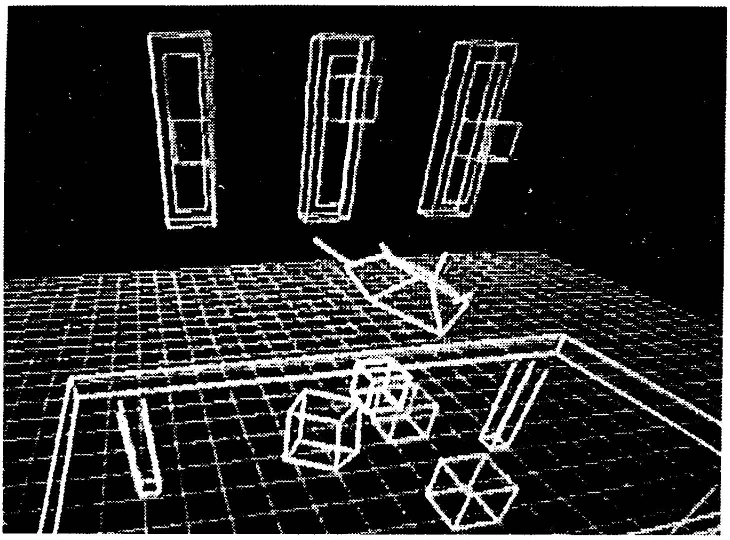

Fig.-7 Virtual Physical Space Simulator

The second virtual environment developed is called the "World of Einstein". In this world, the light velocity is supposed to be 2 m/second. By using "ray tracing"-like methods, we could generate and experience the strange world which is expressed by mathematical equations. In this world, the effect of the theory of relativity such as distortion of the space, and length shrinking of moving objects can be experienced. This environment is also implemented on the Iris 4D 210 VGX. Since "ray tracing" is a computer power consuming task, wire frame models are used to maintain a refresh rate of 8 frames per second.

Experience in the simulated environment is very helpful to students in understanding the dynamics under various conditions, relationships between various constants and causality in the physical environment. This method of "learning by experience" provides an additional method of understanding dynamics, reinforcing what is traditionally learned through symbolic equation manipulation . Thus, visualization paves the way for a more dynamic methodology of education.

5. Conclusion

In the '90s, it is said that information processing technologies which enlarge human intelligence capability will be largely appreciated. In other words, IA (intelligence amplification) technologies which help human computer coordination will be required as well as AI (artificial intelligence) technologies which make computers intelligent. By coordinating humans and computers, far more sophisticated information processing can be realized. Visualization is one of the most promising examples of the IA technologies. And the author is convinced that artificial reality will provide a powerful frame work to this field.

6. References

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