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VIRTUAL REALITY : AN EMERGING TECHNOLOGY

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INTRODUCTION

Virtual reality is an emerging computer technology which has got enormous potential in engineering, medicine education and war. It is likely to revolutionize the way we design and engineer new products and services. I. Sutherland in 1965 suggested the use of 'ultimate display' as the ultimate form of interaction between human and machine [1]. M. Krueger termed this as 'artificial reality' and denotes the technology by which everything you perceive is generated by a computer that responds to your movements with sights and sounds designed to make you think that you are in another world [2]. In the last two years this technology has become a major product conceptualization and product visualization technology. According to a US Congressional Hearing of the Sub-committee on Science, Technology and Space this new development in computer technology promises to revolutionize the way we use computers, namely

* the way we design new products
* the way we teach our children and
* the way we spend our free time [3].

It has the potential to change design and engineering practices. This paper gives an overview of this technology and its importance to developing countries, though most of the present uses are in developed countries.

WHAT IS VIRTUAL REALITY

Virtual reality is a breakthrough technology that allows you to step through the computer screen into a three dimensional artificial world so that one can look around, move around and interact within computer worlds [4]. Virtual reality is no longer limited to scientific research centres. Desktop Virtual Reality computers presents the basic building blocks for designing a virtual reality system using a desktop personal computer. The realization of this technology has been

made possible through a number of new technologies such as

* real time image generation systems
* head mounted display devices
* head tracking systems etc.

With the fantastic possibilities and the promise of widescale availability virtual reality technology has been used in a wide variety of applications covering design, engineering, education, entertainment, medicine, training etc. In 1993 virtual reality was used for design in a large number of industries making virtual reality a real tool for rapid product realization in the competitive context.

VIRTUAL REALITY TECHNOLOGY

Virtual reality is a technology for generating an immersive experience in which participants wear tracked, head mounted displays, view stereoscopic images, listen to 3D sounds and are free to explore and interact within a three dimensional world. The three elements of virtual reality technology are

* **Effectors** : Kind of hardware that allows to experience flying over hills, or moving and rearranging objects in a virtual room
* **Reality engine** : The computer system and external hardware, like sound synthesizing equipment, that supply effectors with the necessary sensory information
* **Application software** : This software describes the context of the simulation its dynamics, structure and the laws of interaction between objects and the user.

Virtual reality or cyberspace technology takes alternate reality a step further by introducing a computer as a mediator or imagination enhancer. There are two types of virtual reality namely immersive or desktop. A typical virtual reality system consists of a) one or more input devices such as joy stick, a steering wheel or a body harness b) several forms of output (such as light, sound and pressure) and a computer to manage all the data. For

example, you might be sitting in control room of a steel plant with your hands on the control panel, staring straight ahead at a computer panel as though you are seeing the steel melting furnance starting and providing liquid metal and leading to rolled products, using glove inputs as though you are operating the steel melting furnace.

The main virtual reality products are

* **Glove input devices** : These use electronics to sense the position and orientation of the hand wearing it. As the hand moves around in three dimensional space, the glove sends a stream of electronic data to the computer in the form of three dimensional coordinates. The computer then uses the data to manipulate the object on the display. Fig. 1. shows a typical glove input device.

* **Head mounted displays** : The most effective virtual reality input device is the head mounted display (HMD). This device which can handle both the input and outside sides of virtual reality fits over the users head like a helmet. The head mounted display monitors the side and up and down head movements and sends a corresponding stream of data to the computer about its position. The computer uses this data to generate stereo images of the virtual world. The stereo images are then sent to the pair of miniaturized displays that are an integral part of the head mounted display. Because the stereo images are synchronized with head movements, the effect can be quite realistic giving the impression of actually moving about in a virtual world. The head mounted displays also stimulate your auditory sense through its stereo head phones, giving one cues about the source and direction of the sound by presenting the sound to one ear a split second before the other. The head mounted displays also monitor your head movements, feeding a stream of data to the computer about your head's position and orientation in three dimensional space. The computer in turn adjusts the display on the HMD, resulting in visual stimulation that is synchronized with your head movements. Head mounted displays contain monitors for each eye that generate stereoimages.

* **Bodytracing devices** : These are small spatial positioning devices with multiple, six degree of freedom sensors

Fig. 2 gives the elements of virtual reality system [1]. Virtual Reality devices let you see, hear, feed and interact with real or abstract data of the computer generated models. Fig.3 gives a schematic diagram of a comprehensive virtual reality environment [4].

APPLICATIONS

The various elements of virtual reality (VR) tools allow you to see (Visual displays), hear (audio systems), feel (force feedback devices) and position yourself in a virtual environment. Some of the emerging applications of VR technology are examined in this section.

Design : Conventional computer aided design systems replaced the drawing board with TV monitors allowing us to generate the same two dimensional projection as the first drawings. Through the use of VR it will be possible to experience three dimensional objects by walking around them and feeling them if they are small enough, or walking inside them or amongst them if they are large like buildings [5]. Virtual design provides the ability to design products interactively, long before they exist in the real world. The main advantage of using virtual reality for designing and shaping objects is the ability to experience other attributes of the objects not only the visual ones. The potential for virtual reality in design work is enormous. Engineers who would like to work on a computer screen could actually enter their product and once inside the computer model, they could check for ergonomics, move parts from one place to another and witness various tests and analyses as part of the device. Expensive and time consuming mock ups can be eliminated, with the virtual model being used to check that parts fits. Boeing is using virtual reality in design [6]. Sun Microsystems has introduced a virtual holographic workstation which allows users to view three dimensional images that move as their heads turn or they bend down to look under the image.

Apart from mechanical design, in drug design virtual reality is proving to be very cost effective and time saving. VR can be used for determining how to fit a molecule into a receptor site of a protein enzyme. Stress patterns around objects can be visualized, flow pattern of gases can be shown, the accoustics of buildings can be experienced, the effects of lighting can be

visualized and many other features which are important to design can be expressed in a form amenable for interactive design. Using VR manufacturers are moving over to the artificial three dimensional world for help in designing of new products. Caterpillar (USA), has been able to design cabs for loaders and wheeled shovels (earthmoving equipment) in about one week in contrast to the traditional cycle time of six months to one year [7]. Virtual reality is being used by a number of firms for design. Table.1 gives a selected list of applications of virtual reality in design. Design analysis and verification can be performed on the computer in real time with interactive modelling using these approaches.

Prototyping : Prototyping using virtual reality helps designers to virtually see the manufacturing process. The virtual prototyping promises to bring together design engineer and the manufacturing engineer. Virtual prototyping allows firms to fabricate real parts for short production runs with the ease of printing out an engineering diagram. From a wire frame skelton that the designer can stretch and bend, twist and shape a rough form is crafted. Then the parts are given a skin and smoothed with a surface modeler or converted to solids with more traditional three dimensional computer aided design tools. The tools will eventually be available by speech command or whatever interface the designer wants. Virtual prototyping, allows for the reduction of design to manufacturing cycle time and also allows a variety of prototypes to be made quickly thereby allowing firms to have a higher new product introduction rate and shorter cycle time to conceptualize and introduce new products. One of the first major commercial applications of virtual reality technology was by Matsushita Electric, Japan to provide a Virtual Decision Support System (VDSS) for conceptualizing a kitchen [8]. The system has been designed to allow customers to design a kitchen based on over 30,000 products. This system allows you to sketch out the shape, size and structure of your present kitchen and then to remodel and select the new appliances, floor, tile, shelves, cabinets, colour, curtains and

to have floor plans and countertops. The interactive nature of virtual reality provides for quick customer feedback. Hospitals and industrial layouts are also being reconstructed using virtual reality tools. Virtual prototyping has immense potential in designing and constructing buildings, bridge design, design of space stations, cars, ovens, sports equipments, aeroplanes, telephones, washing machines, cameras etc.

Training : The most valuable application of virtual reality is in training operators to manipulate complex equipments, simulate real life situations and hazardous environments [9]. Virtual reality facilitates the training environment specially in the following applications :

* situations in which training mistakes are costly
* situations in which the necessary environment cannot be experienced in the real world
* designing interfaces which are sensible and can be easily manipulated
* making training situations real
* to make perceptible the imperceptible

Virtual reality simulators are the largely used application segment as on today. Mitsubishi Heavy Industry Co. has manufactured an active type simulator for fighter aircrafts. Simulation is among the most successful real world applications of virtual reality. VR allows pilot and soldiers to take part in 'Virtual War'. NASAs Houston space centre started training astronauts for a mission to repair the Hubble Space Telescope using virtual reality for simulation of how objects behave in space. They wear helments with screens inside that give a 120 degree view of a cartoon like but geometrically exact satellite in space and by using gloves on their hands with sensors they simulate the maneuvering of a satellite. Power plant operation chemical plant operation etc. are not the only ones to use virtual reality. NEC of Japan has developed a virtual reality ski training system which places users in a simulated ski environment and responds not only to physical movement but to the users mental state. Yasukawa Electric, Japan marketed the teleexistance system for the first time in the world for simulating electric

power distribution controls in large power systems. virtual simulation is far superior to three dimensional simulation. A three dimensional simulation does not present the information in an ergonomic way since the users are passive observers. Virtual reality provides much better solutions. The operator, using a data glove and a head mounted stereo display can act in a virtual world. Even inexperienced test persons will be able to realize complicated movements. The learning is rapid and experiential.

Education : Virtual reality is penetrating not only the operator training but school education as well. For a large number of children who cannot imagine what algebra is about, this colourful, noisy, three dimensional world is a perfect way to learn and to understand [5]. Virtual reality is not only interactive as opposed to the passive world of television and books, it accepts imaginative inputs from students. Virtual reality has the potential to revolutionize the education at all levels.

Entertainment : Virtual reality entertainment has a large market potential. Large movie producers, video game producers are all at work to bring a new era in interactive entertainment to global customers. The "Mandala System" of Vivid Group, USA captures your image in real time and projects it on a wide screen so that you can step inside a virtual world without having to put on any equipment or sit inside a cab. They also have created musical simulations where you can play virtual instruments by watching yourself in the virtual world and guiding your own movements. Virtual movies are on the cards. While game and entertainment experiences are already available, creators are already looking beyond these forms of enhanced video games [10].

Virtual reality overcomes the main difficulty in the traditional three dimensional animation namely lack of three dimensional interaction. The new technologies allow us to immerse in the computer generated worlds. With the use of graphic workstations it is possible to display complex scenes containing several thousands of polygons at interactive speed and with the advent of such new interactive devices such as 'Space Ball', 'Eye Phone' and 'Data Glove' it is possible to create applications based on a full 3D interaction mode in which motions are in real time. The virtual reality technology devices [4] with corresponding input data and applications are given in Table 2. Real time complex animation systems using virtual reality and simulation are invading arts, music, advertising and theatre in a big way.

Medical applications : The future of health will be inextricably linked to virtual reality [1]. As improved medical techniques and drugs create an ageing population, so there will be an increasing demand for sophisticated medical services. The biggest contribution of virtual reality to medicine might be in improving the doctors learning curve. In many medical situations, from surgery to training, the medical use of virtual reality technology might benefit less from head mounted displays and more from wide screen monitors and projected reality. Three ways in which virtual reality will help medicine are :

* Virtual reality is helping researchers to design new drugs through better understanding of the structure and properties of large organic molecules while working with these molecules to understand receptor - drug interactions visually
* Virtual human bodies can be viewed on surgical workstations
* Increased use of telepresence interfaces and computer aided surgery.

Business : Virtual reality has already invaded the business management segment. 'Virtual spread sheets' allow executives to simulate the behaviour of their markets, products and firms. Virtual reality has already entered the stock market. Another type of artificial reality created by using

virtual reality software has been used by a few Wall Street traders to spot trends. Maxus System International, USA, has devised such a system. The 'Metaphor mixer' portrays the worlds markets in three dimensions on a videoscreen grid. By looking at the visualization of the whole world of stocks, traders can spot trends and spot highly volatile stocks. Virtual reality is already begining to change the way business works. It provides new ways to represent and communicate reality and abstract data by customizing it for our senses. NTT, Japan is developing interactive systems which will react to users expressions and body language as well as voice. Fujitsu, Japan is developing 'Virtual Organisms'. These are imaginary living organisms capable of displaying complicated behaviour depending on the ever changing conditions, reacting to human presence and also they are capable of carrying on a dialogue. The potential of virtual reality application are continuously on the increase.

SIGNIFICANCE TO DEVELOPING COUNTRIES

The two major applications of immediate significance to developing countries are

* virtual design
* training.

As developing countries are experiencing the forces of globalization they are devising ways of responding to global competition. The major imperatives for firms from developing countries to improve their intrinsic competitiveness are to train the technical people to improve the manufacturing competence and design competence [11]. Virtual reality based training is one step ahead of three dimensional simulation as it permits interactive participation and full body participation. It eliminates the unexpected as much as we can and it is closer to the reality. Virtual reality can be the quickest way of training operators for complex task in a cost effective manner. Virtual reality based design allows for collaborative engineering, in which various

experts can interact. It supports experiential prototyping, by which product characteristics can be experienced in a more realistic way before the actual design. The use of virtual reality reduces the time between design and manufacturing in a drastic manner. This is of paramount importance for developing countries since design has been one of the basic capabilities which has been neglected. Only strong design capability can help the developing countries to achieve the transition from a non industrial society to an industrial society. Virtual reality can facilitate the learning process and help in this transition.

Lastly, services sector is also becoming technology oriented especially telecom, financial services, building construction, electricity, supply education, travel, etc. Virtual reality can help in improving the management of these services. Virtual reality makes experience a composable medium through rapid learning using virtual simulation systems. In otherwords, virtual reality can help developing countries to learn quickly. The imperative is to train people in virtual reality and to accelerate the adoption of use of virtual reality in manufacturing industries and services segment without much delay.

TECHNOLOGY TRENDS

Virtual reality products are becoming more popular as the cost of systems are declining. In 1992, about 150 head tracked fully immersive virtual reality systems were sold and in 1995 the market is likely to be of the order of 1000 systems. The total global market for virtual reality products in 1993 is estimated to the order of 35 million US$ and it is likely to be of the order of 600 million US$ in 1999 [1]. The major applications of virtual reality during this decade is likely to be :

* training and simulation
* entertainment
* scientific visualization

* design and modeling
* information and
* communication.

A large number of firms are investing in virtual reality for creating a competitive edge. Toshiba has developed a virtual reality based design platform. VPL Research has introduced a low cost VR system which will go a long way in increasing the diffusion of virtual technology. NASA has developed a virtual wind tunnel which uses virtual reality, supercomputer, high speed distributed networking and highend graphics. Marconi Simulation has introduced a 'Virtual Cockpit' which is a visually coupled Airborne System Simulator. This is a helmet mounted display onto which is projected an exact simulation of the world around the aircraft. Using two displays the scenario is developed using information from all sensors to allow night vision, visibility in poor weather or clouds and visual modification of threats and targets mapped onto the real world simulation. To drastically reduce the design cycle time for ships, Lockheed Missiles and Space Corp., USA is using virtual reality and virtual prototyping involving high resolution graphics, stereovision, 3D-cursor, a Dataglove for manipulating graphic objects and spatially located sound. National Advanced Robotics Research Centre, UK has a project namely VERDEX Virtual Environment Remote Driving Experiment which is a programme for developing telepresence and virtual reality technologies in the design of human-system interfaces. Massachusetts Institute of Technology Scientists have developed a walking, talking and a virtually living tool which can communicate with virtual actors.

Japanese firms are investing large sums for using virtual reality for such wide ranging applications such as

* controlling construction robots
* creating computer programmes
* designing molecular models

NEC is developing a virtual reality based three dimensional computer aided design system. Fujita is developing systems which can operate construction robots using communication lines [12]. Dai Nippon Printing Co. and Intel Japan are using Digital Video Interactive along with Virtual Reality. Tokyo Electric co is developing electric Power distribution system based on virtual reality. Ishikawajima-Harima Heavy Industry is developing remote control technology for next generation space robots using VR technology. Autonomous control function will be achieved using remote control functions based on virtual reality technology and integrating it with the skillful actions of the operators.

CONCLUSIONS

Virtual reality offers us a new version of reality that can suits our whims, and it is technology with enormous business opportunity. Virtual reality removes the boundary between artificial reality and physical reality. Developing countries can use the enormous application potential of this technology for simulation, design, education as well as entertainment. Low cost virtual reality systems are entering the market and developing countries can use these. Immediately steps should be taken to introduce virtual reality technology in industries, research institutions training institutes and educational institutions. Design and training provides for intrinsic competitiveness and virtual reality allows for collaborative design and rapid prototyping. The developing countries have to improve their design competence by using new product realization technologies such as virtual reality to create and sustain industrial competitiveness in emerging industries, traditional industries as well as in services.

TABLE - 1 :

VIRTUAL REALITY APPLICATIONS IN DESIGN

FIRM	APPLICATION OF VIRTUAL REALITY
Boeing, USA	Virtual Reality engineering system for design verification
Burroughs Welcome, USA	Drug design
Calibre Institute, Netherlands	Allows prospective buyers of buildings to walk through
Caterpillar, USA	Evaluate performance of design
Ford, UK	Virtual prototyping
Lockheed missiles & Space Corporation, USA	Designing complex ships through 3D graphic manipulation
Marconi Simulators, UK	Design of virtual cockpit
Matsushita, Japan	Designing a virtual kitchen for customers
NASA, USA	Virtual wind tunnel for flow visualization
NEC, Japan	Virtual design network for collaborative design
Rolls Royce, UK	Computer design of high thrust aeroengines using VR images
Rover, UK	Virtual prototyping
Tokyo Electric,Japan	Power flow visualization for power system control design
Valencia, USA	Virtual prototyping
Virtual Presence, UK	Virtual CAD for product manipulation
Vickers Shipbuilding & Engineering, UK	Use of virtual submarines for design verification

Table - 2 :

VIRTUAL REALITY DEVICES

VIRTUAL REALITY DEVICE	INPUT	APPLICATION
Data Glove	Positions, orientations, trajectories, gestures and commands	Hand animation
Data Suit	Body positions, gestures	Body animation
6 Dimensional Mouse	Positions, orientations,	Shape creation
Space Ball	Position, orientations, forces	Camera motion
MIDI Keyboard	Multidimensional key-board	Facial animation
Stereo Display	3D perception	Camera motion, positioning
Head Mounted Display (Eye-Phone)	Camera positions and trajectories	Camera motions
Force Transducers	Forces, torques	Physics based animation
Real Time Audio Input	Sounds, speech	Facial animation of speech

REFERENCES

[1]. K. Pimentel and K. Teixeira, Virtual Reality, Intel/ Winderest/Mc Graw Hill, New York, 1993

[2]. M.W. Krueger, Artificial Reality II, Addison-Wesley, Reading, 1991

[3]. Committee on Commerce, Science and Transportation, United States Senate, Virtual Reailty, US Government Printing Office, Washington D.C., 1992

[4]. R.A. Earnshaw, M.A. Gigante and H. Jones, Virtual Reality Systems, Academic Press, London, 1993

[5]. B. Sherman and P. Judkins, Glimpses of Heaven, Visions of Hell : Virtual Reality and its Implications, Hodden and Stoughton, London, 1992

[6]. S. Machlis, Computer Create a New Reality, Design News, Vol.48, No.20, pp. 60-70, 26th October, 1992

[7]. D. Traherne, Virtual Aid, Real Design, Economic Times, pp. 8, 25 November, 1993

[8]. K. Hayashi, Integrated Sales/Manufacturing System : Virtual Reality in Japan, Techno Japan, Vol.25, No.5, pp. 15 - 17, 1992

[9]. C. Carr, Is Virtual Reality Virtually Here, Training and Development, Vol.46, No.10, pp. 37-41, 1992

[10]. A. Wexelflat, Virtual Reality, Academic Press, Boston, 1993

[11]. B. Bowonder and S.V.R. Rao, Creating and Sustaining Competitiveness, World Competition, Vol.16, No.4, pp. 5-47, 1993

[12]. D. Kahaner, Virtual Reality in Japan, IEEE Micro, Vol.13, No.2, pp. 66 - 73, 1993

LIST FOR FURTHER READING

1. N. Lavroff, Virtual Reality Playhouse, Waite, Corte Madera, 1992

2. B. Woolley, Virtual Worlds : A journey in Hype and Hyperreality, Blackwell, Oxford, 1992

3. P.J. Theasby, The Virtues of Virtual Reality, GEC Review, Vol.7, No.3, pp. 15-28, 1992

4. H. Rheingold, Virtual Reality Summit, New York, 1991

5. M. Hirose, Advances in Virtual Reality Technology, Journal of Robotics and Mechatronics, Vol.4, No.1, pp. 2-6, 1992

6. K. Hayashi, Virtual Reality Systems For Sports, Techno Japan, Vol.25, No.5, pp. 29 - 32, 1992

7. K. Hayashi, Virtual Organisms, Techno Japan, Vol.25, No.5, pp. 41-43, 1992

8. K. Hayashi, Virtual Reality Technology in Japan, Techno Japan, Vol.25, No.5, pp. 8 - 14, 1992

9. R. Pausch, Three Views of Virtual Reality, Computer, Vol.25, pp. 79 - 82, 1993

10. J. Grimes, Virtual Reality Goes Commercial With a Blast, IEEE Computer Graphics and Applications, Vol.12, No.1, 16-17, 1992

11. R. Stone, Virtual Reality and Telepresence, Robotica, Vol.10, pp. 461-467, 1992

12. M. Haggerty, Serious Lunacy, Art in Virtual Worlds, IEEE Computer Graphics and Applications, Vol.12, No.1, pp. 5- 7, 1992

13. K. Hayashi, Driving Navigation and Flight Simulator, Techno Japan, Vol.25, No.5, pp. 33-35, 1992

14. K. Hayashi, Virtual Reality for Space Work, Techno Japan, Vol.25, No.5, pp. 44-46, 1992

15. M. Hirose, Real World Computing Related Technologies : Virtual Reality, Japan Computer Quarterly, No.89, pp. 38-44, 1992

16. J. G. Neugebauer, Virtual Reality : More Than Just Simulation, Industrial Robot, Vol.19, No.3, pp. 30-34, 1992.

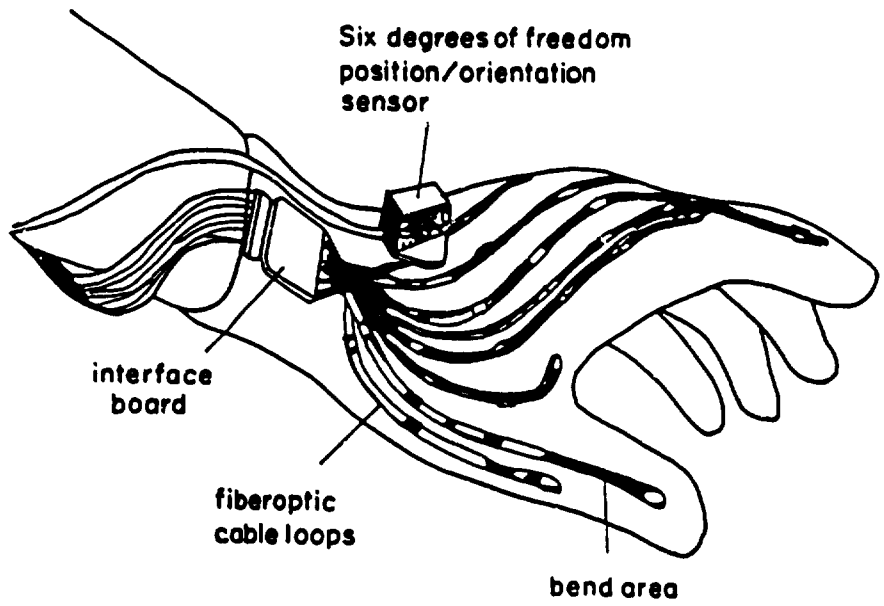

FIG. 1 . DATA GLOVE USED IN VIRTUAL REALITY

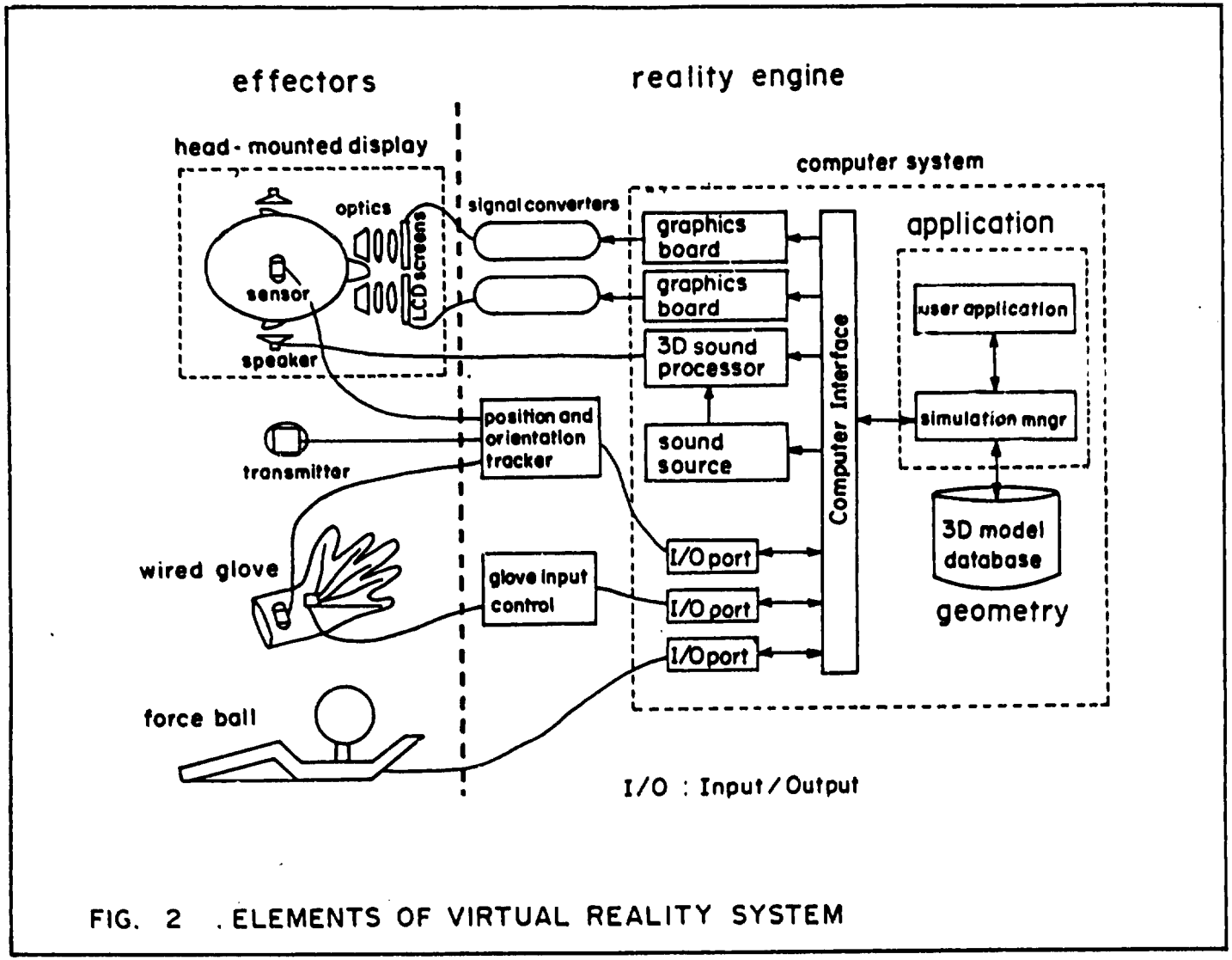

FIG. 2 . ELEMENTS OF VIRTUAL REALITY SYSTEM

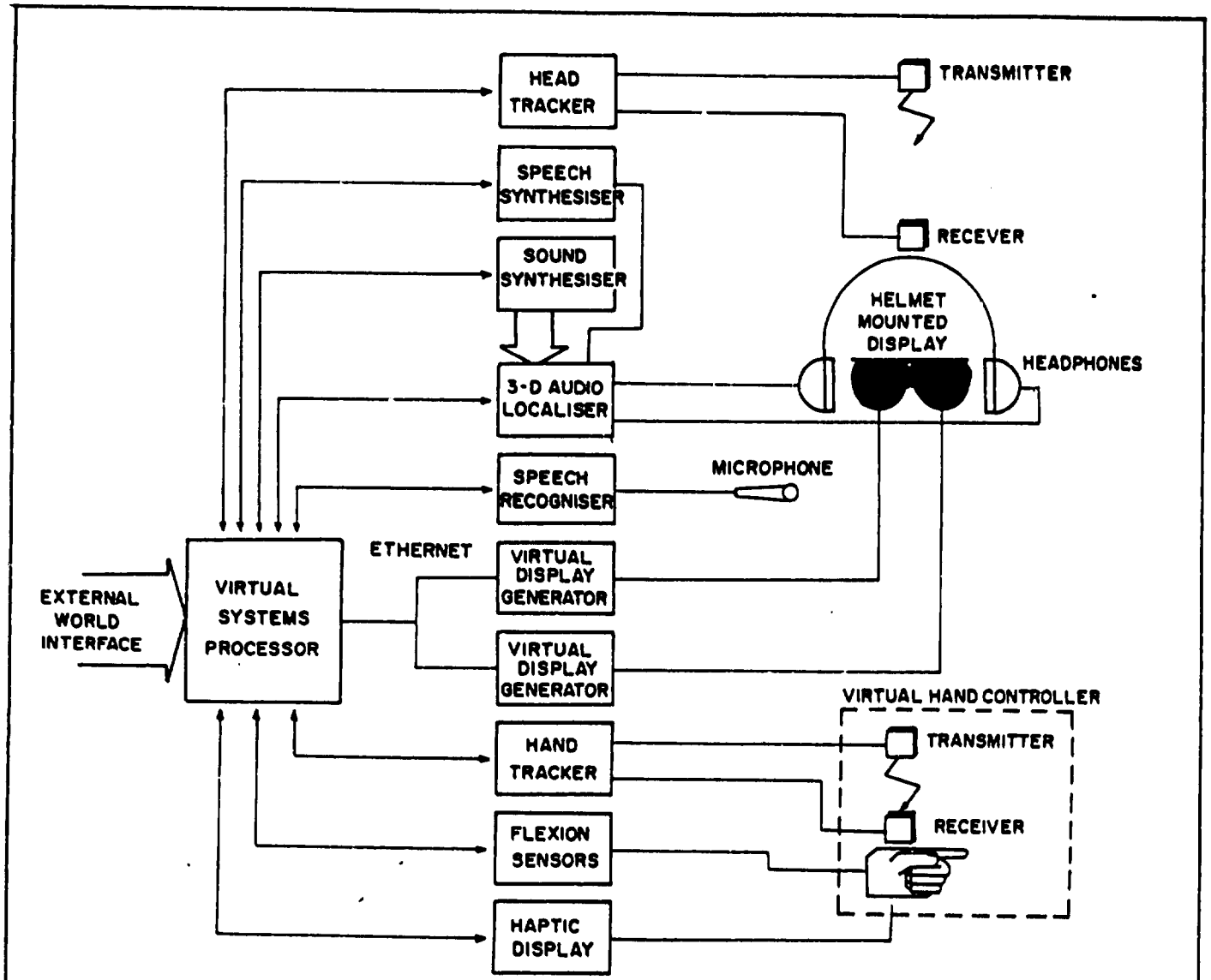

FIG. 3 . A VIRTUAL REALITY SYSTEM