Virtuality™
The Worlds first production Virtual Reality Workstation.

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The history of the development of W. Industries Virtuality™ technology is covered. Virtuality™ technology comprises three key low cost components that enable W. Industries to offer Turnkey Virtual Reality products to its customers. The key elements of the technology are discussed including the Expality™ computer, Animette™ simulation software and Visette™ visor. Virtuality products are housed in two separate enclosures the Stand-Up (SU) and Sit-Down (SD). A variety of tools such as the Sensor and Feedback gloves enable user interaction with the virtual environments. Virtuality™ products are used in commercial, scientific and leisure applications.

BIOGRAPHY

Jon received a first class degree in Industrial Design Engineering in 1981. As a student he won three separate national awards for innovative engineering design. Becoming increasingly aware of the future needs of computer graphics in design engineering, Jon designed and built his first Virtual Reality(VR) system in 1984, as part of a PhD in Computer Science at Loughborough University of Technology. This also gained him the National Award from the Designers for Industry. Whilst continuing the development of his 'Spatial Workstation', he established a profitable consultancy working on new computer system designs for major UK clients. In 1986 Jon received the London Science Centre's 'Most Significant New Development in Entertainment Technology' Award.
In 1987 Jon founded W. Industries (WI) to develop the first production Virtual Reality system intended for commercial, scientific and entertainment use. In 1988 the company won the UK National Award for best new start-up business from a field of over 90 entrants. In 1989 W. Industries became part of a large multi-national UK group with operations in the US and Japan. In November 1990 W. Industries launched the worlds first purpose built production VR system called Virtuality™.

VR is an important tool to aid high bandwidth communication between Humans and Computers. Jon is committed to the design, development and manufacture of cost effective VR systems for use in powerful, easy to use, computer graphics applications.

INTRODUCTION

Over the past year there has been increasing interest in Virtual Reality (VR). People are becoming aware of the immense possibilities this type of technology will have upon many computer applications, including design generation and image manipulation. As computer systems advance in power and complexity, new types of Human Computer Interface (HCI) are required to make computerised tasks more analogous to their real world equivalent. VR promises to provide users with interfaces more akin to their real world counterparts and therefore more approachable by untrained users. For example, senior engineers under pressure to produce solutions for a complex engineering product find their creative abilities are undermined by the protocol of existing interfaces. The ideas just cannot be manipulated at the spontaneous rate that a creative mind demands.

VR holds the promise of providing simplicity of use through apparatus that allows a human activity to be accurately simulated, and controlled, through natural actions. For this reason, VR applications will develop and vindicate the technology in a variety of key markets, ranging from CAD and Leisure to Medical and Military.

W. Industries has been actively developing VR for use in commercial applications since 1985. Our early prototypes have been progressively developed to form the current Virtuality™ product range. Although the apparatus needed for VR poses some challenging design constraints, the finished product must conform to the highest standards of health and safety and offer the quality that we expect from a contemporary manufactured product.

VIRTUALITY™ - a CONCISE HISTORY

The Virtuality™ system developed by W. Industries is based upon early work conducted by Waldern in what he then called "Spatial Imaging" whilst studying for a PhD in Computer Science at the Human Computer Interface Research Centre (HCIRU) at Loughborough University of Technology in the early 1980's.

Motivated by the constraints imposed upon design engineers when using geometric modelling CAD systems (Waldern, 1981), and upon reading the early work conducted by Sutherland (Sutherland, 1968)(LAND 1964) and James Clarke (Clarke, 1976) (Clarke later founded Silicon Graphics in 1984) at the University of Utah, Waldern built the UK's first operational VR system upon which he performed a series of experiments using mixed age subjects (Waldern,1985).

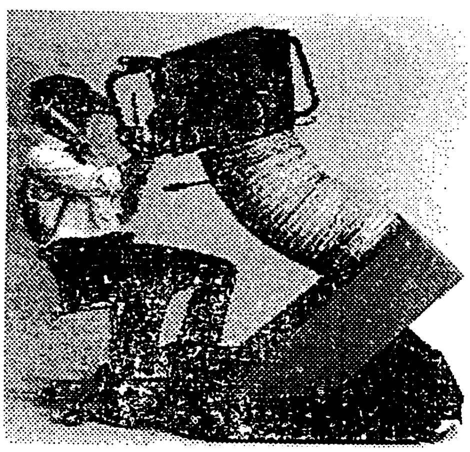

FIG 1 The Spatial Workstation 1985

This system (see fig 1) used a pair of calligraphic images and a head mounted visor containing a rotating shutter which occluded each eye in turn in synchronism with the display, which showed alternately two stereoscopic images, one for the right eye and one for the left. The viewer and his viewing screen were tracked using a sonic 3D digitising system. A series of experiments were performed which successfully demonstrated the potential of the technique for use in 3D CAD (computer aided design) applications, especially those related to geometric construction of solid models.

Working with the three other founding directors of W. Industries, a helmet based system was developed in 1986 using low cost microcomputers and high performance simulation software. Many prototypes were developed and rejected for various reasons related to health and safety. The first operational system nicknamed the Giraffe (see fig 2), was completed in 1988 shortly after W. Industries was formed in 1987. This system used several home computers and had limitations in its graphics capability in terms of detail and resolution but had a full stereophonic sound system, also computer driven, which could generate a range of sound effects and produce correctly vectored sound images and doppler effects to give velocity cues. The system allowed a user to play simple games against the computer using a hand held trigger in addition to a purpose built mechanical head angle sensor which allowed unlimited movement in azimuth and elevation.

Considerations of cost were often the most important criteria in the design of the early prototypes, leading to extreme solutions, some of which were tested to destruction, as well as other successful designs which were selected for future development. W. Industries can boast probably the largest collection of Virtual Reality relics in the world.

The first visors were designed to house the LCD displays, four speaker quadraphonic sound system and also the head position and angle tracker sensors. These systems were the forerunners of todays more advanced visor system and were used for developing the features now evident within the products. One of the most elegant features of the present system is a simple locking device called Ergolok™ which allows the visor to be firmly attached to a variety of head shapes and sizes to prevent movement between the head and the visor. It also has a quick release mechanism which allows instant unlocking for removal, both quickly and safely in case of panic (entertainment applications).

Virtual Reality systems have also been mounted on motion platforms to add a further stimulus isolating the user from the real world and reinforcing the experience of the computer generated environment.

VIRTUALITY™ - the SYSTEM

The Virtuality™ system is constructed from the **Expality™** computer, **Animette™** simulation system and **Visette™** visor. Other elements include the Virtuality™ **Toolkit** which includes gloves and force feedback tools etc.

The functions of the elements are as follows:-

- Graphics to provide real time computer generated images derived from three dimensional mathematical models.
- Sound to provide instructions and sound effects from digital samples held within the computer systems.
- Motion to provide the motion data derived from dynamic vehicle models to drive a motion system which provides motion cues for the user. A motion platform may be electrically or hydraulically driven.

- Proportional joystick controls for man-machine interaction.

- Tracking system for head tracking in position and orientation, to maintain the viewing direction of the user and ensure that the correct parts of themodel database are used by the graphics system in providing the images.

- Local area network to allow many individual users to meet each other within the experiences provided by the Virtuality™ system in a number of disguises, which are part of the virtual world as described within each experience.

These elements are the building blocks for a variety of applications which are mainly based upon entertainment experiences using interactive rides in a variety of imaginery environments. The devices which have been developed have been designed and tested to stringent health and safety requirements which are detailed elsewhere.

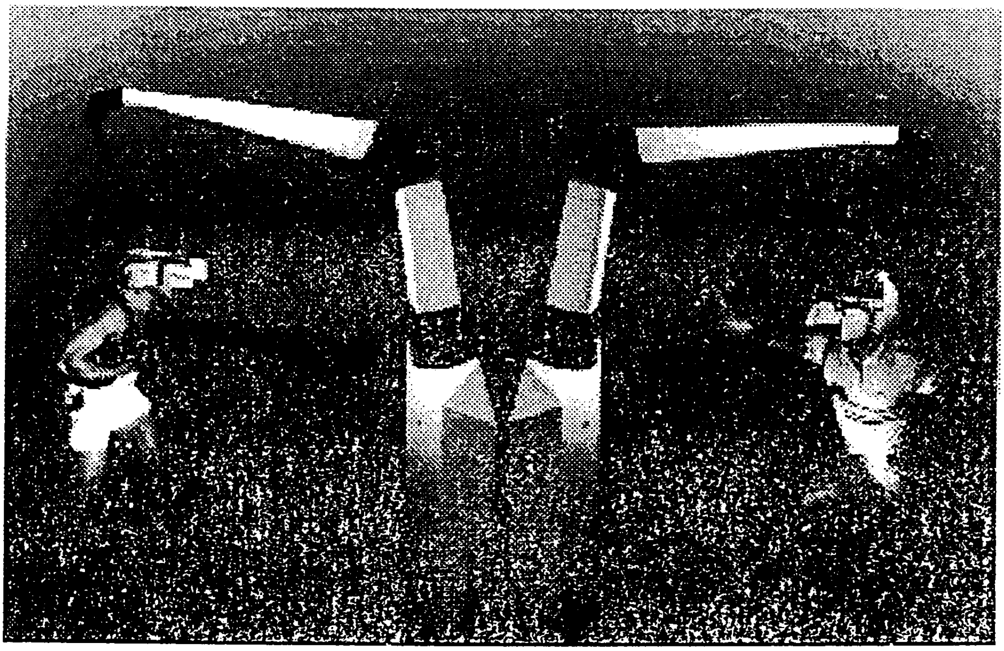

FIG 2. The Giraffe. An early prototype, one of many developed to explore usable Virtual Reality systems to comply with stringent public health and safety constraints.

Two products based upon Virtuality™ technology are in current production. The first is the Virtuality™ 1000 SD (Sit Down) in which a person can pilot a vehicle within any simulated virtual environment. The second is the Virtuality™ SU (Stand Up) which enables a user to stand or move freely within a virtual environment. This unit is intended for scientific and industrial use and has a trackable hand held toolkit, comprising the Virtuality™ Sensor Glove, the Virtuality™ Feedback Glove and the Joystick.

ENABLING TECHNOLOGY

W. Industries has developed various technologies which have enabled the development of the Virtuality™ system at realistic price levels. The most dramatic developments have been in the graphics field where there have been advances in the ability to manipulate large amounts of graphics information at high speed, leading to the Expality™ computer and also a huge advance in LCD display devices, which are necessary to interface this pictorial data to the user using Visette™. A complementary area has also developed rapidly, namely the tracking of head and eye in linear and angular movement over a wide range and to great precision and reliability. In the case of head tracking this has also been used in Visette™. Eye tracking is planned.

The electronic component industry has concentrated on the design of VLSI chips and very large compact memory which has been a force in the reduction of the costs of computing and allowed the development of powerful single chip computers which specialise in high speed graphics or very fast floating point arithmetic. From this, powerful cost effective systems can be designed at the board level. Using parallel processing and pipelining techniques with such components, graphics subsystems which were huge and expensive only a few years ago, can now be produced cheaply, simply and reliably and be interfaced to the modern generation of high power personal computers to provide a convenient software interface. These techniques are used in the Expality™computer with the Animette™ simulation system. The development of high resolution, full colour, small and light-weight LCD displays for the T.V. industry has also meant that the design of a head mounted display system such as the W. Industries Visette™ has been made possible. The thought of a head mounted cathode ray tube system such as that proposed in the very early days by Ivan Sutherland, with its high voltages and great weight, makes one realise the impact of the LCD developments which are continuing and producing increases in performance.

The ability to provide images only where the observer was looking has been an attractive goal since computer generated images were first produced. With modern head (and hand) tracking devices the dream has become a reality and the images may be concentrated in the field of view of the single user wearing the Visette™ visor.

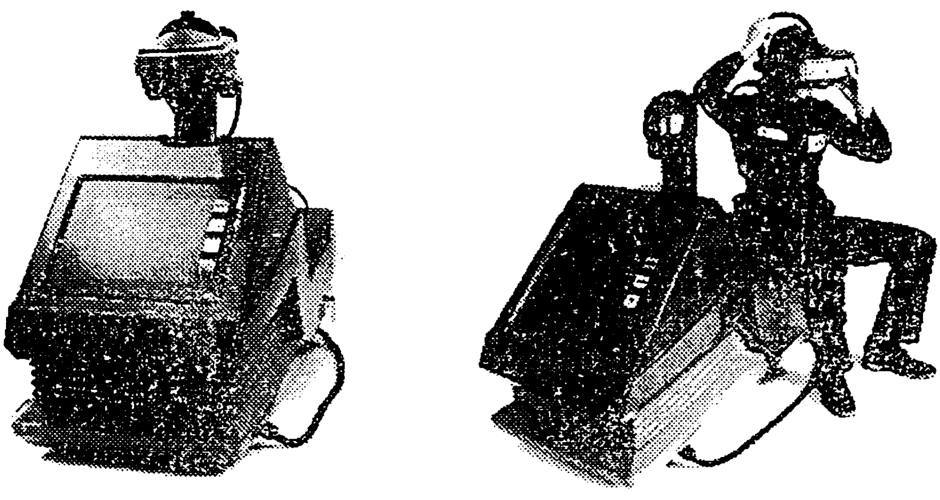

FIG 3. The Virtuality 1000 SU with a tracked joystick tool for basic user interaction. The toolkit includes a Sensor Glove and Feedback (Feel) Glove for more intricate hand manipulation.

PRODUCT DESIGN ISSUES RELATED TO THE HEAD MOUNTED APPARATUS

A number of complex aspects needed to be considered at the preliminary design stage :

1. Optical Configuration
2. Engineering Construction
3. Form
4. User Considerations
5. Wire Management
6. Safety Standards

The single most difficult aspect is user considerations. This encompasses anthropometric, ergonomic and health and safety factors. If these are wrong, even by a small degree, the design will be a failure because people will choose not to use it.

Head Restraint

A head restraint system to accommodate all users poses the greatest problem. This prompted the design programme for the single action head securing device, known as the ERGOLOK™. From an early stage we rejected all currently available options for securing the head worn visor, e.g. buckles, velcro, ratchet straps, etc. These offer no safe quick release solution, or have proven to fail in durability and performance.

The Ergolok™ solves the dual problem of how to secure head mounted apparatus and simultaneously accommodate a wide range of head geometry and sizes. It is of prime importance that the apparatus is held stationary in respect to the head even during rapid movements. Of note is that when operating in the virtual world, real world intrusions detract greatly from the quality of simulation. Standards are an important factor for incorporation into the design of any new product, indeed they are intrinsic to most

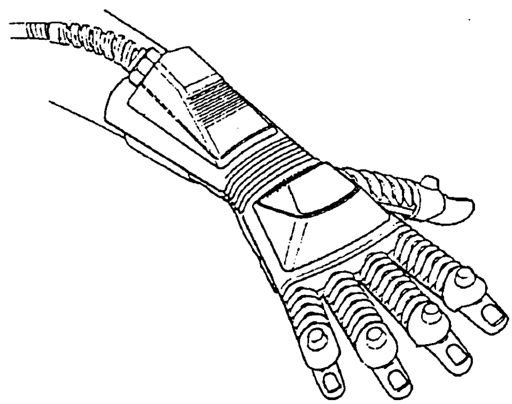

FIG 4 The Visette™ visor using the unique ERGOLOK™ single action head securing device. Also the Virtuality Sensor Glove providing an exo-skeleton hand monitor with built in proximity sensor.

advanced man-made products in the industrial world. As one might expect, head mounted VR equipment is too novel to be specifically covered by standards, further complicating the design task.

APPLICATIONS IN RESEARCH AND DEVELOPMENT
Interactive systems such as the Virtuality™ system have commercial potential in areas, some already existing, where the benefit of ease of use leads to high performance accomplishment of the task in hand. These applications include:

Computing
Any applications using computer aided design software.

Medical Imaging
Aiding visualisation of data or use in therapy.

Command and Control
Remote visualisation of real world data.

Civil Training
Driving instruction and machine control.

Military Training
Weapon systems and vehicles simulation.

The uses of the system are only limited to customer demands.

APPLICATIONS IN ENTERTAINMENT
Entertainment based upon technological devices have been gaining ground for some years. These are to be seen in home computer games in their simplest form, but cover the range to sophisticated arcade games which require great skill and dedication to master, and are based upon techniques on the leading edge of electronic simulation technology. The Virtuality™ system is aimed to give an experience which is completely interactive and allows the operator to have a free hand with the control of his vehicle which is simulated in the experience. Several experiences are currently available including VTOL™ (Vertical Take-Off and Landing) in which a Harrier aircraft is simulated within a playing area consisting of mountains, coastline, sea, towns and military installations. In this experience there are many active aircraft and other vehicles. A number of missions may be carried out once the mastery of the controls has been accomplished. There is ample opportunity in the future to add to this experience and introduce current topical scenarios. Scheduled experiences are set around a starship, hover bike and bob sleigh. Many others are planned with ideas only limited by the imagination of customers and in-house

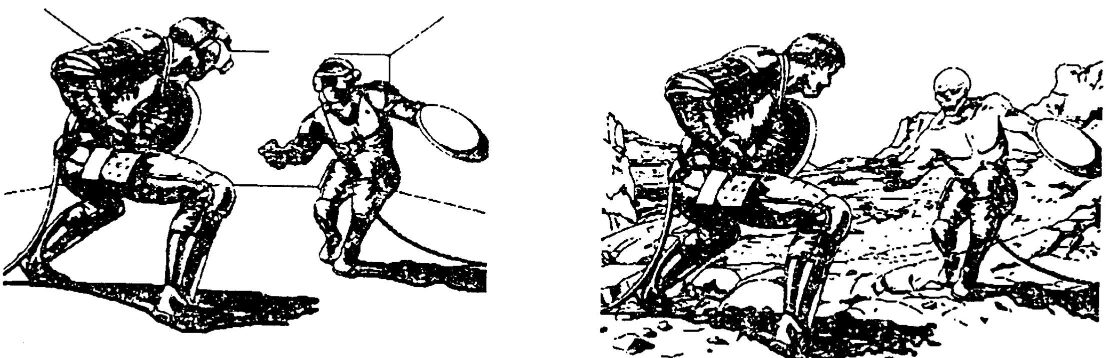

FIG 4 Interactive experiences project humans into the computer generated worlds.

designers.
Such experiences can be designed to introduce people to environments and opportunities which they would never normally achieve and hence provide a high level of interest and excitement within a very safe situation and a small operating space.

DESETTE'
DATABASE CREATION SYSTEM
One of the most difficult and time consuming tasks in the simulation of vehicles is the provision of a three dimensional data base of sufficient size and complexity to provide the environment in which the person or vehicle is to be modelled. Interesting and mission intensive environments are the basis of most of the experiences of an adventure or combat type nature, and require the development of a number of utilities which allow the generation, editing and development of the simulated environment to ease the tasks of the support group and allow quick and efficient updating and tailoring of the simulator environment. Using these it is possible to produce a range of experiences, or even keep up with a topical theme by providing up to date landscapes and missions in line with the current world events.

The development of such utilities to provide a rich and growing set of data generation techniques and facilities is an important support operation which is required for provision of a continuing series of experiences for the Virtuality™ system. The utilities developed so far include a fractal model landscape and coastline generator (as predicted by Mr. Slartibartfast in 'The Hitchhikers Guide to the Galaxy') which is capable of generating scenery of a controlled but generic nature on a large scale in a short time. A track generator which allows roads or other tracks to be fitted to landscapes which have been generated already to ensure that contour hugging contact is maintained by the track, and other feature and object placement aids which allow the environment to be enriched as required.

Another aspect of the work of the support group is the provision of vehicle dynamics, which provide a compromise between the problems associated with the control and management of the real system, and having an easy driving mode which allows quick adaption by an inexperienced user so that the full experience becomes rapidly available. The ability to change from the easy system to a more realistic one allows a variety of user goals within the same experience, so that the same system can be used to experience training to a high degree of expertise. This also allows missions to be flown where the emphasis is on accomplishing a number of tasks in a short time, with the minimum of expertise needed.

FUTURE DEVELOPMENT
The technologies on which the systems are based are moving rapidly and the expectation is to stay with those technologies and exploit the new developments as they come along. VLSI chip design will provide more powerful processors and more compact memory. New and better tracking systems are being developed, capable of multiple sensor applications and eye tracking, which is essential for correct stereo images. The integration of visuals, sound and motion will be further enhanced with more sensory stimulus. The networking will be expanded to include larger numbers of simultaneous users taking part in a common experience. The power of the graphics and the upgrading of the displays using the Rendette™ rendering system will allow increased realism in the graphic images. All these developments will lead to a more realistic and convincing experience in the VR world which may become the computer system system of the future. In January 1991 we are adding the sensations of touch and the ability for greater interaction using tools and/or hands and feet, which will have sensors attached to interface to the system.

Although Virtual Reality Systems are at present in their infancy they will grow and develop rapidly in the near future into a powerful new medium, capable of combining many sensory components into an integrated environment which, for some applications, will transcend present day VDU based computer graphic systems.

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