Report on the One Day
Immersive Virtual Environments Workshop

Department of Computer Science and
London Parallel Applications Centre,
Queen Mary and Westfield College,
Mile End Road, London, E1 4NS
Friday 2nd July

1 Introduction

This workshop brought together UK researchers in Immersive Virtual Environments to discuss their ideas about the problems and promises of virtual reality in an informal setting.

The day was split into seven sessions with short introductions to each session given by people with particular interests in those areas. Summaries to each session can be found in section two. In addition each of the attendees was invited to write a summary under one of the session titles. These articles can be found in section three.

The workshop was organised by Mel Slater and Anthony Steed. Thanks go to Lorna Kyle and Sue White for their administrative help.

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2 Session Summaries

10.00-11.15

"Psychology is the Physics of Virtual Reality."
Introduced by Simon Rushton and Rupert England

A discussion of the implications of perceptual psychology for our understanding of what happens when people are immersed in virtual environments.

Points Raised

1. We have to research what information is crucial to the performance of the application tasks.
2. The performance of tasks with a VR interface has to give significant advantages or else it will not take off.
3. Use of eye-tracking hardware to indicate a high resolution area to be drawn.
4. Humans are not passive tranducers, they have intentions in the virtual environment and participate in an active way.
5. We may now be seeing the festishization of the technology.
6. We have to define metrics of performance within virtual environments, as eventually these systems have to be sold.
7. Maybe our model of VR is wrong and we should choose a model such as Laurel's theatre model.
8. The interface is not only visual, other modalities may compensate for lack of visual information.

11.30-12.15

The Sociology of Virtual Environments
Introduced by Ralph Schroeder

A discussion of the different social contexts in which Virtual Reality will be used and the different technical possibilities which these contexts allow.

Points Raised

1. Difficult to extrapolate where VR is going. The public image of a technology is a significant force in driving development.
2. The interaction between, development, image, popular culture, commerce and definition is shown in Figure 1. Basic research doesn't have a significant influence on this interaction.
3. Consider the social consequences of using the technology. Scientific research agenda is towards applications such as walkthrough, prototyping and communication. However the only big current application is for games.

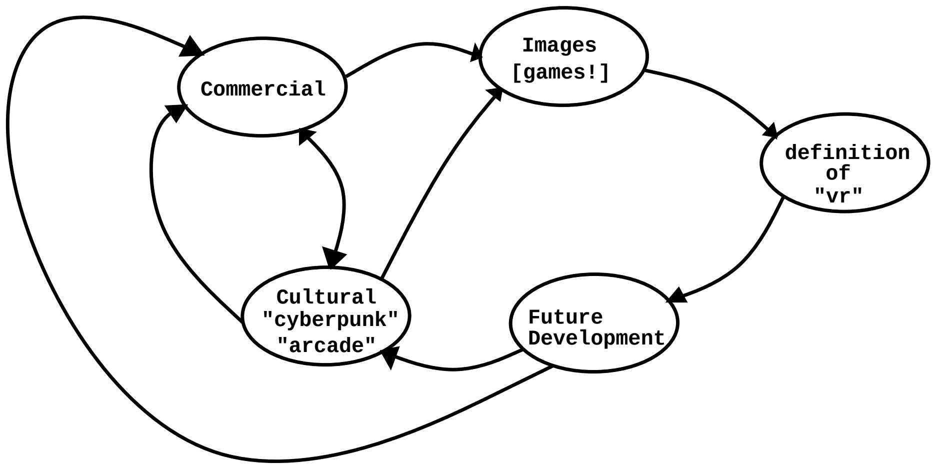

Figure 1: No place for basic VR research?

12.15-1.00
Metaphors for Interaction
Introduced by Anthony Steed and Andrew Tyrell

Interaction in immersive virtual environments is supposed to be "naturalistic". Yet there is limited sensor information regarding what the human operator is doing. The gap between requirements and information, as in 2D interfaces, requires bridging - with models and metaphors for interaction.

Points Raised

1. The walking metaphor introduced is not 'natural' as the direction of walking is the direction of gaze. This could be remedied with a position tracker on the body.

2. It was questioned whether a 3D generalization of the desktop would be anymore efficient to use than the usual 2D desktop.

2.15-3.30
Object description standards
Introduced by Roy Kalawsky

An area of 3D visualisation that seems to have received only limited attention is that database standards. There is a clear requirement for the development and promotion of vendor/systems independent standards to allow objects from multiple data sources (such as CAD, raster/vector/video images, DTMs, and other independent objects) to be archived in existing data management systems and interfaced to Visualisation systems while representing object relationships and behaviour. One application area of interest is the promotion of a distributed 'World Model' for representation of the real-world within Virtual Environments.

Points Raised by Roy Kalawsky

- The current situation:
  1. There is no general standard in object description databases.
  2. Database design sometimes tuned to hardware platform.
  3. No provision for system connectivity.
  4. Proprietary vendor defined databases that are incompatible between vendors and expensive to convert.
- Future Requirements:
  1. Vendor and system dependent standards
  2. Compatibility with existing CAD databases as much has already been invested in their creation.
  3. Good virtual environment development tools
  4. Robust performance metrics
- A particular vendor's standard might be adopted or there could eventually be an ISO standard. Such a standard must encompass:
  1. All types of geometry description
  2. Descriptions in other modalities
  3. Dynamics and behaviour
  4. Levels of details and dynamic performance timings
  5. Virtual environment relational databases

General Points Raised

1. We don't know how long this standard will take to develop
2. How can we standardize now?
3. Who will eventually become the standards committee?
4. Our first action should be to challenge existing standards and force vendors to give us the functionality we require
5. In any event we are unlikely to get a standard to cover all possible application requirements

3.45-4.45
Presence in Virtual Environments.
Introduced by Martin Usoh and Mel Slater

The factors that influence presence, and the necessity (or otherwise) for it.

Points Raised by Mel Slater

1. Presence is THE central concept - it is the unique property that IVEs can provide — they are general purpose presence transforming machines.

2. Each feature of an IVE can be evaluated against its contribution to the sense of presence.

3. Not all tasks require presence. If features in an interactive 3D interface do not enhance presence, but are ideal to the task, then maybe this task does not require immersion.

4. What is presence? Still really undefined.

5. How can it be measured? Measurement should be

   - intrinsically connected to presence, rather than possibly associated attributes such as arousal, awareness, involvement, etc..
   - can be used in any environment
   - the means of obtaining the measure should have a natural explanation in terms of the environment and application (eg, presence might be measured by observing participants' responses to a sloping floor - but this cannot be used in every application, and would not have an easy explanation in every application!)
   - it should not force the subjects to be aware of any environment other than the one that presence is being measured for
   - it should be measured "objectively", without interpretation on the part of the experimenters
   - it should produce repeatable results.

General Points Raised

1. About measuring presence, maybe this should be based simply on a standard set of questions to the subjects, and if all agree on this set of questions then we can make progress.

2. Observations that we might take as indicating presence might be independent of subjects' self-assessment of presence. For example, when standing on a virtual sloping floor, people might be observed to lean, and yet still report a subjectively low level of presence. So the leaning was possibly an automatically and unconscious response, and not contribute to the subject's sense of being there.

3. So maybe it is mainly the subjective sense of being there that is most important, and if this is the case, then presence can be "measured" by asking people.

4. There are accepted scales that measure "involvement" — eg, while watching movies. These scales should be considered.

4.45-5.30
Implications of virtual reality for computer graphics research Introduced by John Vince and Mark Williams.

VR systems currently use the z-buffer, and maybe Phong Shading. It employs a pin-hole viewing model - suitable for looking at images externally displayed - as on a screen or photograph. It is not appropriate for immersive displays. Shadows are typically not possible in real-time with z-buffer techniques. This area will examine alternative architectures/algorithms/pipelines for computer graphics in VR.

Points Raised by John Vince The example of a virtual surgery trainer brings out several research problems.

1. Modelling. How do we represent flesh and blood within our current polygonal data paradigm?
2. How do we render such things as flowing blood?
3. How do we interact with the model? How does blood flow, what happens to the model when it is cut?

This area is wide open for research, and there may be different types of model waiting to be discovered and new ways of rendering that do not use polygons.

5.30 -
Future Actions for Fostering Research in the UK
Introduced by Mel Slater

3 Abstracts and Articles

Visual Perception and Immersive Virtual Environments
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We ask how current understanding of human visual perception may aid subsequent development of immersive virtual environments (IVEs)? Three questions appear particularly relevant:

1. What recommendations can be made in the design of 'visual' displays such that computational resources are targeted to render only those aspects of the scene that the user can see? - as distinct from the aim of fully animated, photo-realistic, computer graphics.

2. How can veridical perception of depth be promoted when rendering stereoscopic displays.

3. What aspects of visual perception are important in promoting a sense of Presence in IVE's.

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At Leeds we are interested in the following topics:

- Implications of virtual reality for computer graphics research
- Object description standards
- Future Actions for Fostering Research in the UK

And also what we call

- Low-cost desk-top VR

  How much full immersion is really required to obtain augmented interaction? For what range of applications is a more low-cost solution appropriate? We think that fully immersive VR systems will be few and far between simply on the grounds of cost. However, there are useful elements that can assist with some applications. These should be identified, researched, and ranges of applicability investigated. In this way new areas can open up, VR tools can obtain more visibility, and more general uses developed. Then the subject can begin to move forward in a positive manner, in the way that scientific visualization has over the past 6 years. It started with specialist equipment such as supercomputers and has now moved down to the desk-top.

A desk-top VR project has been initiated in Chemistry (and with possible extensions to educational instruction in Earth Sciences and Medicine). We are looking at pilot projects to use VR interfaces to enhance visualisation tools. For exploring 3D and more dimensions we can provide VR feedback to enhance the flow of information about what is being observed.

Immersive Virtual Environments — some implications for Computer Graphics

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Introduction It has been suggested that immersive virtual environments (IVEs) pose special challenges to the "classical architectures", for both software and hardware, used in computer graphics and this paper examines a few of the areas where divergence of requirements may occur. The observation has often been made that the computer industry is developing rapidly and that the power of computing hardware can be expected to nearly double year on year. To a great extent it is this which has made IVEs a possibility. There is an increased expectancy of greater "realism" in computer generated images, although it becomes more difficult to define realism when the virtual environment is used to visualise complex data - for example, the 6 degrees of freedom, or greater, in studies of electromagnetic phenomena!

Professor Vince mooted at the workshop that in ten years time graphics primitives will not be described in terms of polygons or NURBS or patches, but something more sophisticated,(yet to be defined). In addition, Professor Kalawsky noted, also at the workshop, that the synthetic environment consists of more than just the representation of visual objects and other human senses will also be involved. With this increasing complexity it is likely that Object Oriented Analysis and Design techniques will need to be applied to IVE systems as a *whole*. In particular the use of those techniques which take into account time constraints will be especially important. For example, the problem of latency in the graphics pipeline which, when coupled with current position sensing technology, causes mis-registration of direction of gaze with the view rendered.

A notable commercial failure in recent years was the Silicon Graphics VGX system. Here Z information was lost early on in the pipeline and so perspective correction for MipMapped texture was not possible — the texture was distorted for large polygons and so these had to be split up into smaller ones in the hope that this would be less noticeable, (in practice, in the dynamic case, this appeared as a 'swimming')[2]. Subsequently this problem was fixed with the VGXT system. Texture mapping techniques are very valuable in certain applications such as flight simulation where they supply additional motion cues — in the pursuit of "realism" — but they, along with various shading algorithms, have the flavour of a Ptolemaic view of the virtual universe with epicycle upon epicycle in a Sun centred system. With the advent of faster processors, some distributed, ray-tracing architecture may be simpler and preferred — a "Copernican virtual universe"?

We should also note that, increasingly, display devices are being used which are not raster devices (e.g., LCDs and in the future holographic systems). Taken together it seems reasonable to suggest that the "Graphics Pipeline" model which, after all, is a conceptual mechanism for the transformation of 3-D models to rasterized 2-D images [1], may not survive this onslaught in its "classical" form.

A "Non Pin-Hole" View of the World

Introduction This section of the paper looks at some demands placed by the IVE which are not met by traditional Computer Graphics viewing models. In the design of many systems, certainly military ones with the MANPRINT initiative being an example, there has often been the cry of "involve human factors design principles from the beginning". Will IVEs be another example of technology being developed and then turned over to human factors specialists to try to remedy its shortcomings? The main thrust of the following observations is that the human visual system is complex, with many different interrelated systems co-operating or interfering with each other. Because IVEs are intended to provide many more cues to their participants than a simple static image, they also provide the opportunity for additional confusion if a cavalier approach is taken.

Non-Uniform Resolution Displays Recent announcements have been made of the proposal to have high resolution "areas of interest" which are slaved to direction of gaze in an Helmet Mounted Display. In the spirit of matching display performance to some aspect of human performance (actually the proponents say this will save computing costs) the argument is that high resolution vision is only available to a narrow lobe centred on the optical axis of the eye. This is true for simple visual acuity, but ignores evidence that motion detection performance is maintained out to optical eccentricities of 20 to 30 degrees. The image at the periphery of the retina is blurred by the optics of the eye, in addition this image is further low pass filtered by low spatial frequency sampling by receptors and subsequent ganglion cells. However the human visual system is capable of detecting *changes* in blur patterns which are much more subtle than would be expected from a simple acuity model. Whether this would be a first or second order effect is not known, however if too many second order effects are ignored then they become a first order problem!

The difficulty, then, is that an image which is already coarsely spatially sampled may not be able to provide the subtle motion cues needed. This would manifest itself to the user as some "undefinable distraction" in their peripheral vision. Maybe these effects could be overcome either by some form of anti-aliasing technique or by the provision of greater resolution in the *intensities* available in the periphery. At the moment the solution to this problem, if it is one, is open to speculation.

Stereopsis and Accomodation The traditional approach to displaying stereo images is simply to use the conventional "view plane" model twice and to render the same scene from two slightly different viewpoints. Presented with two, perspective drawn, 2-D representations of a 3-D scene, one to each eye, the visual system is left to interpret these as a single 3-D scene. Such representations provide both perspective cues and appropriate disparities in the positions of corresponding objects in each image. In order to see an object the eye needs to accommodate ("focus") on the object. To get a 3-D effect, especially for close objects (ie. at a distance of less than 500m [3]), it is necessary for the two images to be correlated on the two retina and this is accomplished to a large extent by vergence (the eyeballs rotate inwards or outwards in their sockets). Unsurprisingly, the two mechanisms are linked and each can drive the other to some extent. This gives the possibility of the generation of conflicts since stereo cues may cause the IVE participant to verge on an object, at 10 m away for example, in order to fuse the two images into one. This motor effect may drive the accommodation of the eye to be at that range *also*. Unfortunately, the physical image will be at some other optical depth depending on the display viewing system and so will be out of focus.

It has been suggested that some observers may be able to dissociate these two effects to some extent, i.e. relax their accommodation irrespective of the vergence cues, and this seems to be the case. Some preliminary testing, at BAe's Sowerby Research Centre [4], appears to show a correlation between the ability to focus on images which have the above conflict, and the individual's AC/A (Accommodative Convergence to Accommodation) ratio. The AC/A ratio measures the amount by which an individual verges as a ratio to the stimulation accommodation, (where vergence is measured in prism dioptre, a value of one for which corresponds to angle of 0.57 degrees, and the accommodation is measured in dioptres). The AC/A ratio is a constant for each individual and is linear over an accommodation range of 4 to 5 dioptres for about 90% of the population. The mean value for the general population is approximately 3.5 but can be modified by environment and / or drugs (!). A small AC/A ratio means that a small change in vergence produces a larger change in accommodation. The speculation is that such individuals may have difficulty relaxing their accommodation to compensate when conflicts arise. This has found to be the case in the limited number of individuals tested.

The implication of this, of course, is that a section of the general population may find IVEs uncomfortable to use. There is no clear solution to this problem except, possibly, the use of holographic lenses but the state of the art in such devices seem likely to provide only three separate depth planes.

Temporal Aliasing A third area of interest is the phenomenon of temporal aliasing. The visual system is used to interpreting moving images which are blurred as the object's image slews across the retina. In all computer graphics systems, moving images are sets of "frozen in time" snapshots which are distinguishable as such in certain circumstances. Depending on the update rate and the angular velocity of the image, a single object may be perceived as several. Work at BAe's SRC has suggested that, for typical velocities of objects in flight simulators and the like, refresh rates of several hundred hertz may be required!

There are, of course, other approaches to this problem. These approaches usually involve pre-blurring of images using models of camera optics or simpler, weighted sum averaging algorithms across multiple image frames. None of these run satisfactorily in "real-time" as far as we know.

Acknowledgements I would like to thank Drs. Catherine Neary, Antonia Tomoszek and Graham Edgar for information, many helpful suggestions and constructive criticisms in the preparation of this article.

References

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A Discussion of the Premise: 'Psychology is the physics of VR'

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Psychology can be broadly described as the study of mental behaviour. It encompasses the study of perception, which essentially is the interpretation of external and internal sensory information.

Physics is a natural philosophy. It is a science of the properties of matter and energy. The rules of this science enable explanations of why matter behaves in the way it does. With these rules we may also predict physical and interactive behaviours.

VR offers a novel means of interaction with 3D data-structures. Such interaction may be passive as in flying around an environment (multi- viewpoint) or active such as in the direct manipulation of a virtual object. Many applications for this novel form of interaction are being suggested.

If psychology is to be the physics of VR the implication is that it could explain and predict VR interaction (i.e. the interactive behaviour of a user or cybernaut in a virtual environment). How would this be possible?

Our understanding of the real world comes from the perception of numerous environmental (and internal) perceptual cues from which we are able to extrapolate relevant information. In a visual scene for instance, many such cues would supply depth information. If there was temporal change in such a scene then depending on its nature, motion may be perceived. This motion may be either of an object, of the observer, or of both.

An example of shadow as a perceptual cue is given. The shadow cast by an object can describe its shape and the visual system takes full advantage of this. When shadow cues are present (such as from an overhead light source) a slide depicting several circular objects may on the basis of their respective shadows be interpreted as pits (depressions) and bumps. If the slide is rotated through 180^o the pits and bumps are reversed (i.e. the pits become bumps and vice versa). Why?

The accepted explanation for this phenomenon considers human evolution, where the sun is seen to rise each morning, reach its zenith at midday, and then set each evening. In other words, the source of sunlight is primarily overhead. A consequence of this natural phenomenon is that the human perceptual system tends to perceive light coming from an overhead light source, even when it is not. Thus when the slide is rotated the light source is still perceived to be coming (in the presented example) from above and the shadow cues are inverted. In much the same way as physics has its rules, the perception of shadow represents an example of a psychological rule.

In the real world perceptual cues may be cumulative and may interact with one another in specific ways. As we have developed from childhood the nature of these cues and their interactive relationships have been learned by our perceptual system. Thus, if the nature and relationships of these cues are now distorted or misperceived, false perceptions and illusions may arise. These will in turn affect our behaviour.

In VR many perceptual cues are manipulated to create the artificial environments; to give them depth; to create motion. Many appropriate cues are however, usually unintentionally, misused or ignored. This provides conflict (e.g. after reaching for an object the cybernaut realises it is still beyond his grasp). It is most likely that it will only be once these conflicts have been resolved that the goal of true naturalistic interaction within cyberspace will be achieved. Psychology thus provides a means to both optimise and to assess the quality of a given VR.

An Object Orientated, Distributed Virtual Environment to Support Research into the Applications of Virtual Reality

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The techniques of Virtual Reality would seem to have great potential for revolutionising some currently problematic areas of human-computer interaction. The Advanced Interfaces Group at the Computer Science Department, University of Manchester are currently engaged in addressing major issues in the use of these techniques for real applications. Part of this work is the construction of an environment, called AVIARY, capable of hosting a wide range of Virtual Reality based applications and providing a coherent interface to them.

We intend to conduct projects with other groups and are currently exploring the possibilities for joint research with the departments of Psychology and Medicine. We are also in the process of setting up a laboratory for research into VR and scientific visualization in conjunction with the Centre for Novel Computing at Manchester.

The AVIARY environment is a high level, generic, system designed to be able to exploit available parallelism either on a multi-processor or a distributed system.

Different applications of VR will require different features, some may need to closely model physical laws, other may be more abstract. To support this AVIARY has the concept of a 'virtual world'. A 'virtual world' defines a set of attributes which will be possessed by all artifacts in an instance of that world. It also specifies a set of constraints which govern artifact behaviour. The definitions of the 'virtual worlds' form a multiple inheritance hierarchy allowing new worlds to be defined in terms of existing worlds rather than from scratch. The model allows for multiple worlds to be active.

The implementation is composed of loosely connected autonomous objects which execute concurrently. Some objects will represent artifacts in the virtual world, other objects act as device drivers for input and output devices or provide services. An example of one type of object which performs a service is the 'object server' which provides an execution environment for other objects and a means for defining them. One of our interests is in the area of Computer Supported Cooperative Working (CSCW) and to this end AVIARY is capable of supporting multiple simultaneous users, applications and worlds.

References

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Presence in Immersive Virtual Environments

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Presence is the central concept in IVEs. This is because the sense of participants being in an environment other than where their real body is located, is the fundamentally new dimension that IVEs offer. This is different even from, for example, flight simulators, often thought to be a type of IVE. However, when a pilot enters a flight simulator, there is no sense that his/her body is other than in - of course - the flight simulator. In this context, information is presented to very effectively fool the pilot's senses - visual, auditory and tactual - that s/he is flying an aeroplane, but the system cannot suddenly transport the pilot into being in a new office block, or a street, or some other place. It is this generality that IVEs offer which is new: just as the computer is a general purpose machine, so IVEs provide the possibility of being general purpose presence-transforming machines. In this talk we will outline some of the factors that may be important in influencing the sense of presence in IVEs.

Navigation in Immersive Virtual Environments

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A major feature of IVEs is that this form of human-computer interaction can be "naturalistic", with the participant carrying out activities in a manner much as in everyday life. Indeed, where the IVE is used in a training context, such a naturalistic form of interaction is an absolute requirement: for, in this case, operations within the IVE must be similar enough to the real world so that the learning in the virtual environment can transfer to the real world.

This is impossible with todays systems because only limited information about the user is available usually only the head and hand position and occasionally the current posture of the hand.

VPL use a DataGlove and a certain gesture initiates movement, in the direction of pointing. Velocity is controlled as part of the gesture: for example the smaller the angle between thumb and first finger the greater the velocity.

DIVISION's ProVision system typically employs a 3D mouse (though it supports gloves as well). Here the direction of movement is determined by gaze, and movement is caused when the user presses a button on the mouse. There is no control over velocity.

The first technique involves the user's hand being used for two tasks. A task such as trying to navigate up a flight of stairs holding a virtual fish tank so the water doesn't pour out could be very difficult. The second makes navigation over long distances time consuming and it is not clear whether the user will have a good sense of distance covered.

At QMW we have tried to overcome this with a metaphor that allows the user to virtually walk[1].

We use a neural net to detect patterns in the position of the head that occur when the user walks on the spot. Our preliminary results have been very encouraging with the net accuracy being around 97% the error being mainly due to the lag time between the user starting or stopping walking and the net recognising this.

References

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The Case for Perceptual Psychology Simon Rushton

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The ability to move through a VE, and change viewpoint with ease is the defining characteristic of VR. Change of viewpoint can disambiguate shape, form and unity of objects. Unfortunately, current support for movement in VEs is very poor with users often seen crashing through tables and missing doors. The obvious culprit is the visual information provided in VEs which is sparse, and in many cases contradictory. Two remedies to this problem appear possible: the brute computation solution - concentration on the development of rendering technology so that all the visual information from a natural environment can be incorporated; the necessary and sufficient solution - a research effort founded on the work of perceptual psychology to determine the minimum information necessary for specification of motion. I contend however, that the brute computational approach is doomed to failure as the visual information of a VE will never approach the richness of the natural world, and more importantly, the future of VR is not with poor attempts to replicate the natural world, but with more abstract or 'unnatural' VEs (such as is illustrated by the 'metaphor mixer' stock market system) in which there is no place for shadows, light sources, and textured ground underfoot. To build such VEs with no knowledge of how to support movement, but instead embark upon a course of development based upon trail and error and crude metrics, and hoping for saviour by 'a few more polys/sec' is doomed to (if nothing else, commercial) failure.

Sociology is the Environmental Science of Virtual Reality

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If "psychology is the physics of VR", then sociology is its environmental science. The emergence of new technologies and new media typically calls forth two kinds of reactions among researchers: On the one hand, there are universal pronouncements about how these new machines will radically transform our lives (see, for example, Jaron Lanier), and on the other, there are detailed empirical investigations of individual behaviour and psychology (see some of the contributions to Presence, Vo. 1, no. 3).

What these two types of responses leave out is the middle ground, the analysis of the different social contexts in which VR is used and the different technical possibilities which these contexts allow. The examinations of “presence” in virtual environments, for example, may be one thing in the laboratory and something else again in the bustling atmosphere of a videogame arcade. Again, the experience of “presence” will vary between the tasks that have been set for users in laboratory experiments as against the trials faced in a VR arcade game -both may result in experiences in which the user fells “present”, but they may be absorbing or disorientating, numbing or refreshing, pleasing or frightening in different ways.

What is needed then, especially at the stage when the direction of technological development is still very open and applications are only just emerging, is a dual approach steering in between the two mentioned above: on the one side, this approach will spell out the range of technical options among the devices, both existing ones and ones that may be possible in the future (ie, immersion in “room” environments, various means of navigating, shared environments etc) and the constraints and opportunities, technical and social, for developing them. On the other side, it will examine the emerging and the likely social settings of VR and of its consequences by drawing on comparisons with similar technologies and media and how they have shaped and become embedded in various similar contexts - and also develop a typology of existing uses of VR and their consequences through close examination of the interplay created by VR betweeen devices, users and the environment in which they operate.

By combining these two sides, it may become possible to see which types of devices will suit the needs of different areas of application and vice versa, in this way informing an expert as well as a lay understanding of the different paths which VR may follow. In addition to looking at the psychological reality of virtual reality, we also need to examine the real environments of virtual environments.

Sensori-motor Coordination in Immersive Virtual Environments

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Human perception and sensori-motor activity can be investigated using virtual reality (VR) systems which feature computer-generated environments and virtual objects (Foley, 1987; Ellis, Kaiser and Grunwald, 1989; Brooks et al., 1990; Iwata, 1990). Subjects can explore phenomenal properties of these simulated three-dimensional (3D) environments, and objects within them, with the aid of suitable interface devices such as a head-mounted display (HMD) and wired clothing (e.g., VPL’s DataGlove). Similarly, a six-degrees of freedom tracking/input device (e.g., SimGraphics’ Flying Mouse) can be operated by subjects to navigate and explore spatial properties of VR constructs (Ware and Osborne, 1990; Wann, Rushton and Mon-Williams, 1992; Feiner and Beshers, 1990).

During my final year (1991/2) at Manchester University I submitted a dissertation entitled ’Towards a Psychology of Virtual Reality’, in which I discussed a number of issues regarding utilization of VR technology for psychological experimentation.

I recently (June 1993) submitted a formal proposal to undertake a PhD research project at the Department of Psychology, University of Manchester; this proposal has been approved by the Department. The primary research topic will be - human perception and development of sensori-motor cognition under conditions of VR immersion.

This research will involve collaboration with other VR groups, such as the Advanced Interfaces Group (AIG) at the Computer Science Department, University of Manchester.

I am particularly interested in the use of VR systems to study perception and sensori-motor coordination during VR immersion. There are a number of general psychological questions which I would like to address, for example:

- How does eye-hand co-ordination develop in VR-based teleoperator systems?
- How is body-image altered when mapped onto computer-generated images and teleoperated devices?
- What are the important parameters in 'proprioceptive' experience of VR, and what are its phenomenal effects?
- To what extent can Piagetian accounts of sensori-motor development, and Gibsonian concepts of ecological optics, facilitate our understanding of action and spatial perception in virtual domains?

More specifically; the proposed research will focus on the processes by which visuo-manual coordination is achieved within a virtual environment which is novel to the subject (Churcher, 1983; Ware and Osborne, 1990; Richard, Burdea and Coiffet, 1993). Previous relevant work on skill acquisition in adults and on sensori-motor development in infants would also be consulted (e.g., Adams, 1977; Harvey and Greer, 1980; Butterworth, 1981; Piaget, 1953, 1954). In addition, the project should provide an opportunity to investigate any concomitant changes in the body-schema and/or body-image (Head, 1920; Macauley, Churcher and Bowers, in prep.) and the little understood but practically important phenomenon of 'presence' or sense of reality of the virtual world and the subject's experience of immersion (Slater and Usoh, 1993; Held and Durlach, 1989; Stone, 1991; Springer, 1991; Stone, 1992). Both quantitative and qualitative evaluation of VR/telepresence would be employed to study psychological phenomena and assess the relative efficacy of VR as a tool for perceptual/conceptual augmentation.

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Implications of VR for Computer Graphics Research

John Vince
Hughes Rediffusion Simulation

Over the last 25 years one has seen computer graphics emerge from early primitive systems driven by punched cards, to real-time interaction, which today is providing the mechanism for virtual reality systems. To support these developments modelling techniques have evolved to support the wide range of objects required by different users, which include: polygons, surface patchs, particles, CSG, voxels etc. As applications for VR take computer graphics into a wider range of subject areas, one must anticipate that new modelling techniques will be required to support these environments. Similarly, new rendering techniques will be needed to render these new forms, and provide greater realism. Algorithms working in a real-time mode impose tremendous constraints upon their design; nevertheless, this should stimulate researchers into developing new and original ways of rendering images.

There must be many other ways of building models apart from polygons and patches, and there must be some exciting rendering techniques apart from Gouraud and Phong shading radiosity or ray tracing waiting to be discovered. Computer graphics is far from being a well-researched domain. As far as research is concerned, we have only just touched the surface, and VR promises to provide an excellent reason for increasing the momentum.