ADVISORY GROUP ON
Computer Graphics

The Potential of VR for UK Higher Education

sima
Support Initiative
for Multimedia Applications

Part of the JISC New Technologies Initiative

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

Background

Directions in Education

Educational provision has been undergoing rapid change recently and this is likely to continue with accelerating pace. The trend is away from a short, sharp burst of residential higher education early in a person's career towards a demand for lifelong continuing education and retraining. This will be based either locally to the student or, increasingly in the future, provided remotely over networks.

These developments will change the educational, economic and social basis for the higher education system as we know it today. They will require greater flexibility in the methods of delivering teaching, in the accessibility of learning material and in a person's ability to select course content appropriate to their own personal needs. They will also result in a much larger number of students seeking access to educational resources. There is unlikely to be a proportional increase in the economic resources available to meet there demands.

The challenge to technology, and in particular to information systems, is to provide solutions to these problems.

Some progress has already been made. The Teaching and Learning Technology Programme (TLTP) has developed new teaching and learning resources for UK Higher Education. The Computers in Teaching Initiative (CTI) Centres have helped lecturers in their introduction of TLTP and other resources. Further work is still necessary to build on these early successes.

Directions in Technology

The rapid growth in exploitation of networks and the development of network-based software tools is providing access to an ever-widening range of resources on a global scale. This has already had a major impact on research and is now impacting teaching and learning. The possibility for collaboration on the development and use of materials offers real potential for economies.

The use of workstations and PCs by researchers, teachers and students is now widespread. Their configuration and performance continue to increase at reducing cost in real terms. Their increasingly powerful graphics capability offers the potential for improved interaction techniques.

The availability of an increasing range and volume of material on-line and improvements in the hardware and software resources for interacting with it are key elements in the exploitation of technology for UK Higher Education.

The Role of Virtual Environments

Virtual Environments, as a powerful emerging technique for interacting with on-line information, are potentially well placed to take advantage of these advances. This Workshop was held to investigate this potential and indicate how it might be realised. Following scene-setting and review presentations, four discussion groups explored the area of Education Issues, Technology, Software and Applications. Each had a brief to identify the key issues in their area and to make recommendations on what should be done.

Several example scenarios for the use of virtual environments emerged from the meeting covering a wide range of disciplines. These included:

- virtual laboratories providing access to remote, expensive or scarce resources or possibly hazardous environments;
- virtual art and design studios where the student can experience the full creative process from concept to realisation and evaluation;
- medical training using virtual instruments and virtual patients to acquire a basic level of manipulative and interpretative skill;
- foreign language acquisition through immersion in a environment where a language and be heard and its meaning understood.

All these virtual scenarios recognise the enhanced level of experience afforded by the greater visual, and potentially auditory and tactile, involvement of the user with the subject matter. The user can experiment and make mistakes without possibly dangerous or embarrassing consequences. The ability to model situations, exert control and observe behaviour, and the increased sense of presence afforded by virtual environments, offer the possibility of greater understanding. Virtual environments build on other technologies such as CAD, visualization and multimedia which are already, or are becoming, well established within current practice.

The potential of virtual environments to impact teaching and learning across the whole educational spectrum is exciting and challenging. However, the Workshop recognised that there is still much work to be done to establish firmly the benefits of virtual environments and to identify the ways of achieving these. The following issues and recommendations point the way forward.

Issues and Recommendations

Virtual environments as part of the educational process

We need to prove the pedagogic value and soundness of using virtual environments as part of the educational process. This can be achieved through examples of successful and beneficial use (and also examples of unsuccessful use) and by reviewing how they are used in other contexts.

Recommendations:
Demonstrate the value of virtual environments and make it clear where they can be used effectively by:

- producing case studies;
- providing application-oriented examples;
- reviewing industrial applications;
- reviewing international work;
- reviewing related technologies (e.g. games)

Good practice in the use of virtual environments

We need to establish good practice guidelines in all aspects of the use of virtual environments in an educational context and to understand how this complements other techniques.

Recommendations:
Develop guidelines on good practice including:

- integrating virtual environments with applications;
- usability issues;
- ethical issues;
- cultural issues;
- legal issues (IPR, copyright, etc.);
- health and safety issues.

Provision of information about virtual environment systems

We need to provide information about current virtual environment technology and systems and associated tools to help users implement solutions appropriate to their needs.

Recommendations:
Organise reviews and disseminate the information on:

- hardware and software virtual environment technology and systems for use in an educational context;
- tools for building models and authoring virtual environments;
- public domain and commercial model libraries and databases.

Access to virtual environment systems

We need to ensure that virtual environment technology is available to users at affordable prices. This is central to its widespread adoption.

Recommendations:
Ensure access is available to virtual environment systems by:

- obtaining CHEST prices now for the most widely used systems;
- getting CHEST licensing agreements for the best systems following evaluation;
- advocating purchase of appropriate commercial model libraries.

Providing support for users and developers

To ensure that the introduction of virtual environment techniques into teaching is soundly based, we need to provide access to training resources and technical support for users and developers of virtual environment systems within the community and encourage the exchange and sharing of common resources such as software and models.

Recommendations:
Provide support for users and developers by:

- making training materials available for appropriate virtual environment systems;
- making technical information and support available;
- encouraging sharing of resources within the community.

Exchange of ideas on teaching issues

We need to encourage an exchange of ideas on issues related to both the use in teaching and the teaching of use of virtual environments throughout the curriculum.

Recommendations:
Set up a means for people to exchange ideas on the use of virtual environments as a teaching aid across the curriculum.

Set up a means for people to exchange ideas on the teaching of virtual environment techniques as an aspect of the curriculum.

Standards

We need to participate in standards development with a view to establishing de facto and de jure standards in this area. These are needed to ensure that virtual environment systems can interwork, that the results of developments on one system can be moved to others and that libraries of commonly used components can be established within the community. This is particularly important given the cost of developing virtual environment solutions and the consequent need to reuse models, software and courseware.

Recommendations:
Ensure the community is adequately briefed on standards.

Participate as a community in the development of relevant standards such as VRML.

Links within the community

We need to ensure that the JTAP Focused Club in Virtual Environments is established and provides an effective way of bringing people together and disseminating good practice. We need to encourage links between existing initiatives and programmes (e.g. AGOCG, eLib, TLTP, CTI) to promote the effective use of virtual environments and the exchange of good practice.

Recommendations:
Liaise with JTAP Programme Manager to ensure that the JTAP Focused Club in Virtual Environments is set up and involves a wider community than JTAP projects to maximise its value.

Ensure that the JTAP Focused Club provides a useful and effective channel for dissemination.

Promote the results of this Workshop to existing initiatives and programmes.

Encourage people working on related projects to share good practice.

Links with industry

We need to maintain close links with the UK virtual environment supplier industry to ensure that we benefit from its dominant global position and also help it to maintain that position.
Recommendations:
Be proactive in stimulating links with the UK virtual environment supplier industry through:

- software acquisition;
- joint development of case studies;
- collaboration on joint projects;
- encouraging their participation in community activities.

Encouraging further research

We need to encourage further research in virtual environments including research into human factors (physiological and psychological) to improve the design of future systems and better exploit existing systems, and research into the impact of virtual environment methods on the way organisations operate. Much of this work is multi-disciplinary in nature which can lead to difficulties in funding. A Community Club in this area is needed.

Recommendations:
Promote the results of this Workshop to the Research Councils.

Encourage setting up a Community Club activity in Virtual Reality and Virtual Environments.

THE BACKDROP TO THE WORKSHOP - ANNE MUMFORD & JOHN SLATER

The workshop formed a part of the SIMA project funded through the JISC (Joint Information Systems Committee of the HEFCs) New Technologies Initiative. SIMA (Support Initiative for Multimedia Applications) runs as part of the programme of the Advisory Group On Computer Graphics (AGOCG).

JISC have recently produced an issues paper entitled: "Exploiting Information Systems". The key areas identified in the discussion are: teaching and learning experience; distance learning, on/off campus education; role of HEIs in the local, regional and global environment; research techniques, especially collaborative distance research and the virtual laboratory; exploiting IT in running "the business" and campus.

This workshop addressed some of these areas and issues and focused on the ways in which the use of virtual environments might help in the realisation of the emerging strategy in the context of HE teaching and research in the future.

In introducing the workshop, Anne Mumford explained that the aims of the workshop were to:

- review current systems and use
- look ahead to technology which is near market
- what are the realistic possibilities for the use of virtual environments in both research and teaching
- recommendations for action by AGOCG and to other groups

John Slater continued Anne's theme of looking at the political backdrop to the workshop and focused on the role of JISC.

JISC is concerned with infrastructure. Its major funding activity is concerned with the provision and maintenance of a leading edge, service network. Related to that are the network services which utilise this provision (e.g. NISS, Mailbase, BIDS, MIDAS funded through its Information Services Sub-committee). The Electronic Libraries Programme (resulting from the "Follett Report") and Management Information Services are other major areas of activity. JISC also have groups concerned with Information Strategies (a report has recently been produced) and with Standards.

A call has recently been made for the JISC Technology Applications Programme (to follow from its New Technologies Initiative). JTAP is concerned to see applications proving the use of technologies and helping pull those technologies through to services where this can be proved to be effective and efficient. The JTAP call recognises virtual environments as a technology of interest to JISC and projects are likely to be funded to consider the use of the technology in application areas. The emphasis will be on "pull-through" with developing technology typically taking up 5% of resources, the rest being use of existing technology.

The use of virtual environments will be of interest to HEFC-funded activities for teaching and learning, including TLTP and the recent HEFCE/DENI initiative for the Fund for the Development of Teaching and Learning which is concerned with the dissemination of good practice.

JISC consider standards to be of importance across the whole of its programme and have allocated limited resources for travel and subsistence for standards activities. Standards in the area of virtual environment may attract funding if the workshop perceive these as being important.

There may be a need to have a mechanism for disseminating guidelines and information relevant to VR which has been developed across various initiatives.

John suggested that a workshop to consider the future network needs of VR, in conjunction with other associated groups (visualization, multimedia, HPC) to pool their requirements and identify common needs may be of value. This could be under the SIMA "umbrella".

POTENTIAL OF V.R. FOR UK H.E. - ROY KALAWSKY

Professor Roy Kalawsky from Loughborough University gave the keynote address to start the workshop and to focus attention on the issues before the participants. The report below notes the themes addressed in his presentation.

Education today

There is a growing demand for continuing education. This relates to the fact that our industrial competitiveness depends on skill acquisition We can see a change in career patterns emerging with many people retraining at least twice during their working life.

The rapid technological changes we see today need a more responsive educational process. Open learning centres can be very effective in providing the resources needed which can be accessed in a flexible way. Large corporations are turning to universities for support in helping to give their staff appropriate skills. Residential training courses are expensive both in cost and time. We need something that is more accessible and affordable.

The Shape of Things to Come

We are likely to see education services available on demand. These will be tailored to the client's need. Remote learning could become the norm. Already, distance learning initiatives are on the increase. These take a technological approach making use of advanced IT and telecommunications. We do however need to look carefully at the educational processes.

We need to consider what the role of universities will be in such a setting. Will they become limited to examinations at undergraduate level and to research? Is there, however, no substitute for hands on learning experiences?

Revolution or Evolution in Education

Technology is evolving to provide richer environments at a cost which is viable for use in teaching.

Multimedia has been around for some time and is cost effective but does not allow a high degree of interactivity or model development. The internet, through WWW and the emerging VRML, is easy to access and has a wealth of information but is open to abuse as the quality cannot be guaranteed. We are getting access to high bandwidth networks and intermittent predictable access can be provided through ISDN, making remote working using new technologies viable.

VR brings together many of these developments and has the potential to provide a solution and to provide a very rich learning environment.

Strengths of VR

VR applications allow high levels of interactivity which can provide a strong sense of immersion - this is a powerful characteristic. Systems have inherent flexibility and adaptability.

Weaknesses of VR

VR is frequently seen as a visualization front end and it is more than that. Low cost systems suffer from poor quality interfaces and are frequently disappointing. In proposing increased use of VR we need to be very clear of what VR brings to education.

Why VR Systems: An Educational Context

VR systems are more than just a visualization system. We can have personal simulators. The underlying modelling environments hold the key and VR systems enable users to control these models.

VR systems will exploit interactivity. We all learn faster by 'doing' rather than reading. People learn from mistakes. Virtual environments make this possible.

We can get more efficient learning by an enhanced sense of presence. Students can get a better understanding of process. An example was quoted of using VR to show the inside of a piston design which revealed how it works. Students were able to see interactions which would not normally be covered in a lecture - engineering is 3D.

VR systems also have an inherent flexibility. Virtual environments are re-programmable.

Potential Applications

The following are examples of potential application of VR in education:

- Virtual science/engineering laboratories - giving access to otherwise expensive or prohibitive facilities.
- Virtual art/design studios - VR can give student involvement in the full design process.
- Medical training - VR is useful for procedural training.
- Foreign languages - Students can be immersed in a foreign country.

Critical Underlying Issues

What will be the quality of teaching and learning delivered? The key question is will a VR system be better than current approaches?

As with other aspects of online material there are issues of IPR and copyright. Who owns the material? How do we protect material over the network? This is a wide issue.

Many of the issues are "people issues". Will this create jobs or remove jobs? How do we introduce the concept? Will people accept the concept? Unless we can answer these questions people will not take on the use of virtual environments.

What is the Right Technology?

If VR is to have a widespread takeup we need to advise the community on the delivery technology to be used. What sort of display should be used - desk-top, projected or head coupled? How important is multi-sensory interaction? Will environments be single user or shared ones? What technologies will gain greatest user acceptance? What can we use in labs with large numbers of students and what is more suited to home use for distance learning? Can we develop a system that is truly independent of the user's technology? What is the minimum assumed level going to be?

We also need to advise on the cost of ownership - compared to cost of a lecturer?

Obsolescence is also an issue. The shelf life of a great deal of technology is typically 3-4 years. Stability may never be achieved in VR systems.

This is a problem of insufficient development of standards. There are different standards for equipment. There is a need for a standard interaction interface. There is a need for an open transport protocol and format standards to facilitate remote use and exchange of models.

Courseware/Environments

The preparation and maintenance of the software for courseware needs careful consideration. Will this be developed in HE by programmes such as TLTP or will commercial offerings emerge? How do we integrate the new resources into current courses to ensure that there is a good educational gain? We will need courseware tools to help us develop resources. These need to be accessible to a non-expert user.

When developing software, do we want to simulate reality, or do we want to use the fact that we are not working within real physical worlds with constraints of time and distance? An interesting thought.

Courseware has a dependence on delivery technology - we need to have open standards to ensure we are futureproof and that as many people as possible can use the systems developed. Courseware production may be the dominant cost of the whole system - we want to develop courseware that can transfer to new technology as it emerges, again this is a standards issue

Education/Training benefit

There are many questions to be answered.

How do we measure the educational benefit? Do people learn better in a virtual environment? Will virtual training experience ever replace real training experience? - would you be a passenger in an aircraft whose pilot had never flown a real aircraft before? Can we quantify the payback? How do we realise/achieve the potential benefits?

We need to start to gain the experience to answer these questions and to disseminate that experience.

A Personal Vision

Roy suggested that over the next 3-5 years he could see PCs becoming Personal Assistants which were intuitive (using online intelligent agents) and which would require only low computer-literacy by their user.

These PCs will employ VR style interfaces, that is they will have: head tracked stereoscopic display capability; head mounted display capability; outputs for large screens; voice input; 3D interaction system; wireless ISDN or similar networking; applications downloaded from network

Following this we will see over the next few years the availability of freeware from wireless network service provider who will offer services. People will subscribe to education service provider for courses. Virtual laboratory bureau will emerge.

Discussion Points

Following Roy's talk a number of points emerged in discussion:

VR is hard to distinguish from other technologies. Technologies are converging - pure immersive VR, CAD, multimedia and low cost WWW/Internet access via TV technology.

We need to look at applications and ask how we are going to deliver that need.

VR needs to show "real" lab effects of mistakes - explosions, electric shocks etc!

Portability is vital - across systems, space and time if the cost of producing educational material is going to be able to be justified.

SURVEY OF ACTIVITY IN THE UK

Background

Roger Hubbold of the University of Manchester presented the results of a survey of UK activity in the VR area. There have been 2 studies supported by AGOCG - one towards the end of 1994 and this one in the autumn of 1995.

The second survey attracted 58 responses (51 in 1994) and the results are given in AGOCG Technical Report 27 which should be obtained for more details.

35 of the respondents were from Universities, 14 from vendors and the rest from other types of research groups and users. Many of the groups are small (39 having 1-5 people) though larger groups are starting to form in some institutions. Most have been in existence for less than 3 years and most come from a background in Computer Science, Engineering or Psychology.

Applications

Many people are working on applications, perhaps reflecting the increase in industrially sponsored work. Human factors, software architectures and development of peripherals are also major areas of interest. Data visualization and VRML have emerged during the last year as new areas of activity. There was a wide range of specific application areas reported including: education and training; information visualization; construction planning and scheduling; driving/flight simulation; CAD/CAM; medical simulation; virtual retailing/marketing.

Respondents were asked what they saw as the perceived benefits. The main ones were: increased and improved human-computer interaction; better visualization of information; a sense of "presence"; more rapid prototyping; improved simulation.

Hardware and Software

During the last year there has been a considerable increase in the use of Silicon Graphics machines. Superscape remains the most popular package with dVISE/dVS in second place. Many people are still developing their own software. An increasing number of sites now have immersive facilities.

Research

The respondents reported that the UK has so far conducted research of excellent quality in the field of VR and its applications, and that it is ideally placed to become the world leader if sufficient funding and support is forthcoming. Many respondents specifically requested increased and targeted funding for academic/industrial collaboration. The need is for a multidisciplinary initiative along the lines of the now closed Joint Council Initiative (a joint activity between the then SERC, ESRC and MRC). This needs to be medium to long term project funding.

EXTRACTS FROM THE WORKSHOP INPUT PAPERS

All participants submitted a position paper to the workshop which outlined their interests and the issues they perceived as important to the workshop. This section of the report extracts some of the points made in those papers which set the scene for the event.

Applications

The paper by Hewitt and Preston noted the growing interest in the use of VR and their view that it could provide a critical technology to their users at Manchester. They feel that there is more of a need for the application of VR to be the focus of activity in the medium term than the development of fundamental technologies. There is a need for investigation into the development of robust tools to apply to real problems.

The use of VR is seen as being important in the context of Geographical Information Systems. Jonathan Raper noted the way that VR offers the potential for: exploratory data analysis; virtual observation and measurement and spatial decision making environments to be offered to students to enhance their learning experience. There are problems to overcome before this can be a reality, particularly in terms of the cost of systems. There are also problems relating to the nature of the software toolkits which means users need to be developers at the current time.

Andy Avery also picked up this theme and noted that the integration of GIS and VR offers an alternative, more intuitive interaction to the data than is currently available. But the GIS/VR integration has more to offer than simply an improved interface. The GIS/VR integration offers the opportunity to remove some of the data abstraction, permits free viewpoint movement anywhere within or outside the model boundaries, and generates views in real time. Again the cost issues were raised by Andy who also stressed the need to prove that there were considerable cost benefits in using advanced systems in education.

Vassilis Bourdakis reported on the potential of VR to help architects appreciate and utilise Computer Aided Architectural Design as an everyday tool in their design work - that is not just for drafting and presentation. In order to start enabling students to use the technology it is probably wise to use non-immersive systems and have them more widely available.

The benefits of VR in museums were described by James Hemsley who noted the educational benefits to be gained in the representations of reconstructions of archaeological remains and of historical buildings. Also of benefit is the development of 3D object resources. Current projects include those which bring together physically separated objects into one whole to aid understanding.

A paper by Ken Brodlie, Peter Dew and Terrence Fernando from the University of Leeds described the interest of the Computer Studies School in the teaching of virtual environments and their application to a number of practical situations. The teaching is focused on their M.Sc. programme in Vision, Visualization and Virtual Environments. The applications used on the course are mainly based on research in the school and include: advance driving simulator (which uses reality where possible - steering wheel, accelerator peddle - with the input devices all being real and the output devices being part real, part virtual); collaborative engineering environment; virtual science park (saves using a green field site); synthetic virtual worlds.

Robin Helmsley described the work of the Medical Imaging Group at UCL in developing the "Interactive Skeleton". This allows the student of anatomy to manipulate a virtual human skeleton and provides rich textual information. Other work is progressing on access to models of scanned human bodies. The work throws up the question, as in other application areas described above, as to whether the cost of immersive VR can be justified for teaching purposes. The cost of scanning is also an issue which needs

to be addressed. We need to consider how the models will be stored, exchanged and subsequently accessed and manipulated.

The benefit of VR for medicine was a theme of the paper by Averil McCarthy who reported on the work of the VR in Medicine and Biology Group at the University of Sheffield. Although the group have been mainly concerned with the use of VR in research, the group has also investigated the use in teaching and administration. A major problem with teaching is the availability of suitable equipment in sufficient numbers. On the administration side, there have been models built to illustrate the set up in expensively equipped rooms prior to purchase to ensure that the set up is optimal.

The paper by Henry Rzepa and Omer Casher described their work in the area of chemistry and molecular sciences which they feel provides a perfect application for VR methods. Molecules are well defined three dimensional objects with a variety of inter-related attributes and computable properties. They are well indexed, and a wealth of published information is available about them. They have worked to enable use of molecules across the internet by developing various MIME types. Recent work has focused on the use of VRML and their current work involves the development of a properly supported 3D virtual chemistry library. This will be based on courses at Imperial College and will link to other resources elsewhere in this "Open Molecule Initiative".

Colin Shell and Timothy Ritchey discussed their work on the VR modelling of a major archaeological site, Catalhoyuk, in Turkey. Virtual Reality reconstructions of archaeological sites abound, but they are usually very generalised structures with simple rendering of simplified geometry. Most archaeological sites, and certainly Catalhoyuk, have irregular structures and uneven, not truly rectilinear walls. Similarly, the wall may not be represented by simple rendering. In some cases high resolution digital images of art need to be displayed in their correct relationship to features in rooms. To be a useful archaeological research and teaching tool VR must go beyond the simple geometries and be able to put back in their correct relationships portable objects and the structures that contained them. Ultimately, with high resolution digital recording during the course of an excavation, and accurate 3D surveying of all structural features and object positions, VR could provide the only surviving true record of a site after its excavation. For this voxel information needs to be included and displayable.

One of the principal benefits of Virtual Reality in archaeological teaching will be the training it will give in requiring the student/archaeologist to think in three dimensional volume terms. This is a particular problem arising from the established method of excavating sites horizontally, leaving vertical sections at appropriate intervals. The excavation report is limited to these plans and sections to physically represent the site. The vertical sections are not normally sufficiently close together to allow the intervening stratigraphy to be interpolated.

The other area where real-time VR will be very useful is the visualization of simulation models of past human-environment interaction, where the impact of changes in agricultural strategies can impact significantly on the landscape. The need is to display spatially the interrelationships of the models component variables in real time as the model runs, as well as showing visually the consequent changes in human and animal populations, vegetation and geomorphology etc.

Many disciplines use field courses to address a variety of objectives. David Unwin suggested that some of these needs could be met using virtual environments. Field work has many benefits but it is expensive. It also has some important equity considerations. Field trips present problems to people with disabilities and/or who are athletically challenged - this is an increasing issue with lifelong learning on the agenda. There are inequalities concerned with the types of places visited due to remoteness (beyond Europe) and safety (preference for rural over inner city). It is also becoming more difficult to timetable field courses with modular degrees. The virtual field course, David suggests, will find application in three educational contexts, providing enhancement of the current learning experience for some and a replacement for others. Firstly, it will be useful in preliminary work before going on the field course as well as during and after to organise data; secondly, is the ability to work in physically challenging environments which students would be unable to visit; thirdly, it will enable students to experience, at low cost, at least something of an environment which might be otherwise denied them for personal reasons. There are problems which need to be addressed including: choice of appropriate tools; the question as to whether it needs immersion; the problems regarding the massive amount of data needed.

Research

Nigel Birch from EPSRC reported that VR was an area of relevance to a number of research areas covered by the Research Council. A workshop in the autumn of 1994 identified a number of research opportunities in the technology, the applications and the human factors of VR. The latest (Human Factors of VR) was being pursued as a new initiative and a second meeting was held in September 1995 to define the scope. Two themes emerged from this meeting: the need to support basic studies of human interaction (including physiological and psychological aspects) both to underpin the design of future systems and to improve human interaction with VR; and, to understand the impact of VR on the way in which organisations operated. There is discussion underway concerned with how these themes might be incorporated into future programmes. Nigel also noted the current interest in VR within the DTI as a result of the Foresight activity.

Educational Needs

Many papers noted the cost of systems at this point in time which made it prohibitive for widespread use by undergraduates.

Chris Osland noted that the main financial pressure will come when, as a result of the price drops which are likely to occur over the next few years, it becomes cheaper to install a turnkey virtual laboratory (for instance) than a real one. It is unfortunately unlikely that quality of teaching / learning will be considered as strongly as price and this will probably tend to cause VR/VE solutions to be attempted rather prematurely.

Averil McCarthy stressed the need to identify real problems which may be solved more easily or effectively with VR. From an educational point of view, we need to be able to justify the use of VR by its contribution to an enhanced learning process. What is the "value added" that VR will contribute to the process?

Noel Williams noted that embedding VR in a classroom is not merely about giving systems to teachers. Even where a system successfully addresses a generic educational objective, it may not be taken on board by the educators. There may, of course, be resistance to the technology for political, occupational or ideological reasons. But there may also be fundamental educational problems, if the system cannot be integrated into the actual curriculum as currently delivered. Courseware using virtual environments needs to be developed to meet desirable educational goals using the right combinations of expertise and the right tools. Such courseware needs to be able to be embedded in varying educational contexts. How can we achieve this?

Roy Ruddle described the use of virtual environments as providing lecturer aids to help illustrate a lecture and as an addition to traditional handouts. This requires "just in time" preparation and this leads to the need for the availability of efficient database generation. Roy suggested some desirable requirements for software tools to help promote rapid database generation - though these do not appear to be a feature of commercial packages at this time. This use requires more limited functionality than professional courseware development. The need is for suitable tools which can be used with minimum author experience.

Venkat Sastry reflected the general view that we needed to address the question as to where the significant gains are if we adopt VR. We also need to look at current usage (not, as he points out, mere interest) of VR in the classroom and to start to record some case studies as the technology matures. If VR is to be taken up we need to have recommendations on the minimum required set up and to start to acquire appropriate skills in order to develop and use systems.

John Wann reflected on the questions surrounding the technology which need to be addressed before VR becomes widely used. The issues addressed concerned the display technology (when is stereoscopic information important; when can other information sources supplement for binocular information; what kind of trade-off can be made between field of view and resolution?); image generation technology (what

will be the primary image generation requirements of users in HE?); peripheral technology (is there a subset of user interfaces that rapidly become intuitive, but do not limit the application; can the same interaction protocols be mapped to devices suitable for users with restricted movement opportunities?). We need to be able to define the requirements for education and consider whether these are likely to be met by systems in the medium term.

Support and Infrastructure Needs

Bob Hynds gave a perspective on the needs of an institution introducing an area of new technology which has widespread implications.

If new IT developments such as Virtual Reality Environments are to be effectively utilised on campus, then there will need to be co-operation between the developers, the campus computer service providers and academics within departments. The role of the computer service providers must be to provide a bridge between the developers and the academics, to provide the relevant computing infra-structure on campus and to promote the potential and capabilities of virtual reality environments.

To achieve the above roles the service providers need to be informed in good time! To implement any new IT development two things are needed. One is some (often modest) investment, and the other is time. This is needed to explain the new ideas to Centre staff and allow them to become comfortable with the concepts, to develop the facilities and infra-structure to support the development, and to begin to demonstrate on campus the system in action.

There is a considerable amount of information needed by Centres to achieve the role outlined above, and Bob suggested, one of the outcomes of this workshop should be a synopsis sent to Centres which provides this information. At least the information shown below is needed:

1. Time scales of development
   - When will a demonstration system be available?
   - When will a robust system be available?

2. The economics of VR
   - What are the costs of a system?
   - How do such systems scale with numbers of students?
   - What is the economic comparison with alternative methods of teaching?
   - Does the new method offer unique teaching methods?

3. What campus infra-structure facilities will be needed to implement VR systems i.e.
   - Hardware requirements
   - Software and its support implications
   - Network and bandwidth requirements
   - Advisory, training and information support

A further concern for institutions is that of the health and safety of their staff. Huw Jones brought this issue to the attention of the workshop in addressing the concerns which are around concerning the use of VR. Such concerns often relate to entering and leaving virtual environments (e.g. neck stress, hearing loss, nausea). Huw widened the discussion in recognising that the issues can be broadly categorised as physical and mental health problems with short and long term effects. Most concerns which are commonly listed fall into the category of short term physical problems. Issues such as eye strain, exposure to electromagnetic fields fall into the long term potential hazards. Psychological addiction, problems associated with isolation in virtual environments are examples of mental health hazards. If VR

is to be taken seriously, then the developments need to be accompanied by research into these health problems so that all possible safeguards can be taken. We need to lobby for such work to be undertaken.

Awareness

The need for training and awareness in this area was highlighted by Adrian Clark. He noted that there is a great deal of good work in the UK but that we are not exploiting this as well as we could. We need:

information provision - there is a need to exchange ideas and to make the technology and it potential better known in HE
demonstrators - in order to illustrate the potential benefits, there is a need for proof-of-principle demonstrators that people can try out by downloading them from the network
community voice - there is no well developed community which is involved in training, promotion, workshops etc to help with the flow of information between academe and industry, to promote VR with the general public and to provide a common voice to funding/political bodies

Standards

The aim of VRML is to "become the standard language for interactive simulation within the WWW". It was conceived in spring 1994, and has developed via discussion on the www-vrml mailing list to a specification of VRML version 1.0 released in third draft in May 1995. It is based on a subset of the Inventor file format. Ken Brodlie noted that the format is currently not about VR as it is commonly understood. However, Ken suggested, that as support for behaviour is added, and multi-user participatory worlds are created, then VRML becomes a serious candidate for distributed VR. Research work will be needed on improving the performance - investigating, for example, more sophisticated approaches to level of details, and recognising different environmental factors, such as network bandwidth and processing power of the client. We need to debate how we can get acceptance and stability of standards and the processes used to achieve this. Is a formal standardisation process required?

Henry Rzepa and Omer Casher also discussed the importance of VRML. They noted that VRML is currently significantly less mature than say HTML, and so is likely to develop rapidly. Some of the issues to be resolved include;

- Availability of VRML authoring and browsing software. CHEST should have a significant role to play here.
- Developing methods for indexing and structuring document collections. Programs such as Hyper-G or SiteMill may play an important role here.
- Develop methods for choreography of documents. JAVA will play an important role in making VRML files responsive to users.
- The development of SGML2VRML and CML2VRML filters. CML is a chemistry based SGML dtd being developed at Imperial. This in turn will impinge on the form of electronic journals of the future.
- Current generations of VRML browsers do not support disk caching. Although a compressed VRML description of a medium sized molecule is perhaps a factor of ten more compact than a 24-bit JPEG image, with more complex scenes the ratio can reverse. Network bandwidth needs to be carefully considered.
- The proprietary Microsoft "Blackbird" multi-media authoring initiative is attracting much attention, and there is some suggestion that VRML may be supported within this. The X-Window consortium also has a desktop product called "Broadway" under way, which purports to integrate X, NT, Desktops, and the Web. We need to understand the implications of this and other developments.

- We need to address the issues of how University teaching might change with increasing use of such tools. For example, does the current ethos of HEFC assessment of individual departments inhibit the creation of virtual 3D libraries of information not directly attributable to any particular institute? Will file encryption and charging issues complicate the implementation?
- Using VRML in a collaborative environment. This is a top priority among the VRML community. Imperial have already developed a prototype may be able to play a significant role here.

The need for standards in architectural applications was noted by Vassilis Bourdakis. The industry has long recognised the need for standards and now there is a need to go beyond formats such as Autocad's DXF format. VRML may be the format we need as it is gaining considerable recognition.

Design Issues

The paper by Stephen Boyd Davis and John Lansdown raised some important issues of the design of virtual environments.

There has been a tendency for VR to be hailed as an unproblematic answer to many problems in computing, from database, through educational technology, to virtual museums. The task of making virtual environments is seen as a technical one - essentially of reconstructing reality in the computer. Indeed this is seen by many as a sufficient definition of VR. However, there are two clear problems. One is an assumption that a representation is the same thing as the thing it represents. The other misapprehension is that simulating reality will in itself be sufficient.

Even the most ambitious virtual reality will not be the reality it represents. It is clear that we are dealing with a representation: as creators of such environments we have both the obligations and the freedoms that any designer has in constructing a representation.

If we take the idea of a virtual museum - are we to limit ourselves to placing objects in fixed locations in a building of a given appearance? What is the point? It could be argued that a straightforward visual database is a better 'virtual museum' since it allows works to be located within as many dimensions as there are fields in the record. What do we gain by making a virtual physical construction? Nothing, unless we abandon some of the simplistic assumptions about virtuality. We are faced with a rich variety of choices. What should inform those choices? What questions should we ask ourselves?

These and other issues need to be addressed when using virtual environments. The adoption of non-realistic techniques, that is taking advantage of the non-physical nature of virtual environments (doing away with the physical constraints of distance and time) might benefit applications. The authors suggested that we need to stop thinking that the construction of virtual realities is a common-sense operation in which it is obvious what choices should be made, one in which design has no part.

GROUP REPORT: APPLICATIONS

Introduction to the Group Work

The kinds of issues identified for this group are:

- novelty of the application;
- ways in which VR is particularly of benefit;
- does (or how does) the VR solution differ from a desktop interface?
- what hardware and software systems and tools are used and what are the limiting factors?
- how does this application impact on future education (e.g., use as an educational delivery vehicle, or use for educating those in specific disciplines)?
- (un)suitability of existing tools;
- can general-purpose VR systems be adapted for applications, or are more customised solutions necessary?
- problems of cost

We will be trying to amalgamate, structure, and perhaps prioritise, the issues brought to the workshop.

Possible recommendations include:

would it be helpful to have affordable courses on VR, and, if so,

- what topics should these cover and what emphasis should they have?
- should there be moves at a national level to conclude site license deals for specific software systems?
- would it be valuable to conduct evaluations of VR hardware and software systems?
- might it help to have a national resource or centre for information/advice about VR (or does the Web make this idea obsolete)?

Roger Hubbold, University of Manchester

Group Discussions

Roger Hubbold reported on the main points which emerged from the discussion in the applications group.

The group discussed the issue: is VR really useful?

There is a problem with the current state of the art in that users really need to be programmers. As a result, the development times are lengthy and thus much more time is spent developing than evaluating (90/10 balance was suggested as being typical). There is a real need for "non expert" systems.

With the current state of VR technology the benefits are perceived rather than quantifiable. It was felt that waiting until the benefits could be quantified would be damaging to UK industry and HE. In order for UK industries to keep up with progress and maintain their competitive edge, it is vital that students are taught to integrate VR techniques with their other tools in computer graphics, visualization and multimedia.

The perceived benefits are seen as being:

- performance improvement - in design reviews; risk assessment (with EU regulations on health and safety this is a major benefit)
- Computer Supported Co-operative Working (CSCW) can offer savings in time
- access to expensive/inaccessible sources - example include virtual laboratories, virtual field trips (collect data in the field, measure at leisure), inside the patients head

End users are however sceptical at this stage and need to be shown that the technology can be effective and under what circumstances. Good case studies are needed. It is not clear that we can deliver at this stage.

There is a need to provide access to the technology:

- there is a need for low cost systems for wide use
- need access to some high end systems
- site licences for software might be appropriate, though at this stage there is probably no universal best buy
- there is a need for access to novel technology, for example 3D input

There is a need to provide access to the data:

- building virtual environments is expensive
- it would be useful to have shared models/data
- standards for data exchange (VRML) are likely to be important and other standards (PREMO) need to be considered, some standards may need to emerge to meet other needs
- the data required can be large
- there are privacy issues to consider (medical data) as well as other legal ownership issues

Software Issues:

- we need to address the differences between importing applications to VR versus importing VR into applications
- there is a need for application constraints and behaviour in virtual environments
- hence, we may need the integration of VR and the application
- portability is a major issue

The use of VR needs to be an integral part of the application if the technology is to succeed. Data needs to be altered and exported back within the system. Data integrity and version control are issues here.

Educating the Next Generation

- this is essential if the UK is to be competitive in this area
- there is evidence to suggest that such education will yield take-up in industry

Other issues include IPR.

There is also a concern that too many things are called "VR". We need to move to an application focus.

Recommendations

Following further discussion within the group, the following recommendations were made:

1. Conduct an evaluation of software
   There is a need for an evaluation of systems. This would provide a wealth of timely information for the community. There is unlikely to be a single solution to solve all problems but there may be some systems where we should be looking to obtain a CHEST agreement. Any evaluation needs to consider:

   - model building
   - run time
   - formats and standards, e.g. PREMO, VRML, STEP (insufficient is known here)
   - evaluation should look at strengths and weaknesses of packages
   - how the underlying data are handled

2. Conduct a series of application studies

   These should build on other work already underway or completed.

   - looking at the needs and benefits in different application areas and application-specific standards, such as STEP
   - look at the cultural issues involved and conflicts of interest

3. Involve UK HE in definition of standards e.g. PREMO, VRML2, ...

4. Develop a guide to good a practice including ethical issues

5. Recommend to TASC (JISC Technology Applications Committee which oversees JTAP) the funding of some VR application studies - we need to see how VR can be integrated into applications

6. VR Club (initially by EPSRC?) to organise workshops etc...

7. Collect exemplar applications and "object" libraries perhaps through CTI centres

8. Set up a VR training and education centre with short travelling courses - ideas based on successful JISC models for visualization through AGOCG and NTI/HPC training and education

9. Production of generic training materials, e.g. related CHEST packages

10. EPSRC programme to investigate integration of models and VR

11. Support for inter-disciplinary research with VR (computer science, cognitive, user disciplines..) within EPSRC and between Research Councils

GROUP REPORT: TECHNOLOGY

Introduction to the Group Work

Virtual reality techniques are likely to have a major influence on the UK's educational process in the future. For example, it may be possible to provide educational establishments with access to sophisticated laboratory facilities even if in a virtual form. The exact form future virtual teaching aids will take depends very much on the nature of the teaching programme to be delivered. A broad spectrum of technology based concepts will be available and it will be extremely important to understand where and how to apply these to achieve an effective teaching/educational medium.

The aim of the Technology Group is to identify where and how VR technology can be used to deliver an effective educational benefit. An initial specification of the performance required from the technology will be required to be derived for the short(1-3 years), medium(3-5 years) and long term(<10 years).

The group will start with a scoping review of VR based delivery systems for educational systems. The technology area covers the computational resource to provide the VE and the peripheral devices through which the user will interact. We will also have to consider the method of hosting the educational system and whether it is entirely locally based or part of a remote/networked system.

Our emphasis should be on the future requirement rather than what can be achieved today. The objective is to highlight the major technology concerns including :

- technology maturity
- technology trends
- technology performance shortfalls
- technology obsolescence (can we achieve technology independence?)
- health and safety issues (affecting deployment in educational establishments)

Roy Kalawsky, Multi-sensory Virtual Environment Integration Laboratory, Loughborough University

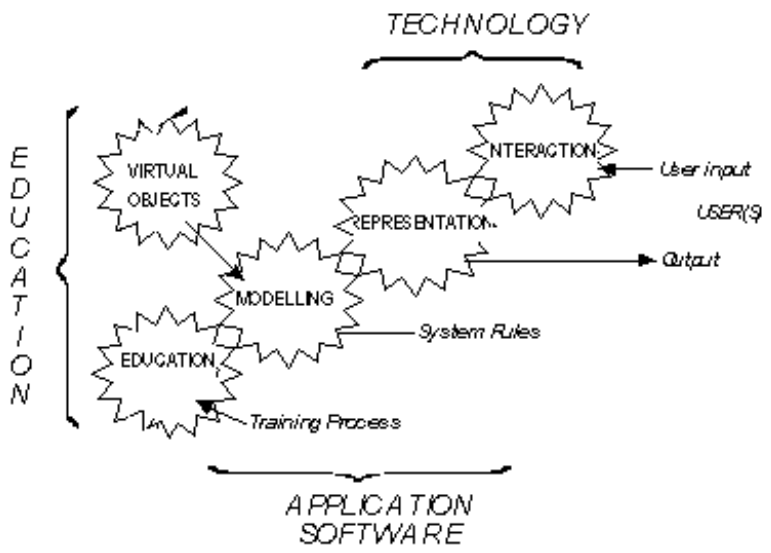
Group Discussions

Roy Kalawsky reported back on the discussions of the group.

What is technology? - it is functionality, not just hardware.

The technology:

- provides host to maintain virtual environment
- provides interface between user and virtual environment
- because of the above points it impacts on user acceptability
- what performance is acceptable? - VR has to deliver better and faster and enhance current applications
- application is key performance driver



With this definition, the group asked other groups to consider the following issues as these decide what technology they need:

- Where would you use 3D virtual environments?
  - visualization
  - interaction
- What are the performance expectations / requirements?
- Knowledge giving - is there a need for enhanced interaction in teaching?
- Skill Training (interaction becomes more important)
- How much are you prepared to pay per seat?
- Databases are an/the expensive component of system (in terms of cost, IPR, creation, maintenance and storage)

Many of the systems at the moment are selling on the basis on photorealism. This is OK for games and walkthroughs but may not be what is required in education. There may be better ways to use the technology depending on the point to be made. We need to focus on the use of real models.

The application defines the technology requirements.

There is a need for standards, but this is difficult as things are changing. The need is for open standards that can evolve.

The group looked at the way technology might emerge and the results are shown below:

Head Mounted Display Single User	300*300 system (50K)	680*480 system (100K)		1024*768 system (70-80K)
Panoramic Single User	Monoscopic (10K) 1280*1024 head tracked	stereo (15K) 1280*1024 (35K)		prices down to less than 10K
Panoramic Systems Multiple Users	Monoscopic (20K) 1280*1024 (20K) + software	stereo (30-40K) 1280*1024 (35K) + software	stereo (25K) 1280*1024 (20K) + software	prices down to less than 20K
	1996	**1997**	**1998**	**1999**

Notes on this table:

- we note price increase in 1996/7 due to move from monoscopic to stereoscopic
- move to single user panoramic systems may be lower cost because Universities may already have suitable projection equipment

In discussion the following points emerged:

- hard to equip labs at these prices
- need to aim for less than £1000 system for teaching use
- costs need to be compared with equipping real labs

Recommendations

Following further discussion within the group, the following recommendations were made:

1. Model database - we need to encourage Research Councils to get centrally stored model databases
2. Demonstration of educational value in a key area - benefit must be obvious
3. Technology roadmap study results to be widely available (SIMA project)
4. Usability research is needed (independent of suppliers) which addresses performance requirements, health and safety aspects
5. Hardware-independent, reusable software (high level) is needed - encourage a standard

GROUP REPORT: EDUCATION ISSUES

Introduction to the Group Work

Current developments in virtual environment technologies and broadband communications are likely to have a major influence on the direction and development of future educational activities. The exact role of these technologies and the degree to which they supplant or support current teaching practises is yet to be determined. As educationalists and developers, how do we manage the transition to employing these new mediums and integrate them into the educational process, how we organise training, package development, widespread access, funding and implementation present a plethora of new challenges.

The aim of the 'Changing Education' group is to identify the issues facing institutions in the best practise adoption of these emerging technologies and establishing guidelines on how to implement and fund the process of adoption. It is hoped that the short (1-3 years), medium(3-5 years) and long term (5-10 years) issues and implications can be identified, along with strategies for aiding the development of these technologies as effective educational mediums.

The group will seek to identify the changing relationship of the education delivery process and emerging broadband & virtual environment technologies. It will seek to identify the changes and trends these technologies offer and their role in the education process. Anticipated issues for the session include:

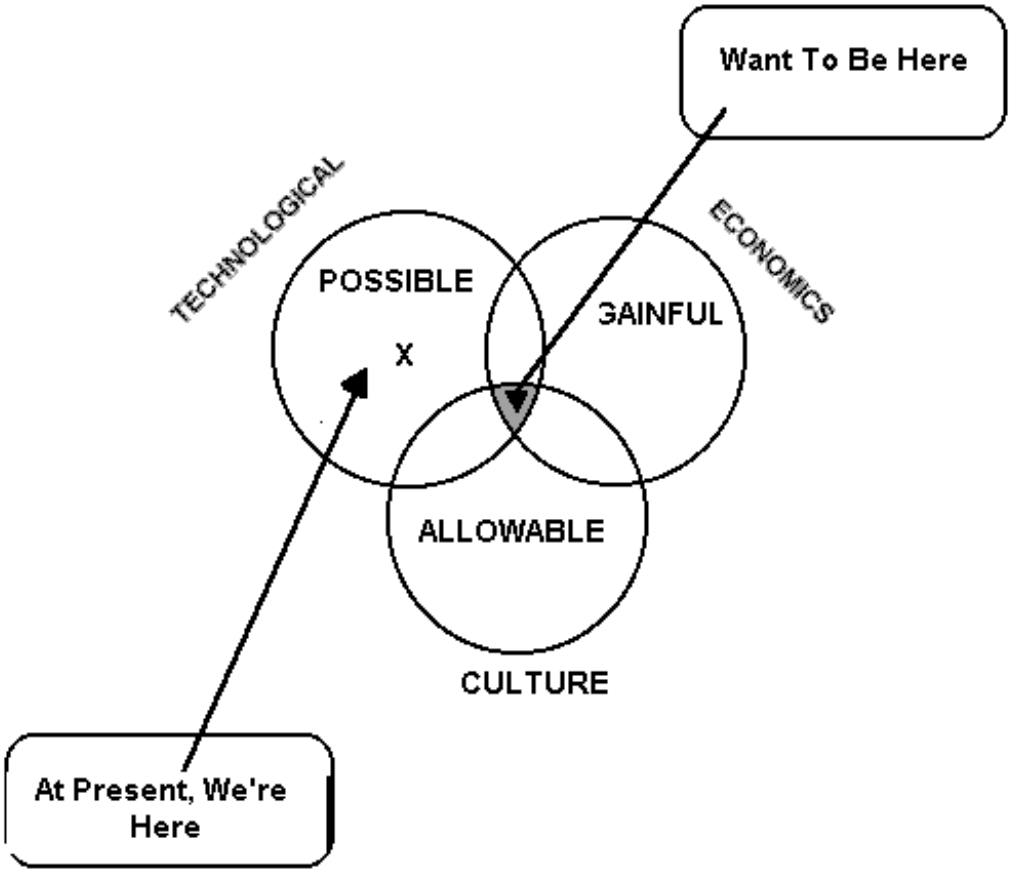
- the increasing presence and changing role of telecommunications organisations & broadband communications in the education sphere.
- the benefits and problems of employing virtual environments for education.
- the problems of funding the development of cultural (teaching tools, learning materials, training, curricula) and physical implementation (locations - central / distributed resources, informed choice of platforms etc.)
- current educational and technological trends / practises and how these may effect the uptake of virtual environment technologies.

Phillip Trotter. National Centre for Virtual Environments, Salford , UK.

Group Discussions

Phillip Trotter reported back on the discussions of the group.

If VR is to be useful in UK HE, it needs to be possible (technological aspects), gainful (economics) and allowable (cultural). Currently it is possible.



In the short term how do we develop and establish pathways towards the appropriate and effective use of VR?

To remove some of the barriers to use we need to have:

- proof of concept through demonstrations and case studies etc to prove that it works (examples of successes and failures)
- information provision on the state of the art and cost effective systems and solutions that are scalable, supportable and robust for educational use
- training and support for service staff on the skills and techniques required to assess the potential of virtual environments and advice on when it might be viable to introduce such systems in teaching
- advice is needed on the skills to be taught to undergraduates on course about VR - need a forum for sharing experience
- more understanding and advice on legal issues - copyright, IPR etc
- addressed the payment for online information issues - accepted as being a more general problem

Recommendations

Following further discussion within the group, the following recommendations were made:

1. A review of hardware and software in an educational context should be conducted with any resulting software agreements being linked with training materials

2. A substantive review of the field should be carried out to include:

- case studies of current examples of VR in education
- scope of potential curricula for VE courses including components of existing courses, e.g. architecture, multimedia, etc.. and potential for experience gained from non-traditional education background
- review of industrial employment of VR/VE technologies
- review of international activity of VE for education
- review of related technologies, e.g. multimedia, games industries

3. The group supported the JTAP concept of a focused club and believe this can be utilised as a dissemination mechanism.

4. There is a need to set up "proof of concept" demonstrators, so the H.E. community can learn from experience. Proof of concept should include

- educational value
- scalable, supportable, stable
- examination of potential standards
- build on existing cases
- deployment
- usability

Discussion Points

The production of games is very labour intensive, so there may be few lessons to be learned there - much bigger market.

We need to look at Netskills as a possible method/model of educating the community as the need for skills training emerges.

VR is relevant to eLib and publishing.

GROUP REPORT: SOFTWARE

Introduction to the Group Work

The emerging use of VR systems in a number of application domains is supported by the falling costs associated with the required VR peripherals and high performance interactive graphics platforms. However, the penetration of VR systems is hampered by the time consuming process of constructing interactive synthetic worlds. This activity can be supported by the provision of effective software tools to aid the construction of these worlds and a number of commercial VR toolkits currently exist on the market. The presently available software tools differ in the functionality they offer, the degree of programming competence required etc. The findings of an initial study to compare different VR toolkits will be presented at the workshop. Many attributes of existing VR toolkits exist in an attempt to overcome some of the performance limitations of currently available hardware. However, as a catalyst to this group's initial discussions I would like to focus attention on not what is currently available but rather on what is required. To this end I propose the hypothetical 'Ideal VR' software system which when run on the 'Ideal VR' platform gives rise to the following:

Performance

- zero lags - infinite update speed, independent of synthetic world complexity
- absolute accuracy on spatial positioning, collision detection and timings

Input/Output

- multimodal display supported, i.e. visual, auditory, haptic
- full range of input/output peripherals supported
- easy integration of custom made peripherals

Import/Export

- allows the importation (without loss of information) of data files from all required sources
- allows data files to be exported in required format for use in other applications
- information available on user performance etc

Synthetic worlds supported

- can simulate all manner of physical properties and interactions, the modelling of natural phenomena etc
- synthetic worlds may be populated with autonomous agents
- multi-user systems supported resulting in shared experiences

Synthetic world creation

- synthetic worlds may be created without he need for programming skills.
- non-immersive synthetic world creation, viewing and exercising supported
- users may create synthetic worlds whilst immersed within the VR system

User interaction

- body-centric and indirect interaction paradigms supported

Portability

- allows the porting of the synthetic world to any platform
- software allows automatic reconfiguration dependent on detected hardware and peripherals encountered

Cost

- the toolkit should be affordable

The above system would certainly allow the creation of compelling synthetic worlds, but would it fulfil all our pedagogic requirements? Furthermore, what are the implications of relaxing the above attributes and what impact will this have on resulting systems, their utility in higher education, etc. I would like to take the opportunity of the forthcoming workshop to address these issues, assess trade-offs and focus on future developments which may include issues associated with:

- data management
- file conversion filters
- costs
- educational requirements
- support of standards
- synthetic world generation and sharing

Nick Avis, University of Hull

Group Discussions

Terry Hewitt reported back on the discussions of the group. He started by noting the need for the community to manage change as we take on areas of new technology. There is a need for:

- a common software base - with a minimum specification - need to define what tools are needed and what are available
- a set of object databases with associated utilities which would operate at a higher level than many of the current systems so
- that users can deal with objects, e.g. chair - concerns re portability - would need to be distributed - would need to include
- different representations, e.g. geometry, sound, video. We would need to be able to find objects and have suitable searching
- tools
- authoring tools which suit a wide range of applications, for example it was felt that while there are many tools suitable for
- engineering use, there is little or nothing ideally suited to the authoring and design of architectural models. Distributed
- search tools should be available from within the authoring tool.
- a substantive set of non trivial case studies should be undertaken, and made freely available to promote and demonstrate
- the usefulness of VR.
- it was felt that there was a definite lack of infrastructure for VR in the UK, and also a lack of awareness of what is available. There is a need to increase awareness of UKVRSIG and VR club.
- it was felt that there is often an overselling of immersive VR for inappropriate uses.

Recommendations

Following further discussion within the group, the following recommendations were made.

These first six recommendations reflect a need for a common software base.

1. Produce guidelines / recommendations on what software might form a common kernel for VR applications (this should be based on the AGOCG funded work being carried out by Nick Avis)

2. Should this software be commercially available, we need to encourage a CHEST agreement

3. Should this require major software developments, encourage Research Council, etc to fund it.

4. Recognising widespread use of DVS and SuperScape and that they are produced by UK companies, encourage a CHEST agreement (no upfront money) with the target price being less than £1000 for a research group purchase

5. Promote efforts to standardise (ISO and de facto) - in particular VRML and PREMO and its VR component

6. Provide guidelines for integrating existing components, e.g. Multimedia, Visualization, animation with VR systems

There is a need for consideration of authoring tools:

7. Develop a number of substantive application case studies that are freely available (architecture, visualization, CSCW, sound, MultiMedia)

8. Report on availability / requirements of "authoring" tools

We need to consider modelling and model databases as well:

9. Commission a report of tools for creating, modifying, interchanging (large) geometric (and audio and video) models (hierarchies, LoD). This should focus on:

- what tools are currently available (are any of catia, hdf, dvs suitable)
- the need for both visually attractive and geometrically accurate modelling
- the need for a model to hold different representations of objects to be used depending on the use of the model (i.e different representations for a visual walk around from those used for an acoustic modelling.

We also need to consider recommendations regarding infrastructure

10. There should be better promotion through the existing channels (agocg, web, midas, ukvrsig, essex etc etc) of:

- model interchange
- model format conversion tools
- products and services

We need to raise awareness through seminars and workshops and to promote use of the products selected by any evaluation. If needed training materials should be made available for the selected products.

A research/discussion forum needs to be set up to work towards common software (something like GNUVRxxxx) with subsequent dissemination of reports produced.

The group suggested a timetable for the recommendations made:

Short term:

- CHEST deals (recommendation 4)
- Identify gaps (recommendations 1, 6, 7, 8, 9)
- Infrastructure (recommendation 10)

Medium term:

- Filling gaps -> EPSRC (recommendation 3)
- Fillings gaps -> other (recommendations 2, 10)

Long term:

- Integration and interoperability with existing (non VR) systems (recommendations 5, 6, 10)

PARTICIPANTS AT THE WORKSHOP

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