Virtual Environments for Special Needs

Changing the VR Paradigm

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Abstract: The normal application of Virtual Reality is to the simulation of environments, which are in some way special - remote, hazardous or purely imaginary. This paper describes research and development work which changes the paradigm by simulating perfectly ordinary buildings for special people. Some 15% of the population have some form of physical impairment - a proportion which is likely to rise in line with an ageing population. New legislation, such as the UK Disability Discrimination Act places additional responsibility on building owners to ensure adequate access for people with an impairment and this in turn will place additional responsibility on the architect. Current methods of auditing access for new building are primitive and require the auditor to interpret plans/sections of the proposed building against a checklist of requirements specific to the special need. This paper reports on progress in the use of an immersive VR facility to simulate access to buildings for two broad classes of user: i) those with a mobility impairment; ii) those with visual impairment.

In the former case, a wheelchair motion platform has been designed which allows the wheelchair user to navigate the virtual building; a brake and motor connected to the rollers on which the wheelchair sits facilitate the effects of slope and surface resistance. In the latter case, the main categories and degrees of visual impairment can be simulated allowing architects to assess the contribution of form, colour and signage to safe access.

1. WHY VIRTUAL REALITY

There are many situations where it is more convenient, less costly, or indeed necessary to simulate our experience of three dimensional space rather than to experience, directly, its physical reality. The inaccessibility of the real world may be as a result of its remoteness, its hazardous character or because it no longer exists, does not yet exist or indeed, never will exist:

1. remote environments:
   lunar homesteads, polar outstations, orbiting space stations and off shore oil drilling platforms are examples of spatial environments which are significantly remote; it is certain that convenience and economy can be served by providing an accessible simulation of the environment.
2. hazardous environments:
   environments contaminated by radioactivity, threatened by fire, structurally unstable or biologically inhospitable are either dangerous or expensive to make safe; economy and safety are promoted by appropriate simulation.
3. non-existent environments:
   these fall into three categories:
   - those environments which never will exist, e.g. the science fiction images of Hollywood movies.
   - those environments of architectural or historical interest which once existed but, due to the ravages of time are under threat or no longer exist, and
   - the hypothesised environments of architects and planners which it is intended, ultimately, to bring into existence.

An interesting example of the application of virtual reality to an environment which is remote, somewhat hazardous and partially non-existent in the Neolithic village of Skara Brae. Around 100 years ago on the coast of the Orkney Islands far off the north coast of Scotland, a severe storm uncovered part of a village believed to date from 2500 BC. It comprised a network of passageways and seven houses, complete with stone furniture, utensils and jewellery. Using digital video and Quick Time Virtual Reality, the Architecture and Building Aids Computer Unit, Strathclyde (ABACUS) created a virtual experience of part of the site (Figure 1), repopulating the houses with virtual representations of the artefacts and making conjectures regarding what was incomplete, e.g. the door opening/closing mechanism (Figure 2).

Quite clearly the benefits of such a virtual experience are widely available to the community. The benefits are particularly valuable to that proportion of the community who, by dint of physical impairment, would find that much more difficulty in experiencing the physical reality.

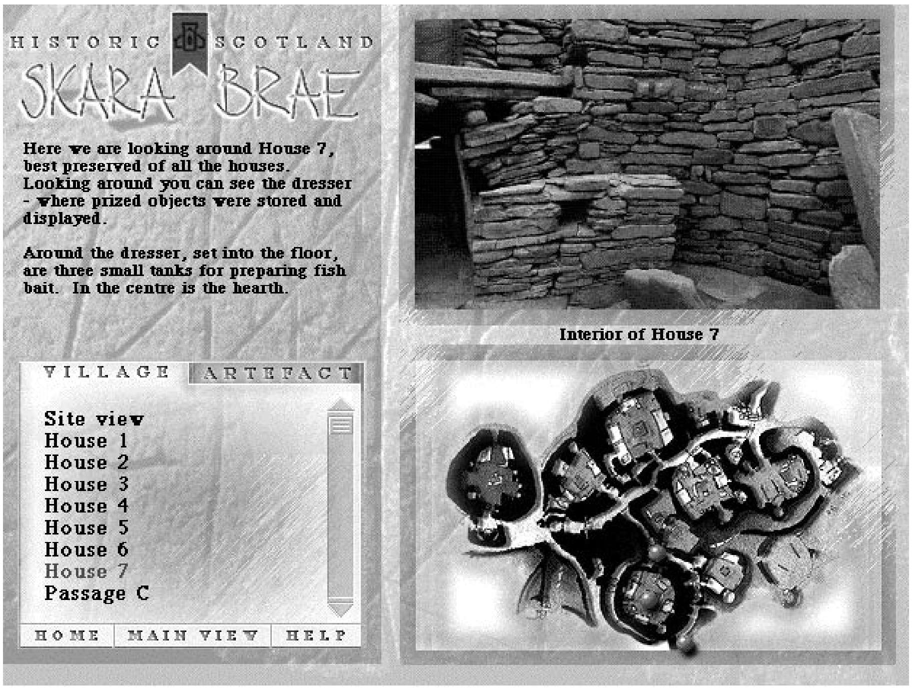

Figure 1. Home page of the Skara Brae Multimedia CD-Rom

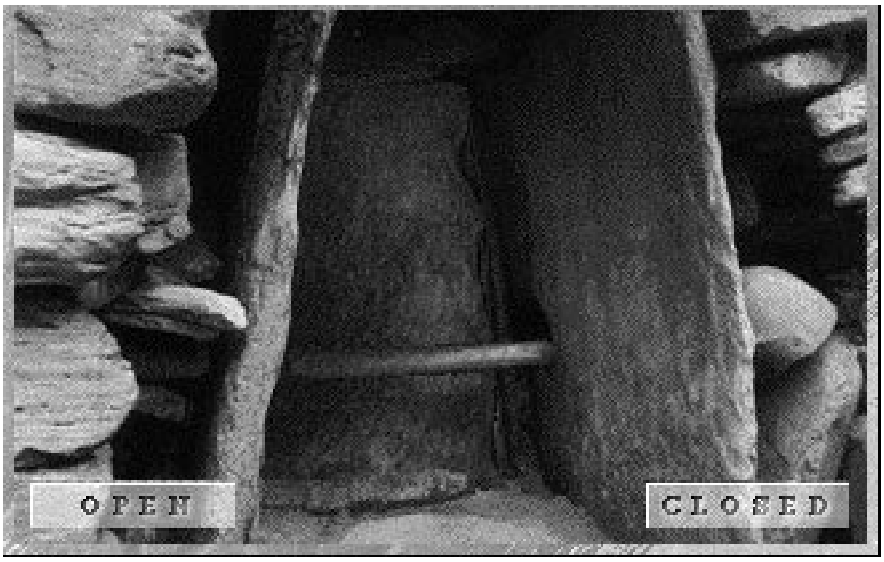

Figure 2. Interactive simulation of door-opening hypothesis

This paper is not, however, about the use of new technologies to facilitate virtual experiences of the built environment as it exists; much more importantly it is about the use of virtual reality of **change** existing and future built environments to enhance the experience of the real world for those with physical impairment.

2. SPECIAL NEEDS

Some 15% of the population have some form of physical impairment - a proportion which is likely to rise in line with an ageing population. New legislation, such as the UK Disability Discrimination Act places additional responsibility on building owners to ensure adequate access for people with an impairment and this in turn will place additional responsibility on the architect. Current methods of auditing access for new building are primitive and require the auditor to interpret plans/sections of the proposed building against a checklist of requirements specific to the special need. This paper reports on progress in the use of an immersive VR facility to simulate access to buildings for two broad classes of user:

a) those with a mobility impairment (approximately 3.5% of the population)
b) those with a visual impairment (approximately 6% of the population)

3. VIRTUAL ENVIRONMENT LABORATORY

ABACUS, in the Department of Architecture and Building Science at the University of Strathclyde is heavily involved in the use of virtual reality for a range of applications relating to the built environment and has a major facility, unique in Scotland, called the Virtual Environment Laboratory.

The virtual environment is visualised using a three-projector system that provides a 150-degree by 40-degree high resolution image mapped onto a five metre diameter cylindrical screen. Each of the three image channels is edge-blended to provide a seamless display. When viewed from any of the 14 seats in the Lab, the composite image fills the viewers' field of vision, providing a highly convincing sense of immersion within the scene.

The graphics images are generated on a 12-processor Silicon Graphics ONYX ll which is capable of processing detailed architectural models at high frame rates in order to provide realistic real-time animations. At each time-step in the simulation the graphics are rendered to three separate output channels, each channel sharing the same eye-point but with a different angular off-set in azimuth, corresponding to the off-sets in the projection system. This circumvents the geometric distortion inherent in large field-of-view displays (Figure 4)

4. SIMULATION OF WHEELCHAIR ACCESS

ABACUS and the Strathclyde Bioengineering Unit are currently engaged on a research project funded by the Engineering and Physical Science Research Council to develop a virtual reality facility that can be used to generate, via an interaction between architects, designers and wheel chair users, guidelines which address the issue of wheelchair access to, and within, the built environment. The project aims to design and build a wheelchair motion platform through which wheelchair users can explore virtual representations of buildings. It is envisaged that such a facility would form a powerful and cost effective means of evaluating wheelchair access provision early in the design of new buildings and in the redevelopment of existing buildings. Accordingly the following preliminary objectives need to be met:

- The design and construction of a manual wheelchair motion platform that can accurately monitor intended wheelchair motion and can provide physical and optical feedback to the wheelchair user on the presence of virtual obstacles or changes in floor coverings or slope.
- Interface the platform with the Virtual Environment Laboratory facility to provide an immersive virtual environment within which navigation is linked to the intended wheelchair motion.
- Generate virtual representations of a range of building types in order to test and calibrate the performance of the platform and perform an evaluation of the system by wheelchair users.

The relationship of the wheelchair motion platform to the display system of the Virtual Environment Laboratory is shown in Figure 4.

The motion simulator and the graphics software are a close-coupled system. The motion simulator communicates with the control system is via a shared memory segment. The task of the motion simulator is to accept incoming data from the control system. This data relates to the individual incremental angular displacement of both wheels on the motion platform. This data is compared to the previous increment, to determine whether the wheel is rotated forward or backward, and to pass this information to the next stage of the algorithm. The basis of the motion control algorithm is the determination, through an analysis of similar triangles, of the location of the centre of rotation along the rear axle of the virtual wheelchair and the angle

Figure 3. The Virtual Environment Laboratory at Strathclyde University

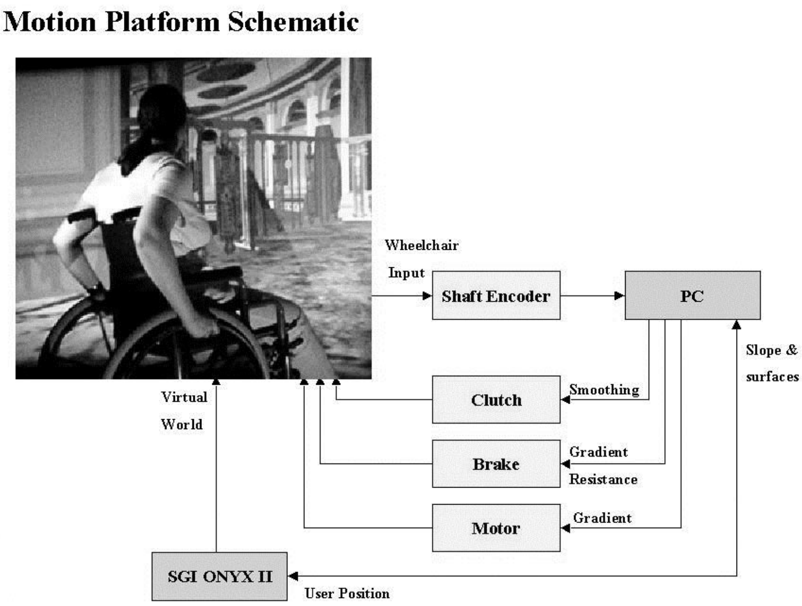

Figure 4.

through which is turned. From this the transformation of the eye point and rotation of the view vector can be determined.

The graphics application requires the Cartesian co-ordinates of the eye point, plus the yaw, pitch and roll angles of the direction of view. Given the yaw angle the remaining two parameters can be calculated based on the wheelchairs attitude on the floor plane. In the database traversal three rays corresponding to the contact patch of each of the rear wheels and the midpoint of the front axle, are intersected with the floor. The normal vector of the ground plane at these points can then be used to calculate the roll and pitch of the chair and the corresponding view. The same intersection procedure can also be used to identify the surface under each wheel, this information can then be used to index material properties, such as rolling resistance, which can be passed back to the control system.

The roller system is housed within a framework that supports the wheelchair and occupant, and converts wheel motion into an instrumented rotation of the main shaft. The system is duplicated for each wheel of the wheelchair. Mounted on each shaft are the brake, clutch, encoder, inertial mass and the take off for the motor drive.

The control system is based on a standard PC with purpose written software, that interfaces with the image generator. The control system feeds the motion engine of the image generator with incremental readings from the rotary encoders on the motion platform whilst controlling the feedback stimuli to the wheelchair on the basis of data received from the simulation in order to effect changes in floor conditions or collisions.

Each of the above elements forms a linked system that is controlled by the bidirectional flow of information from the wheelchair to the virtual environment, and from the virtual environment to the wheelchair. The feedback loop is by the users visual perception of progress through the virtual environment and by the perceived proprioceptive changes associated with alterations in the rolling resistance of the wheelchair. By closing the feedback loop with a human rather than a further pair of sensor connections, it is expected that any minimal latency or hysteresis in the rest of the communications path will be compensated for by the user. By April 2001 the wheelchair motion platform will be fully operational.

5. SIMULATION OF VISUAL IMPAIRMENT

It is currently extremely difficult to determine all the problems which someone with a categorisable visual impairment such as macular degeneration or glaucoma will experience when negotiating an ever-changing built environment. The current methods of assessing these difficulties involve simulating the main categories of eye problems using either 2D fixed simulations (via modified slide transparencies) or adapted spectacles. Extended discussions with personnel from the Royal National Institute for the Blind and the Joint Mobility Unit – some of which took place following demonstrations within the Virtual Environment Laboratory– established that the current methods of simulating categories and degrees of visual impairment by using two-dimensional static simulations (in the form of modified slides or by the use of modified spectacles) are extremely limited. The slides cannot simulate dynamic movement through a space and neither slides nor spectacles offer a mechanism to appropriately simulate future, proposed environments.

There are five main causes of visual impairment: age related macular degeneration (48% of registrations); glaucoma (12%); retinopathy (3.4%); cataracts (3%); and retinitis pigmentosa (2%). Individually, or in combination, these eye conditions can affect perception of the visual field, visual acuity, stereopsis, dark adaptation and/ or colour vision. With the exception of stereopsis, the equipment in the VEL can support manipulation of these facets of the visual field through the virtual image. The project will focus on mapping these deficiencies, with the aim of establishing a methodology which can subsequently be applied to correlating forms of visual impairment and accessibility to spatial configuration.

The short-term objectives of the project are three-fold:

- To establish proof of concept and develop the means to model correlations between a range of dysfunctionalities caused by visual dysfunction and the actual effect this has on visual function when applied to accessing virtual and actual versions of the same environment.
- To establish whether the virtual reality environment can represent a real built environment, such that the experience of it maps sufficiently faithfully onto the experience of negotiating a real environment and can hence be correlated with actual forms of visual impairment.
- To identify and be able to virtually-represent the design features which need to be taken into account when designing an environment that optimises the variable abilities of visually-impaired people negotiating the built environment comfortably and safely.

By comparing the visual ability of respondents with and without various individual and combined visual impairments, also by undertaking these comparisons for both actual and simulated versions of the same route, it will be possible to establish whether the effect on realism and representation of visual impairment is greater than the effect of simulating buildings in the Virtual Environment Laboratory (VEL). This is an important issue for the simulation field, since if the simulation effect swamps participants visual ability then it will raise real questions about effectively simulating visual impairment. If the effect is less, then this will confirm the scope to use virtual environments for developing access audits and other wayfinding analyses for the visually impaired.

6. IN CONCLUSION

The issues presented in this paper represent a shift in the paradigm away from the use of VR to simulate *special* buildings for *ordinary* people to the use of VR to simulate *ordinary* building for building for *special* people in the expectation that we can improve the design of existing and future buildings in order to enhance the experience of the built environment for that section of the user community with special needs.

The research and development required, however, is intellectually demanding and expensive; the authors are in no doubt, however, that appropriate investment in effort and resources will yield an outcome of great significance.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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