Towards a natural and appropriate Architectural Virtual Reality: the nAVRgate project

Past, present, future.

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Abstract: The lure of virtual environments is strong and the apparent potential is enticing. But questions of how Human Computer Interaction (HCI) issues should be handled and married with best practice in Human-Human Interaction (HHI) remains largely unresolved. How should architectural images and ideas be most appropriately represented, and how should designers interact and react through this computer mediated medium? Whilst there is never likely to be unanimity in answer to such questions, we can develop new ideas and new systems, test them, report on them and invite comment.

The nature and novelty of virtual environments is such that refinements and innovations are likely to come from a variety of sources and in a variety of ways. The work described here explains the evolution and current plans for the development of a particular approach that has been developed and refined by the authors. Low-cost, effective and appropriate are the key words that have driven the developments behind the evolving nAVRgate system that has arisen from this work, and that is described here.

1. THE CONTEXT

The paper reports on the nAVRgate project which is now in its second phase. In the first phase a low-cost, but effective virtual environment system was developed. The software used was computationally efficient, and the physical interface was direct and effective. The keyboard and mouse were replaced by an interaction device that we believed was more familiar and hence more appropriate to navigating through urban environments, the bicycle. In this respect the system has a lineage that can be traced back to the Legible Cities idea suggested by Jeffrey Shaw (1994). The nAVRgate-1 system has been demonstrated and reviewed. Following that review a second stage of development has taken place. The paper here will present a summary of the nAVRgate-1 system, the principal points arising from the review process and a description of the current stage of development, nAVRgate-2.

nAVRgate-2 brings together three strands of refinement. First, new ideas on low-cost, natural and appropriate interaction devices have been developed. Second, ideas on how the shortcomings of the software in nAVRgate-1, without the loss of computational efficiency, might be addressed have been investigated. Thirdly, ideas that have arisen from parallel work in the authors' research group on the nature and differences in perception of architectural images in a computer mediated environment are being drawn in. We aim to show that these ideas can bring positive enhancements to what was already an effective system environment.

The work described here emphasises the Navigation aspect of our Virtual environment. Sometimes navigation is confused with locomotion but, as Darken et. al (1998) note:

> 'Navigation must be seen as a process. We often make the mistake of seeing it as its end result – locomotion- navigation's most visible attribute. However, the cognitive subtasks that drive locomotion…are an integral part of the overall task'

Inextricably linked with the idea of navigation is the mental representation, the cognitive map, of our understanding of the environment. In other disciplines concerns over the visual representations of information in virtual environments raises new issues. But in architecture there is a legacy of visual representation in the real world that we need to examine and take account of in designing new virtual environments. Maher et. al. (2000) make the point:

> 'Although architectural design is noted for the forms and places created, the semantics of these places lies also in their function. The functional aspects of physical architecture can influence the design of virtual worlds'

Contemporary thoughts on how we represent ideas and the world around us can be found to be linked to contemporary technological developments. It is not simply a matter of coincidence that Freud's theories on dreams coincided with the birth of the technology that gave us films and cinema in the last century. That was a case of new technology inspiring creative thought and a broader understanding of an issue. This century begins with the technology and philosophy that relate to Virtual Environments in their relative infancy. The work described in this paper is aimed at helping to move the associated debate along.

2. The nAVRgate project

As we mention above, our initial intention in the nAVRgate project (AVR being a sub-acronym for Architectural Virtual Reality) was to develop a low cost Virtual Environment where navigation was driven through natural locomotion. An initial desire was to open up the possibility of experiencing large scale urban environments to an audience; that is with a large display area and wide angle of view. We have reappraised some key research in this area and are now in the process of expanding the interface toolkit.

There are two interesting projects that gave some early inspiration and direction: the "Legible City" (Shaw, 1990) and "Osmose" (Davies, 1996) projects. Both developed a body-driven navigation interface for the particular non-realistic environments (a text analogised city in the case of Shaw and a surrealistic environment for Davies). In the case of the Legible City, the interface was an exercise bike and for Osmose, a scuba diving metaphor was used. In both cases, users could almost immediately concentrate on experiencing the VE rather than learning the navigation method, that is the interface very quickly became transparent to them.

Just as importantly, the sense of presence and connection with the VE was very strong. (Davies, 1998). The aim of the nAVRgate project is the same rapid transparency and sense of presence. In this sense the work of others such as Regenbrecht et.al. (2000) also aims to move the developments in this area in a direction that will produce more effective and appropriate systems for navigation and interaction.

It is, though, easy to fall into the trap of assuming that natural locomotion is best most appropriate for virtual environments. Thus far we have found it to be very effective, but are aware of the fact that assuming ‘natural’ is best may imply “questionable assumptions concerning distance and direction estimation and manoeuvrability” (Darken et.al. 1998).

In addition there are several pieces of work that show that spatial skills are not completely innate, and such findings have particular consequences when we consider designing virtual environments of architecture and for architects; which are not necessarily the same thing. We take up this issue, and the issue above later.

3. nAVRgate-1

It is clear that the method of interaction is a central part in the users immersive experience in a VE. Both the Legible City (Shaw, 1990) and Osmose (Davies, 1996) used a consciously non-realistic environment through which the experience was heightened by the use of a familiar real world navigational metaphor. The importance of retaining a sense of orientation in a VE has been noted (Bridges and Charitos, 1997). Furthermore, the problems of scaling and scalelessness in the locomotion through, and perception of, the virtual space require attention in developing such environments. It has been shown that proprioceptive information aids the human agent in relating motions of the body to movements in space. Loomis et. al. (1992) have shown that distance and direction estimation in virtual space were improved by the introduction of proprioceptive feed-back.

An aim of the nAVRgate project is the development of a generic navigational metaphor, that incorporate a variety of natural locomotion methods. We initially developed an architectural VE using a commercially available gaming engine and, initially, revisited the use of a bike for navigation.

nAVRgate-1 was ruthlessly pragmatic. An exercise bike (Knight and Brown, 1999) has been modified to give the basis of the system using a radically modified serial mouse. Left and right movement of the handlebars is translated into movement in the X axis, pedalling into the Y axis. Whilst this has overcome some of the problems some other researchers have found, such as the optical speed tracking of the wheel, it has raised others in the inflexibility of the scaling parameters of the standard mouse drivers. A purpose written driver would overcome this. The use of standard, modified components allows us to apply the system to other types of natural systems of locomotion such as walking (Slater et al, 1995) and using a wheelchair.

Back projection is used as opposed to a Head Mounted Display (HMD) for two reasons, firstly cost, but secondly, and more importantly, that it enabled group participation in the experience.

The software used was a standard games engine, Half-Life. Models were composed in a shareware level editor, WorldCraft and, whilst this was very effective for the task in hand, the limitation of the software soon became evident. As it is not possible to import CAD data directly into WorldCraft, models had to be (re)created from scratch. A further limitation was that, in common with other games of the time, it was not possible to model curved elements which resulted in either purely orthogonal models or crude misrepresentations. It was evident that a different piece of software would have to be used for the next stage.

User feedback has been very positive. The experience of using the bike has allowed us to learn a great deal about natural navigation metaphors. While users adapt very quickly to unnatural and in some cases slightly surreal situations (for instance, the remarkably entertaining experience of riding a bike down stairs to the sound of foot steps), a more natural locomotion and interaction device is still the goal. With the use in large scale urban environments in mind, nAVRgate-2 is a progression which will continue to use the exercise bike for distance (analogous with cycling between buildings), changing to foot travel using a treadmill or similar (analogous with walking around a building). However, rather than using buttons on the handlebars to change the view up or down, use of the body's natural movements is proposed.

Figure 1. nAVRgate-1 bike in use

4. nAVRgate-2

When we experience a piece of architecture in reality, we look around using head movements. Whilst this is used in commercial products such as the 'Flock of Birds' motion tracking system which uses a signal source and a series of transponders to determine position, it does not fit well with our low cost aim. We aim to use the body's natural resources to provide the signals necessary for navigation.

The human head has three axes of movement, up/down (flexion and extension), left/right (rotation) and tilt. The muscles involved in the two that we are particularly interested in, (flexion/extension for the Y-axis and tilt for the X-axis) are both large and near to the surface of the body. The sternocleidomastoid is present on each side of the neck; movement of the head to the left involves the right side muscle and visa versa. The trapezius muscle at the rear of the neck determines tilt. Muscles rarely work in isolation. For example, if both sternocleidomastoid muscles contract together, the head would tilt to the front, in this case the trapezoid muscle would be inactive. It is possible, through a series of logical conditions, by processing the combinations of electrical signals received, to determine the head movements.

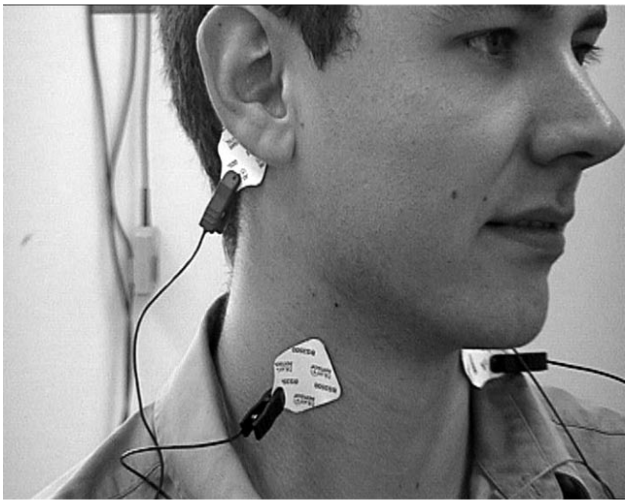

Figure 2. sensors in place

Whenever a muscle is activated a small electrical charge is generated, the size of which is dependent on the type of muscle movement. Muscles that control the head are in a state of constant activation to maintain posture. Movement of individual muscle fibres is evidenced by a small level of electrical activity, whereas in a large muscle movement involving all the muscle fibres, a much higher level of electrical activity is generated. This activity can be detected using surface fixed EMG (electromyography) sensors (Figure 2) similar to those used in detecting other bodily activity such as ECG heart monitoring. These are used as indicators of head movement. Once the threshold level has been determined, any deviation from this will be evidence of movement. For example, a movement of the head to the left would be indicated by a change in the signal strength of the right sternocleidomastoid muscle (Figure 3). In the extract of the signal trace shown, both side of the neck show signal activity during the initial stages of movement due to changes in posture, but once in motion, the left side shows only threshold level of activity.

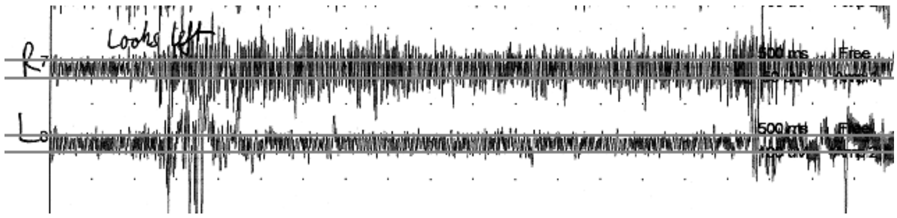

Figure 3. signal trace, head looking left

To date, we have established the feasibility of using the signals for detecting appropriate movement. The next stage will be the construction of a high-quality signal amplifier, interfaced to the system through an analogue to digital converter and processed to provide the necessary information to the locomotion governer.

The table below shows the muscle movements with the corresponding axial movements

Table 1. Logic matrix: muscle activation to head movement

		Sternocleidomastoid Left Side	Sternocleidomastoid Right Side	Trapezoid
-X	Left	-	**X**	**O**
+X	Right	**X**	-	**O**
+Y	Up	-	-	**X**
-Y	Down	**X**	**X**	-

Key: X *above signal threshold*
O *below signal threshold*
- *static (no signal)*

As presented so far this technique sounds promising, but there are several problems with this approach. As with the rest of the body, muscles are several layers deep and there will be conflicting signals as each is triggered. Coupled with this is the variation in signal strength that varies slightly according to the size, age and build of the user. The software used to interprets the signals must be capable of being easily calibrated to compensate for this. A potential problem will arise when using a projected screen as the centre of gaze would shift with head movement, whereas the projected image centre would remain static, problems which we do not see as insurmountable.

To continue to use the games software for the VE environments, the navigation needs to be compatible with conventional interface drivers. To use head movements, the software is configured to 'mouse follow' which means that the equivalent mouse X and Y movements correspond to the left/right/up/down movements of the view. Forward/backward movement is achieved with the keyboard arrow keys which are mapped to the appropriate interface (see system diagram, figure 4). This means that two axis of movement are required of the head, the X and Y, both positive and negative. A straight-ahead gaze would be 0,0, a look up would be a positive Y, a rotation of the head to the left would be a negative X.

To overcome the limitations of the WorldCraft/Half-Life gaming environment, we are currently experimenting with a games authoring package that will allow the direct import of CAD models in a variety of forms. This will, in turn, allow for a higher quality (and more accurate) VE to be constructed. The software also allows scripted events (sounds and behaviours etc) to assigned to individual objects which created an environment which can respond more readily to user interaction.

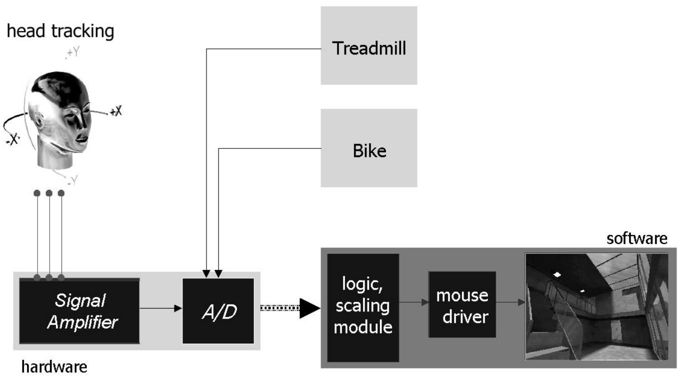

Figure 4. System diagram

5. REPRESENTATION OF ARCHITECTURAL SPACE

Control of locomotion, as a subset of the broader idea of navigation, in the Virtual Environment is one aspect of our work, but as we mentioned, representation is another. This is an area that has particular implications for architecture.

Firstly we need to be aware of the particular spatial skills that aid us in navigation through three dimensional virtual environments such as those used in the nAVRgate system. Evidence shows that there is difference in spatial ability between individuals and genders (McGee, 1979), and this has broad implications. More specifically, research shows that skill in spatial manipulation and understanding can improve with practice and training (Carpenter and Just, 1986). Architecture is a very particular discipline; one where spatial abilities are developed and nurtured. Brown and Ryong (2000) have described and accounted for the particular cognitive skills that are developed throughout and architect's training; and the consequences, in terms of appropriate representations and interfaces are expounded.

Secondly, related to this work, and in particular to consideration of the architectural image Brown and Nahab (1996) have shown that the 'value' and perceived quality of an architectural scene is very dependent on the nature of the representation. Issues such as 'sketchiness', degree of photorealism and colour-monochrome rendering play a fundamental role in determining that perceived quality. In Virtual Environments, as with more conventional static representations, the nature of the rendered image (representation) surely plays a key role in generating an appropriate and successful ambience.

The issues mentioned above play an important part in our current thinking about how the nAVRgate system should be further enhanced. As we said at the outset the issues of VEs for architecture is a multifaceted problem, and appropriate representation is a crucial facet in that problem. As well as moving the interface issues forward, the next stages of the nAVRgate system will also address the nature of the appropriate image. Brown and Nahab addressed the static image, we intend to extend this work to include the images for VEs, particularly of the issues for large scale projection.

6. CONCLUSION

We have shown that it has been possible to implement and develop a low cost VE system for Architectural applications by taking ideas of natural locomotion and coupling that with developments spawned by games technology. The nAVRgate system that has evolved has proven effective and recent enhancements have been described here.

With the higher expectations of users today brought about by the ubiquitous application of computer generated animation, architectural VEs must adapt and be flexible. It is a challenge for the world of architecture to keep pace with, and respond to these expectations. But we should do so from a particular standpoint. Architectural representation in three dimensions has a history that we can learn from and build on. Added to that, architects have particular needs and skills that developments, like the nAVRgate project, can respond to. Bill Mitchell (1995) talked about the idea of clicking "through cyberspace; this is the new architectural promenade". Our aim remains to elaborate on the click and to enrich the promenade.

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