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Abstract

Research undertaken in the Virtual Environment Laboratory (VEL) has covered the ocular effects of Head Mounted Displays (HMD's) on users eyesight; comparison of displays and their immersive abilities; perception and control of motion. A distributed approach has been taken by the laboratory to software development, Virtual Environment (VE) support and hardware integration. Applications include an immersive VR system and a basic driving simulator using projection screen technology.

1.0 Background

The VEL was established within the Department of Psychology in January 1992. Research and equipment are supported by three grants: "Principles for Perception and Action in Virtual Realities" and "Visual Control of Steering", both funded by the JCI(MRC) and "Optic Constraints for Action" funded by SERC. Two full-time researchers and a number of industrial placement students make up the laboratories complement.

2.0 Goals

The main research goal of the VEL is:

> To identify and evaluate the factors affecting perceptual control of movement by humans in both natural and Virtual Environments (VE's).

The premise is that effective Virtual Reality (VR) systems and VE's cannot be built without taking into account the nature of human perception. To that end research undertaken is being directed along the following lines:

- Analysis and support of effective perception and action coupling.
- Identification and assessment of factors affecting immersion in VE's.
- Evaluation of physiological responses to VE's (vision in particular).

3.0 Effective Interaction in VE's

The visual information required to navigate around a VE can be conceptualised in the form of an optic flow field. Navigation may then be expressed as the detection of invariants within the flow field. A natural flow field is rich with information. In contrast, a VE generated one is very sparse. Computational resources being limited, it is expedient to generate only those bits of the flow field which are necessary to support comfortable and effective interaction (Rushton, Wann, 1993).

Providing perceptually important visual information is a non-trivial issue. For example, a VE without texture provides an impoverished flow field. Unfortunately, simply furnishing a VE with finely detailed texture is not sufficient since the fine detail may be lost in a low resolution HMD. Additionally, unnatural VE's such as 'Metaphor Mixer', which allows the visualisation of stocks and shares, may preclude the use of such a textured 'carpet'.

It is proposed that the same information in the optic flow field is used in all tasks of the same nature e.g. Lee's (1976) Tau in the control of braking. To determine how best to support motion perception a series of studies is being undertaken to look at the control of steering and the controlled approach to destination points. Immersive and non-immersive equipment is being utilised, including a simple driving simulator which will be used to examine human performance in VE's representing real-life driving situations.

4.0 What makes a VE Immersive?

Filling the visual field with an optic flow field draws observers into the VE and they tend to become immersed in the perception of self motion. But what makes a VE more convincing than another and what makes a person more VR susceptible than another? We define immersion as the overall sensation of being in a VE. Central to the laboratories approach to immersion is the definition of the sensation's three key elements:

Presence	the feeling/sensation of being in a VE
Absorption	how involved the user is in interacting with the VE
Openness	suspension of disbelief required to overcome inadequate VE representation and display

The importance of these 3 factors has been investigated in addition to what effect a persons self-imagery, the display medium and interactive control over the environment has on the immersive experience (Rushton, Taylor, 1993).

Results showed that absorption positively correlates with immersion as does openness. Vivid self-imagery correlates negatively with immersion and driving or being driven through the VE had little effect on how immersed the participant felt. What was surprising was the relative effectiveness of the displays in supporting immersion. The projection screen was foremost, the monitor second and the HMD last. This may be explained away by recognising that the HMD is cumbersome and provides a poor visual display. Continuing this work will hopefully permit the empirical charting of the physical and physiological factors affecting the feeling of immersion.

5.0 Physiological Concerns Regarding HMD's

This research was based on the hypothesis that the visual systems responses to VR displays are not natural and as such may induce visual stress. A HMD uses two 2-D displays positioned to allow binocular overlap and hence permit binocular fusion. This fused image will then enable the user to perceive the VE in stereoscopic depth. However, this requires unnatural ocular-motor responses, namely the separation of convergence and accommodation. HMD screen images may only be seen in focus by accommodating to a fixed distance. Looking at different objects in a VE, e.g. at distances < 50cm and > 2m, requires differing degrees of ocular convergence which in the natural world would be accompanied by a change of accommodation (focus). A convergence driven change in accommodation is inhibited with a HMD since changing accommodation would bring the HMD displays out of focus. Additionally some of the characteristics of the component lenses, filters and displays (e.g. poor contrast and illumination) have been found by previous researchers to be induce visual stress (Pickwell et al, 1987).

A recent experiment involving a 10 minute exposure to a VE produced alarming results (each participant's visual status was evaluated before and after immersion). After exposure 14 participants reported blurred vision, 3 participants frontal headaches, one of these also momentary diplopia. Three felt nausea, one of these sore eyes, another tired eyes and another motion sickness. Five minutes later these symptoms had disappeared with the exception of two who had a headache until evening. For a complete and comprehensive summary of findings see Mon-Williams et al (in press).

6.0 Virtual Environment Systems Support

The laboratory is equipped with a varied range of input/output devices including 6D trackers, a VPL Eyephone LX, Spaceball and a BARCO 800 projector. All the research requires the real-time generation of texture images.

To that end the laboratory is equipped with two Reality3 PC cards (and an older Super Reality II VME-based system) from Real World Simulation, Hertford, UK. This Computer Image Generator (CIG) may be configured for use with monoscopic or stereoscopic displays. Hosting all the peripherals is a network of three 386/486 PC's running QNX, a distributed real-time operating system from QNX Systems, Ontario, Canada.

6.1 System Requirements

Most of our experiments evaluate human perception and motor responses which occur in a matter of milliseconds. To accurately respond to and measure the effects of such responses it is essential to provide an accurate representation of the VE at any instant in time. With each component of a system comes a response time, a worst and best case for capturing, processing and generating the required data. Co-ordinating and minimising the lags induced by these components is the heart of our system and the job of the Virtual Environment Manager (VEM).

The VE support and most of the device driver software has been written in-house. System flexibility, extensibility, performance and ease of development were primary considerations when designing the system. The details of experiments conducted in the laboratory are almost impossible to predict and hence the equipment used, its application and execution are unknown. A VE for an experiment need only be generated once but may be interacted with using different input and output devices.

6.2 System Design

An object-oriented approach was taken towards design and construction. Each object runs as a single process communicating through message passing. The only processes that are restricted in where they run are the device objects. These run on the machine which has the peripheral attached to it. By providing these devices as exchangeable software components we encourage software re-use, cater for sudden changes in requirement, ease development and hence save time. Although runtime process migration is not supported, reallocating processes to nodes is simple and makes experimentation of system loading very easy to do.

6.3 Developing Applications

Development of a specific VE involves creating the visual database using an interactive 3D modeler (currently Autodesk 3D Studio) and converting it to the CIG proprietary format. Then the optimisation of the VEM (we hope to replace specific VEM's with a general-purpose one in the future) and the selection/implementation of any autonomous Object within the environment, e.g. the user, a robot car etc. Objects have their own interface definition and as such are interchangeable, making the establishment of an Object library possible. Consider the following:

When developing and testing VE's it is often undesirable to use the full experimental rig. For example to use our simple driving simulator involves casting the room into darkness to allow the projection system to work correctly and then walking to the other side of the room to sit in half an instrumented Ford Fiesta. Fine if you are preparing to run experiments, annoying if you are debugging an application. A much more practical configuration is the substitution of the steering, brakes and accelerator for desktop input devices and exchanging the projection screen for a monitor. Since all devices conform to a common interface definition these devices may be exchanged with no effect on the application code. A similar situation exists when immersive technology is to be used in the experiment. A Spaceball makes a good substitute for a 6D head tracker and a monitor for a HMD.

These alternative device configurations would typically be implemented as different user Objects, the relevant one being invoked when needed.

Development of this system and research into alternative architecture's is being conducted in association with the Department of Computer Science within the University.

7.0 Summary

As research continues along the lines described, unforeseen demands will inevitably be placed on the experimental support software. We hope that the modular approach taken to design and implementation will limit the effects of changes whilst providing a flexible and open architecture.

References

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