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The Use of Virtual and Mixed Reality Environments for Urban Behavioural Studies

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ABSTRACT

Virtual/mixed reality 3D models of real-world environments can be used to run behavioural and other experiments with real human subjects, replacing the traditional approach where studies are conducted in physical environments. Use of the virtual/mixed reality environments can minimize problems related to feasibility, experimental control, ethics and cost, but care must be taken to ensure that the environments are immersive and create “suspension of disbelief”. In this position paper the issues involved are discussed and illustrated by a 3D virtual model of an urban environment that is being used to study the role of fear in pedestrian navigation.

Keywords: *Virtual Environment, Urban Environment, Pedestrian Navigation, CPTED, Fear of Crime.*

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1. Introduction

As an alternative to studies in physical environments, three dimensional virtual or mixed reality models of real-world environments can be used to study how built urban environments influence human behaviour. Experimental studies can be conducted with human subjects and the experimenter has much more control over the environment than in a physical experiment. On the other hand, care must be taken to ensure that the virtual or mixed reality environment is sufficiently immersive to ensure “suspension of disbelief”. This paper discusses the issues involved and describes a case study

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where a 3D virtual model of an urban environment was used to study the role of fear of crime in a pedestrian navigation model.

2. Virtual and Mixed Reality Models in Social Science Research

There are many instances where social science researchers wish to study how human subjects react to physical environments in general and urban built environments in particular. These studies can be behavioural, sociological or criminological. They could also involve urban planning, landscape architecture or building design. The common need is to study some aspect of how human subjects behave in a built environment.

Virtual or mixed reality environments where the real-world is simulated provide new investigative tools for social science research. The advantages of using such environments include:

- Control - it is much easier to control and modify situations in a virtual environment than in a real-world environment; also, in real publicly accessible physical environments it can be difficult to avoid interference from vehicles and pedestrians not involved in the study;
- Safety - by using a virtual environment we can avoid any real danger, harm, or risk to human subjects but still achieve many of the dynamics of a real-world environment.
- Cost - building a virtual environment can be less expensive than building or arranging access to a real-world environment and it can be relatively fast and inexpensive to modify the environment.

These advantages must be balanced against the concern that the virtual or mixed reality environment will not provide sufficient immersion for suspension of disbelief. This immersion depends on the technical quality of the virtual environment and on the nature of the tasks the subjects are asked to perform. The more engaging the task, the more likely it is that the subject will achieve suspension of disbelief. There is also the issue of how “real” the mixed or virtual environment should be? For example, computer models of buildings and streets tend to be unrealistically clean. It may be that a mixed reality environment where imagery of the real physical environment is combined with computer models of buildings and people can provide a useful compromise.

Computer models and virtual environments have only begun to be used for research on urban environments. One tool that we have found was developed by a company in the Netherlands (Oxley et al, 2005). This tool focuses on visibility problems in a model environment. Another study by Cozens, Neale, Whitaker, and Hillier (2003) involved safety concerns at Welsh railway stations. Photography was used to create several 360 degree panoramas at various points in and around the stations. These photographs were then stitched together to create a VR walk-through. Participants can virtually navigate the station environment, freely zooming in and out and panning left and right at any time during the navigation. This VR system provided a dynamic visual stimulus based on which participants' judgments and perceptions were generated.

Motivated by of the increasing interest in simulating our man-made environment, especially cities, the IEEE Computer Graphics and Applications magazine has published a special issue on “Procedural Methods for Urban Modelling” (Watson & Wonka, 2008). This special issue captures a good snapshot of work in this emerging area and includes a paper by Mol, Jorge and Couto (2008) on the use of a game engine as the basis for a tool to simulate evacuation planning.

3. Case Study: The Role of Fear of Crime in Pedestrian Navigation

A study using a virtual environment to investigate the role of fear of crime in pedestrian navigation is summarized here as a case study. The approach presented illustrates how a relatively simple and inexpensive VE can be used to study human behaviour in an urban environment.

3.1 Background: Crime Prevention Through Environmental Design

Human-constructed city environments play an important role in peoples’ lives. The influence of an urban environment on human behaviour and life style has become a popular research topic. One of the pillars of research on people in urban environments, Jane Jacobs, carefully observed people and their activities in New York City. She identified many different urban planning problems, including crimes, caused by bad urban design (Jacobs, 1961). Her work has greatly influenced urban planners and architects and caused them to see cities in a new perspective.

Another person who also observed people in New York was William Whyte, who was known as “people watcher”. The behaviour of people was systematically recorded using still cameras, movie cameras, and notebooks over a long period of time. His work shows architects and urban planners what works and what does not (Whyte, 1980). Following these ideas, criminologists began to think of new ways of reducing crime in urban environments. Criminologist C. Ray Jeffery used the phrase, “Crime Prevention Through Environmental Design (CPTED)” (Jeffery, 1971) for the first time. The idea of CPTED is that careful design of environments can reduce possible crimes and fear of crime so that it improves quality of life. Another strategy called the “broken windows” theory was added to CPTED (Kelling & Coles, 1996). This theory states that if people do not fix broken windows, more windows will be broken. And the situation gets worse with worse crimes occurring, including breaking into buildings.

The relation between crimes and the environment was further elaborated by Paul and Patricia Brantingham who pioneered a new field, called “Environmental Criminology” (Brantingham & Brantingham, 1981, 1997). By examining the time and the place where crimes occurred, the spatial pattern of the crimes and the behavioural patterns of the offenders can be discovered.

There has been much research that supports the ideas of CPTED, particularly, the relationship between environments and fear of crime. Fear of crime is not necessarily fear of real dangers, but rather the perceived fear of being victimized by possible crimes. Criminologists and environmental psychologists have studied how people, particularly the most vulnerable, feel fear of crime in various environmental settings. Their findings show that narrow walkways without any escape routes, hidden spaces created by corners, tall bushes, and the presence of threatening individuals generate fear in people (Fisher & Nasar, 1995; Nasar, Fisher, & Grannis, 1993). Lighting is another element that can influence fear of crime (Hanyu, 1997).

3.2 Modelling the Role of Fear in Pedestrian Navigation

We have developed a quantitative model of how pedestrians navigate through an urban environment that creates fear of crime. The model chooses a path through the environment that minimizes passage close to features known to generate fear. These are:

- Narrow passageways with no escape,
- Passageways with hidden spaces off to the side that might hide a threatening individual,
- Passageways with garbage dumpsters and other hiding places,
- Passageways with a threatening individual,

- Passageways with multiple threatening individuals.

At this stage the model does not handle combinations of these features that occur together (Park & Calvert, 2008).

3.3 Validating the Model

In order to validate this model we needed to study pedestrian navigation using human subjects. However, it was difficult to find suitable physical locations that could be used to test our model. Fear of crime research has mainly been done by traditional methods such as surveys, interviews, case studies and experiments with human subjects. For example, some research has been done by asking human subjects to visit various sites on a university campus. The subjects were then asked to answer questionnaires regarding fear of crime and sense of security. (Nasar, Fisher, & Grannis, 1993). Other research has been done by showing human subjects photos of various city sites and asking them how they feel about the sites. The former kind of research could have endangered the human subjects. Because of the real possibility of danger, the research must be limited. The latter kind of research loses dynamics and a sense of real-life situations.

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3.4 Using a VE to Study Pedestrian Navigation

Since observing real pedestrians in a fear-generating area is difficult due both to ethical issues related to the risk and danger involved in the experiment and to our inability to control experimental variables, it was decided to construct a virtual urban environment. This environment can achieve relatively good realism using textures from photographs of real buildings and objects on the streets. It is also easy to create and modify the layouts of a fear-generating area to correspond with the goals of the experiment. Control of experimental variables is straightforward in the virtual environments and adding animated human figures enhances the realism. Human subjects can freely navigate the virtual environments as if they were in the real-world environments.

The design of our experimental setting was arranged to help the participants experience presence during the experiments and to suspend their disbelief. Originally we wanted to make an accurate model of a well-known fear-generating area. Using a

3D modeling tool (3D Studio Max), we created 3D buildings and roads in accordance with satellite pictures and road networks from Google Map. We then visited the area and took photographs of the buildings. It was difficult to take perfect pictures without any interfering objects such as pedestrians, trees, cars, or street lights in front of the buildings. Different light densities due to the weather changes were another problem. We also tried to avoid shadows on the buildings by taking photographs on cloudy days. However, we had to spend quite a lot of time editing the photographs in Adobe Photoshop, removing unnecessary objects and shadows from the buildings and adjusting the brightness. We then mapped these textures onto the 3D models of the buildings created in 3D Studio Max. A layout of the streets was designed in which we could create fear-generating features such as narrow walkways, hidden spaces, bushes, garbage containers and so on.

The VE was controlled by a game engine – Dark Basic Professional (http://darkbasic.thegamecreators.com/). The game engine architecture provides many of the features needed to navigate a VE. These include:

- User control of navigation.
- Support for complex 3D models.
- Support for fast rendering of the scene.
- Collision Detection.
- Ability to easily implement a vision system.

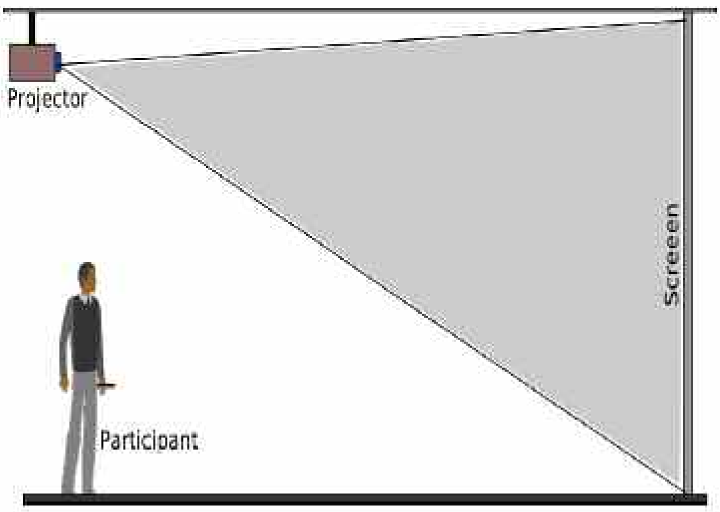

Figure 1. A large screen and surrounding curtains increases the sense of immersion.

Several pilot studies with different experimental set ups were conducted. We tested an Elumens Vision-Station with a few human subjects. Although it generated a good immersive experience, most of the subjects complained about dizziness during the navigation. We then tried a regular screen with a projector. Subjects sat down in front of the screen and navigated the VR environment with a keyboard and a mouse. But this was not immersive enough for them to feel presence. Some people felt that they were playing a game. To increase the level of immersion, we set up a large screen that reached to the floor (about 5m x 4m) so that participants could feel better presence with the big display size, the wide field of view, and the wide field of regard. To overcome subjects' feeling that they were playing a game with a keyboard and a mouse, we used a Nintendo Wii remote controller so that subjects could stand in front of the big screen and navigate the virtual environment intuitively as if they were walking in the street (Figure 1). To help participants feel even more presence, we surrounded the experimental space with thick black curtains. We also played ambient background sound of traffic during the experiments.

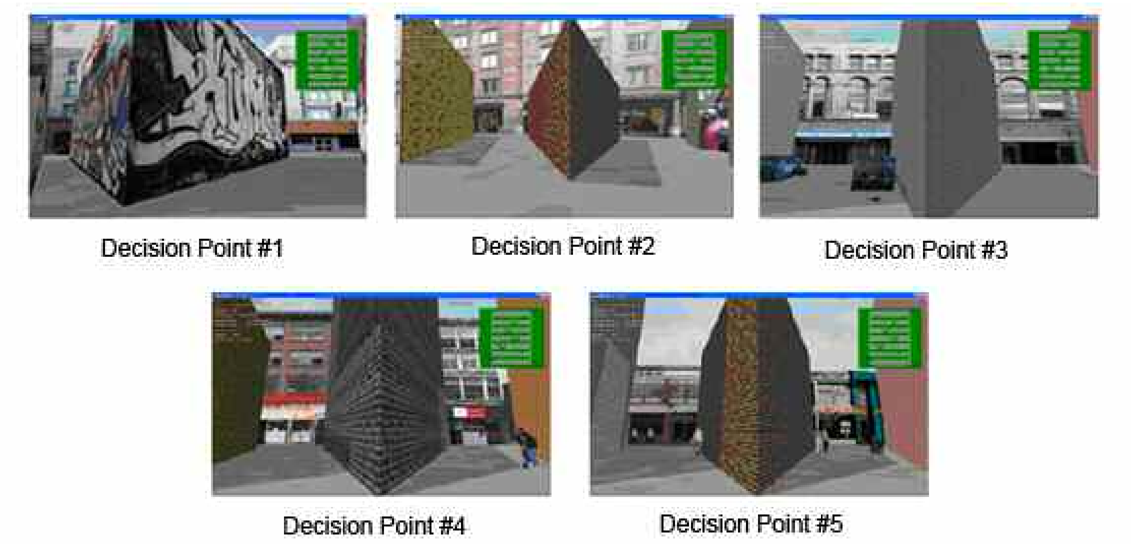

Figure 2. Views of the five Decision Points.

As we were developing this virtual environment, we realized that we were reaching the performance limits of the available computer hardware – it became difficult to achieve a high enough frame rate with the increasing complexity of the model buildings and the large number of different textures. Eventually, we decided to develop a reduced model of the area with the existing textures so that the participants could still feel that they are in the fear generating target area. Since we were not creating an exact model, we modified the environment to set up Decision Points for certain environmental features (wide vs narrow streets, hidden spaces vs no hidden spaces, garbage dumpsters vs no garbage dumpsters, threaten individual vs no threatening individual, multiple threatening individuals vs one threatening individual). Figure 2 shows snapshots of each decision point. As shown in Figure 3, human subjects can navigate the environment from a first person's point of view as in first person shooter games using a Nintendo Wii controller for navigation.

Figure 3. A subject navigates the environment using a Nintendo Wii controller.

Experiments were conducted in which human subjects navigated from a starting position to a destination position in the VE. On the way, there were the five decision points. Subjects judged for themselves which route they should choose. The results from our initial experiments are very promising. Most importantly, human subjects felt as if they had indeed been in the target area and behaved accordingly.

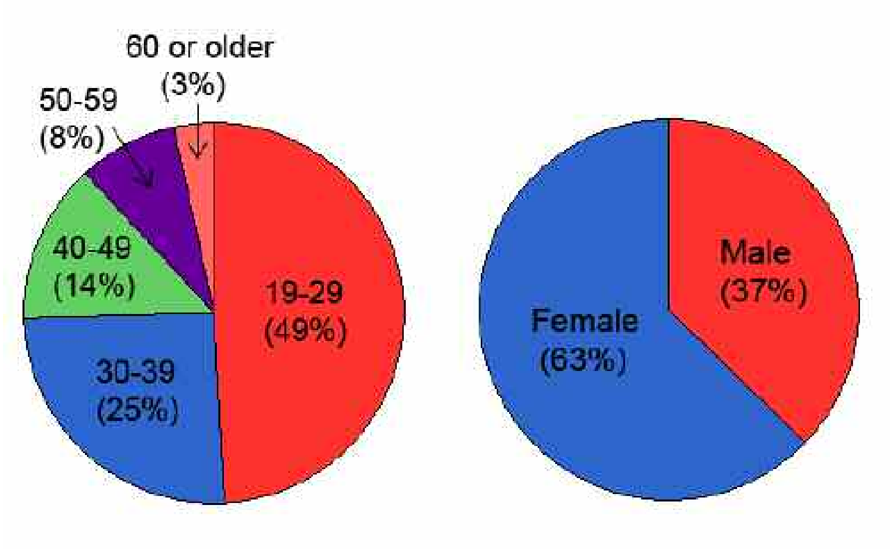

Figure 4. Age and gender distribution of 59 subjects.

Figure 4 shows the demographic statistics of the subjects' age and gender. In contrast to some such experiments, subjects were recruited from the community at large, not just from university students. All subjects provided informed consent. The results for the 59 subjects are summarized in Table 1.

Decision Point	**Shorter Route**		**Longer Route**	
1	Narrow Alley	31%	Wide Alley	69%
2	Hidden Space	68%	No Hidden Space	32%
3	With Dumpsters	32%	No Dumpsters	68%
4	One Threatening Individual	25%	No Threatening Individuals	75%
5	Multiple Threatening Individuals	53%	One Threatening Individual	47%

Table 1. Routes chosen by subjects at each decision point.

In summary, the subjects chose the wide passageway (62%) more than the narrow one (38%), the street without garbage dumpsters (68%) more than the one with dumpsters (32%), and the street without a threatening individual (75%) more than the street with one (25%). The fact that most subjects avoided the street with a threatening individual suggests that social incivilities generate more fear than physical incivilities. The results at the decision points #3 and #5.

In post-experimental interviews, we reviewed the screens recorded during the experiment, questioned subjects about their levels of fear and asked them which features in the environment triggered the fear.

4. Lessons Learned from the Case Study

A number of useful lessons can be learned from this case study:

- Relatively simple and inexpensive VE's can be effective for behavioural and other studies in a built environment.
- The VE layout does not have to be identical to the target physical environment in order for subjects to feel that they are present in the target environment.
- The layout of the VE can be structured to provide subjects with decision points appropriate to the issues being studied.
- A game engine provides a base system that is quite appropriate for creation of the VE. Game engines support navigation, rendering, collision detection and other features need to navigate the VE.
- Creating realistic detail in the scenes can be tedious and time consuming – for example, it is much quicker and easier to create images of clean streets rather than dirty streets with miscellaneous garbage. However, the experimental subjects were quite tolerant of the lack of such detail in our scenes.
- More realistic scenes can be created economically by using digital photography to create panoramic background views photographed from the physical environment. Then a mixed reality (MR) environment can be created by adding computer generated objects and characters in the foreground.

5. Conclusions

The use of a virtual environment to test a model of human behaviour in an urban environment has many advantages in terms of cost, time, flexibility and safety. Our studies show that a VE can also be an inexpensive and effective alternative to real-world environments. This approach promises to be particularly useful for urban planners and criminology researchers.

6. Acknowledgments

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