Rai, S. and Wong, K. (2010) ***The use of interactive simulations to affect driving behaviour.*** **In: 3rd Annual International Conference on Computer Games, Multimedia and Allied Technology, CGAT 2010, 6 - 7 April, Singapore.**

The Use of Interactive Simulations to Affect Driving Behaviour

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ABSTRACT
Many studies have shown that no matter what is done to try to get drivers to improve their driving behaviour there will always be some who would not see the benefit of modifying their behaviour. This paper reports on work in progress using a specially built simulator to convince drivers of the benefit of having good driving behaviour. The system uses Interactive Simulations in a Virtual Reality environment to immerse drivers in various road situations.

Keywords
Interactive simulations, behaviour modification, training.

1. INTRODUCTION
Simulations have a very wide area of applicability. These include manufacturing, engineering, project management, military, logistics, distribution, transportation, health care and business [1] to name a few. Banks et al. [1] describe some of the advantages of simulations and some of these include: testing and exploration of new ideas without disrupting the operations of the real system; plans and designs can be studied without committing actual resources; hypotheses and feasibility tests can be carried out; time can be manipulated to study short and long term effects; interaction of variables can be studied.

There is also an ever increasing use of simulations in computer aided instruction. Some of these include vehicle handling training (trucks, ships, aircraft, submarines, and spacecraft), various forms of military training, training of equipment operators, training of civilians and responsible personnel in incidence response and management.

In this paper, we describe the construction and use of an interactive computer-based simulation to improve car driving behaviour by letting the trainee experience why safe driving practices are important.

2. DRIVER BEHAVIOUR AND ERRORS
Beside factors associated with the vehicle, external factors (environment and road infrastructure) and the behaviour of other road users, driver behaviour appears to be an important component determining whether an accident will occur. It has been reported recently [2] that 75% of all crashes have been linked to driver error. Stanton and Salmon [2] review past literature on human error on roads and work out an error taxonomy that utilises the "dominant psychological mechanisms thought to be involved." They identify these as "perception, attention, situation assessment, planning, and intention, memory and recall, and action execution." The authors then propose some technology solutions to mitigate these errors. Some of these solutions include: Collision sensing and warning systems; pedestrian detection and warning systems; intelligent speed adaptation systems; rear parking sensors; etc. All of these are in-vehicle technologies, some of which, like rear parking sensors are available in many cars. Others like collision sensing and warning systems are becoming available in more expansive cars.

We do not believe these technology solutions are the total solution unless the driver is totally taken out of the loop; in other words the vehicles can drive themselves. While the driver is in control of the vehicle, driver behaviour is critical as much of the technology can be ignored by the driver and there is evidence reported below which supports our assertion.

As reported by Williams, Kyrychenko and Retting [3] there is not much dispute that speeding on the roads is a major problem as stopping distances are increased with a lowering in reaction time. Stanton et al. [2] also report that deliberate speeding was the second most common violation after "unknowingly speeding". So just using speeding alone as an important example of what drivers do, we cite below a number of studies which show that a driver's perception of what they are doing and of what others around them are doing influences their behaviour.

Corbett [4] reported that drivers have their own views on what is right or wrong. When drivers "*felt comfortable and in control*", they did not feel obliged to keep to the posted speed limits.

"*So personal guidelines facilitated an elastic conception of compliance which allowed the individual to maintain a self-image of being a good, law-abiding driver even when travelling in excess of the supposed limit*" [4].

An earlier study by Haglund [5] indicates that if drivers felt that others were speeding, it was all right for them to speed as well.

These reports suggest that drivers have not really understood (or "internalised") the consequences of speeding despite all the road safety education and campaigns carried out in their countries. Mannering's report [6] adds weight to this.

"*A key motivating factor in drivers' tendency to exceed the speed limit is that they believe that the excess speed does not threaten safety. … Estimation findings show that drivers' perception of the speed above the speed limit at which they will receive a speeding ticket is a critical determinant of what they believe is a safe speed …*" [6].

What is even more damning is that only 38% of drivers who did driver rehabilitation courses to improve their speed compliance, agreed to keep to the speed limit in future [6]. There are other reports of stubbornness. Lee [7] cites much earlier work by Rajalin and Summala [8] which indicates that as drivers do not get involved in accidents every time they make a mistake, drivers do not pay enough attention to their driving and even when drivers do get involved in an accident, it does not always lead to a long term change in driving behaviour. Wrapson [9] points out that there are a "hard core" group of drivers who speed and who are aware of their "*deviance from normative driving behaviour*" because intensive traffic safety campaigns had been running for years.

As most people suspect, drivers who speed tend to be younger.

"*Speeders were younger than drivers in the comparison group, drove newer vehicles, and had more speeding violations and other moving violations on their records. They also had 60% more crashes.*" [3].

Young drivers also tended to underestimate the risks involved in speeding [10] and what we have found is that they also tended to overestimate their driving ability. This means that the usual driver training and safety instructions may not be sufficient. The usual form of driver training involves some sort of written test, perhaps a hazard perception test and driving experience on the road with an instructor. As has been shown earlier, knowing what is the right or wrong thing to do is not sufficient to elicit a change in behaviour if doing the wrong thing does not result in a negative outcome every time, (and, for some people, even if there is a negative outcome). Also, actual driving experience on the road would not in reality, cover all the possible situations which can result in accidents as it would be considered dangerous to do this. For younger drivers, it is the acquisition of experience that is important. This takes time when doing it in an actual car on the road and it is also risky. Lee [11] cites reports on the link between a young drivers' experience level and the likelihood of them getting involved in accidents:

"*The first months of unsupervised driving are particularly dangerous. Sixteen-year-old drivers have a crash rate 10 times as great as that of adults but, within the first 500 miles, a two-thirds reduction in their crash rate occurs (McKnight & McKnight, 2003). Similarly, a month-by month analysis of crash rates in young drivers showed a 41% decline in the first six months and a 60% decline after two years of driving (Mayhew et al., 2003). This reduction in crash rates partially reflects the development of basic control skills associated with the operational level of driving … This suggests that deficiencies in vehicle control skills leave young drivers unable to accommodate the vehicle control demands of some driving situations.*"

This should indicate that there should be alternative ways to acquire the experience needed. Also by targeting younger drivers to get them to inculcate proper driving behaviour at an early stage of their driving experience, it is hoped that the chances of picking up bad driving in later life is reduced.

As has been indicated earlier, simulators have been used in training and it has been shown to be cost effective. For example the cost of training in a particular helicopter simulator is only 15% of the cost training in the actual helicopter [12].

There are, of course, other well know benefits of simulator training. The ultimate aim is to embed the knowledge that speeding kills into driver's psyche. This should include the conventional training. It also requires a cultural shift with a deep understanding that speeding is dangerous. Such knowledge is best acquired through experience. This can be done safely through real time high fidelity simulations as many dangerous situations can be catered for without putting any one in danger. Drivers should know that the simulation is that of a real vehicle (with natural user interfaces) on a real road and no matter how good they consider themselves as drivers, the laws of nature prevail. There may be some evidence to support this approach:

"*More specifically, the exercises performed on the training site were aimed to demonstrate to the participants that it is nearly impossible to elude the emergency conditions they experienced. McDonald (1985) and Harre (2000) suggest that the feeling of mastering the basic skills involved in driving is a crucial component in risky behavior of young drivers. Relatedly, reckless driving of adolescents is a source of pleasure as long as things are under their complete control (Rosenbloom, 2003). The increased risk awareness of the participants in the present study, likely resulted from the emphasis put on the thin line between control and loss of control in hazardous road condition*" [13].

Simulators can also permit the monitoring of behaviour along with the ability to re-play for further study.

In the next section we describe the construction of the driving simulator.

3. DRIVING SIMULATOR

3.1 Approach

We used the review of the traffic accident prevention literature and literature on driving errors to guide the design requirements of the driving simulator. We used a modified form of the following categories identified by Stanton et al.

a. Driver. Monitoring all interactions of the driver while the driver is operating the simulator. In-vehicle distractions to be simulated by causing distraction while the driver is in control of the simulated vehicle. These distractions could include asking the driver to talk on a mobile phone or send SMS text messages while operating the simulator. Sound distraction could be simulated by audio playback of "back-seat" distractions like noise.

b. Road conditions. This included road surface and road gradient. Some aspects of the road conditions to be dynamically changeable. Obstacles could be placed on the road while drivers were in the simulator.

c. Vehicle. Mechanical conditions like the conditions of the brakes and the weight of the vehicle.

d. Other road users. Pedestrians and other vehicles on the road. Pedestrians were agent (AI) characters. Pedestrian density and pedestrian spawn points to be controllable. Control of the pedestrian parameters to be also dependant on time of day. For example, there would be a higher density of AI children at certain times of the day near schools. Other vehicles included agent (AI controlled) cars as well as other cars controlled by drivers on other simulators with these simulators in a networked environment.

e. Environmental. These to include weather conditions.

The simulator is also meant to be a data collection tool. All interactions on the simulator are to be logged, along with the position of each vehicle and road user. The state of the virtual world is also to be logged. There are two reasons for this. One was to allow playback capability and the other was to see if there were driving patterns that could be observed for each driver and how these patterns changed over time. This meant that the simulator would have to store login credentials for each user.

3.2 Simulator Design and Construction

In order to incorporate the design requirements, the simulation was done in a networked virtual world. Other drivers in the world could see, collide and obstruct each other. A control console (panel) had to be provided which could be used to change both vehicle and world parameters while the simulation is running.

Figure 1 shows the overall system architecture.

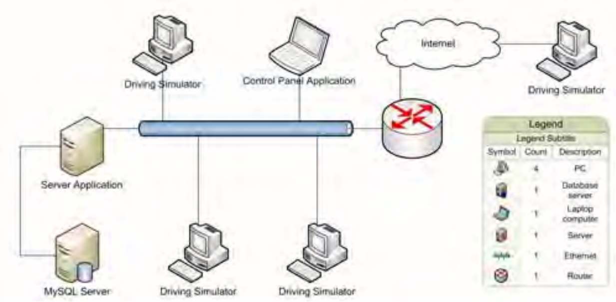

Figure 1. Overall architecture of the simulation system.

In figure 1, there are three main components: server, driving simulator clients and the control console/panel client. The server component actually consists of two servers, one which runs the virtual world and the other which is a database server. The database server is networked directly to the world server via a direct connection. If the machine running the world server is powerful enough, the database server can run on the world server machine. We found that connecting the database server to the local area network and sharing the network with the simulator clients introduced latencies in the server updates.

The driving simulators are standalone computers connected to driving rigs. Figures 2 and 3 show details of the rigs. Figure 2 shows the rigs from various views and figure 3 shows details of the controls available on the rig. These controls are provided by the Logitech G25 driving system. Manual and automatic driving modes are catered for. In the manual mode, gear change is illustrated in figure 3.

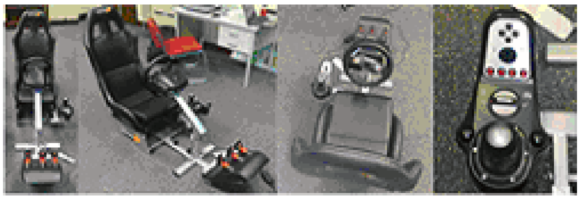

Figure 2. Various view of the driving rig.

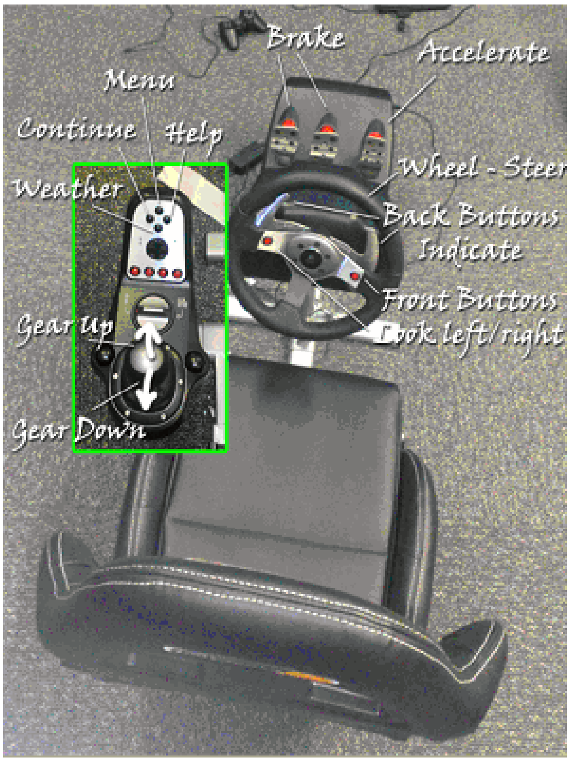

Figure 3. Driving rig controls.

Figure 4 shows an overview of the sub-tasks of each of the three main system components to demonstrate which system component has responsibility for which task. It can be seen that the physics and rendering are done by the simulation clients. Pedestrians (agents) data is handled the same way as agent car data. There are non-agent cars which are driven by drivers sitting on other driving rigs connected to their own networked driving simulator clients. On any given simulation client, the non-agent cars are treated the same way as agent cars for the purposes of physics and rendering.

To reduce the clutter in the diagram, not all processes are shown. For example, the server application receives data from each of the simulation clients as well as from the control panel. This information is not just logged but also processed and sent to all the other clients.

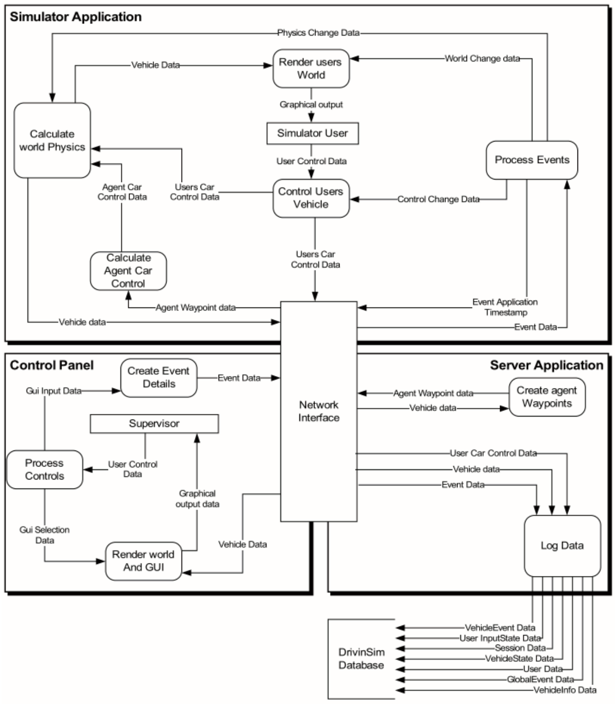

Figure 4. Some internal processes of each of the 3 main components.

All simulation clients view the world in 3D from any angle that a driver inside the vehicle can see. The control panel client only has a top down view (plan view) with multiple zoom levels. Figure 5 shows the view from inside a vehicle. This is the view visible to those who are sitting on a driving rig. Figure 6 shows the head-mounted display (HMD) unit with gyroscopic head tracking used to see the view in Figure 5. Figure 5 is also presented on a monitor. The head tracking unit allows visual immersion of drivers into the simulation world. Drivers can look around their environment while sitting in the rig. The image on the monitor also shows what the driver is looking at.

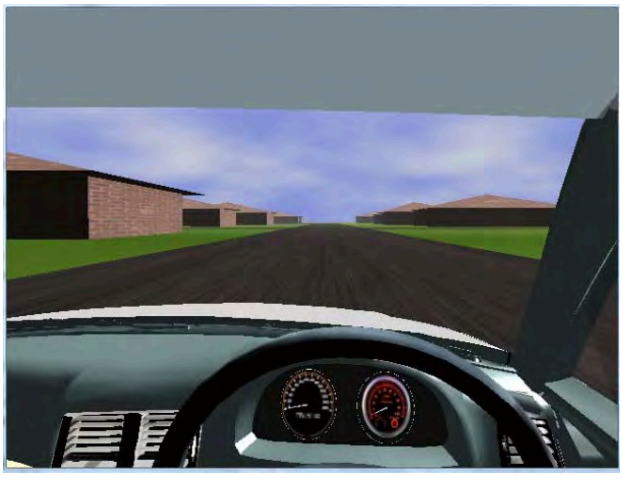

Figure 5. Driver's view from inside a vehicle.

Figure 6. Head mounted display unit with gyroscopic head tracking.

Figure 7 shows the top-down view when using the control panel.

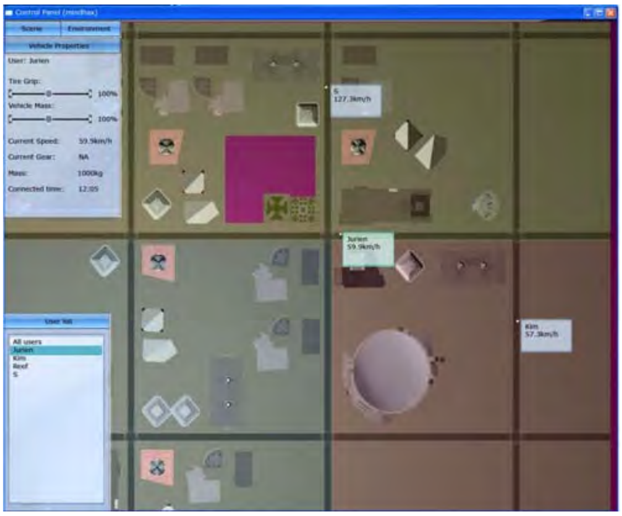

Figure 7. View of the control console/panel.

The right side of the view of the console shows a section of the world which has a rectangular road layout. Three non-agent drivers are in that part of the world. Their login names and speeds are indicated in boxes close to the white dots representing their vehicles. The top left shows properties which can be controlled using the console. The bottom left shows the lists of users that are currently in the simulation world. Changing the vehicle properties of any user is accomplished by clicking on a user in the user list and adjusting the vehicle properties. The users would not be aware that their vehicle properties have changed until they notice their vehicle behaving differently. Properties of all vehicles can be changed by selecting all users. Figure 8 is a close-up view of the controls available, and in this case all users have been selected to have their vehicle parameters modified. In the current version, two parameters are modifiable.

Figure 9 shows a close up of the controls for adding obstacles on the road. This can be done while the simulation is running. For example, if the operator of the control console places an obstacle in front of a vehicle, the driver would see the obstacle appear suddenly. Figure 9 shows only two types of obstacles listed but more can be added by loading the model files for new obstacles.

Figure 8. Control Console modification of vehicle parameters.

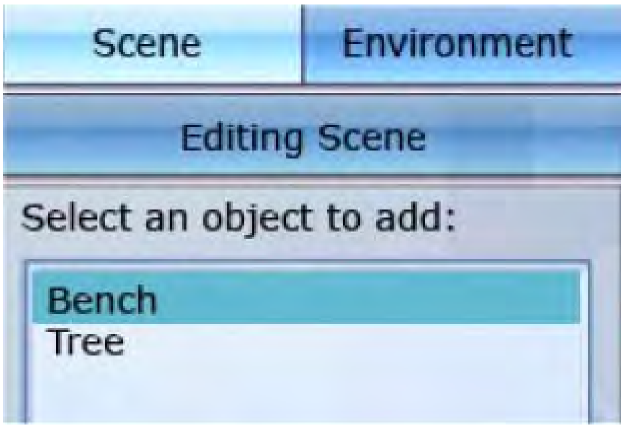

Figure 9. Control Console – adding obstacles on the road.

Figure 10 demonstrates the ability to change the weather in the simulation world using the control console. The weather gets changed in the entire simulation world. The default situation is calm.

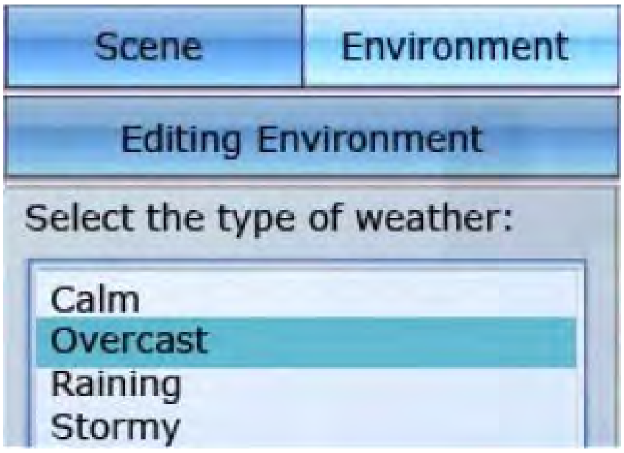

Figure 10. Control Console – changing the weather.

The system was constructed using C++ as the programming language, the Ogre graphics engine for rendering and Newton physics API for handling the physics. The database used was MySQL.

4. OBSERVATIONS AND DISCUSSION

4.1 System

The original design had the world physics calculations on the server to manage world synchronisation more easily. However, during the initial testing, it was found that having the world physics task on the server slowed the server down as more simulation clients connected. The display frame rate also went down for each client as each client had to wait for the server to tell each client what had happened before rendering the scene. A decision was then made to design as shown in figure 4. So by distributing the physics work load to the relevant client, the server was able to cope well as more simulation clients joined the server. The synchronisation process was adjusted to cater for this. For example, collision events were calculated on each client. These events were reported to the server and the server would process the reports from all clients, send updates to relevant clients and log the reports.

Issues with data transfer rates on the LAN also arose. Each client was capturing its current state 60 times a second. These states were reported to the server. Again as the number of clients went up, bandwidth issues were noticed. This was expected but the reason for having such a high capture rate was to reduce any chance of aliasing in the sampling of the reported events according to the Nyquist rate criterion. As the virtual world of the simulator is not a game, it was felt that a high rate was needed to keep the fidelity of the system. The figure of 60 Hz was chosen as that was the refresh rate of the display devices. During the pilot operation of the simulator system, it was seen that no client was generating events that would require a sampling rate of 60 Hz. A vehicle moving at high speed did not really require its position reported 60 times a second. Its position could be interpolated using the speed, position and direction of travel. If a collision event occurred, the client would report it. If the driver pressed the brakes or touched any control on the driving rig, it would be reported. During the pilot run, the highest number of simultaneous interactions noted on any particular client was less than 10. In the next version of the system, we would be looking to see if dynamic sampling could be used. This would mean sampling only if some event occurred.

The other network bandwidth issue that we reported earlier was related to how the database server was connected to the virtual world server. Connecting the database server via the LAN was causing bandwidth issues. Connecting it directly to the world sever by its own network cable resolved the problem. We feel that this is the optimal approach for our situation.

4.2 Drivers

The majority of the drivers of the pilot version of the system were in the 18 to 28 years age group. It should be noted that car insurance companies rate most of the people in this age group as "risky" in terms of insurance premiums as well as the amount of excess they have to pay on any claims this age group make.

It was noted that, at first, almost everyone would treat it as a game when they first get on the simulator. They would drive the vehicle at high speeds trying to avoid obstacles while travelling at high speeds. They were all aware that it was not a game. When asked about this behaviour, the most common reply by far was that it was safe and no one would get injured. This shows that they were aware of the issues associated with particular road behaviours.

As in real life, it is not possible to avoid a collision when travelling at high speeds in the simulator. This is particularly so around corners and in congested areas. In less congested areas, the speeds were quite excessive. The drivers were aware of the capabilities of the control console to place obstacles anywhere. So in anticipation of obstacles appearing suddenly, a number of the drivers started to exhibit an interesting behaviour. They started to turn the steering wheel slightly from side to side. It was not enough to take them off the road but enough to cause the car to vary travel from a straight line. It was like the drivers were introducing *jitter* in their neuro-muscle eye-hand coordination loop. When asked why they were wobbling the steering wheel, their answer was so that they could react faster to avoid obstacles if they suddenly appeared. They were attempting to reduce their reaction time by this manoeuvre.

Reaction time is only part of the problem in accidents. The driver must first notice a potential problem, recognise it as a potential problem and then engage in a correct response. Reaction time can start when the driver recognises a potential problem. Unfortunately by the time this recognition happens, it might not matter how fast the reaction time is if the speed is excessive. Even if the reaction time were to be zero, accidents cannot be avoided as a speeding vehicle would still be moving even if the brakes are applied hard because of the vehicle's momentum. Also, the conditions of the brakes and suspension would be a contributory factor along with the road conditions. One of the reasons for using the simulator is to get across the message that even if they were super-human with zero reaction times, they would not be able to avoid an accident.

Another very important issue to be addressed in accident prevention is driver distraction. It is a very common misconception that human brains can consciously multi-task when it comes to paying attention. It may be possible for someone to train themselves to juggle balls with their hands whilst at the same time juggling something else with their feet. But it is not possible to pay attention to both at the same time. Study after study in accident prevention has pointed out that drive distraction is a leading cause of accidents, and can even be more dangerous than driving while intoxicated. The driving simulator system has the capability to introduce driving distractions while driving. This can be used for both collecting information on driver behaviour as well as getting drivers to understand the issues by experiencing it themselves.

5. CONCLUSION

In this paper we reported on work in progress on a driving simulator that was built to train drivers on the merits of good driving behaviour. We looked at a number of causes of bad driver behaviour in the traffic accident and prevention literature to guide the design and construction of the simulator. We showed how the design of the system was carried out using this knowledge.

A number of issues were highlighted and these are still being worked on. The design considerations highlighted in section 3.1 are being expanded to incorporate more cases.

6. ACKNOWLEDGMENTS

We would like to thank the State's RoadWise program for funding and advice to get this project started and to the Dean of the School of Information Technology, Assoc. Prof. Peter Cole for making resources available for the continued work on this project. We would also like to thank the following individuals who were involved in the construction of the driving simulator system and the system manuals for the system. Jurien Broughton, Reef Turner, Kim Gadecki, Craig Lonsdale, Thaddeus Loke, Nick Tognela, Simon Ollerenshaw, Luke Doherty, Kingston Harding and David Keep.

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