A VIRTUAL REALITY BUSHFIRE MITIGATION TOOL FOR COMMUNITY CONSULTATION

A.R. Walker[A], S. Gard[A], B.J. Williamson[A] and J.M. Bell[A]
[A] Queensland University of Technology, Brisbane, Australia.

Abstract

Instigating fire prevention and mitigation procedures within the rural/urban interface can save properties and lives. Councils and fire services can only do so much to prevent bushfire spread and damage within these areas. It is highly desirable that local communities to take responsibility for fire prevention and mitigation on their own properties. Changing people's fire prevention and mitigation behaviours can only occur through effective education and consultation processes.

This paper presents a virtual reality bushfire mitigation tool that will facilitate community consultation, and thus stimulate behavioural change with regard to fire mitigation. Virtual reality can visualise the effect mitigation can have in saving properties through using an interactive 3D interface that is readily understandable by the general public. This was achieved though a game-like application that allows users to change the vegetation and building configuration on their property. The users can run a fire simulation over the property and easily see the effect that their fire mitigation procedures would have on a fire front as it passes through their property.

This contribution will improve community bushfire awareness and stimulate behavioural change which will directly reduce property damage and potentially save lives within the rural/urban interface.

Introduction

Research suggests that community education and self-reliance amongst residents in the urban/rural interface is critical to ensure self-protection of residents and properties during bushfires (Ramsay *et al*. 1996, Beringer 2000,). From Beringer's study it was evident that residents who recognised the hazard of living in a fire prone area were more likely to have taken safety precautions against such a risk. For example, those residents surveyed who considered they lived in a fire prone area were more likely to have undertaken fire prevention measures such as cleaning gutters and clearing ground litter. As a result of this study, we believe that an educated community is more likely to undertake fire mitigation procedures that will inevitably complement any action provided by local fire authorities. Therefore, an effective community education tool is an essential component in the fight against fire at the urban/rural interface.

This paper presents a virtual reality bushfire mitigation tool that will facilitate community consultation and engagement, and thus stimulate behavioural change with regard to fire mitigation. The novelty of this research is the integration of bushfire modelling and DR05060 standard with a virtual reality (VR) interface that will allow users to assess alternate bushfire mitigation scenarios. The significance of this work is its ability to improve community bushfire awareness and stimulate behavioural change which will directly reduce property damage and potentially save lives within the rural/urban interface.

The remainder of this paper is structured as follows. Firstly, a background into current bushfire mitigation information sources and VR community consultation tools is reviewed. Then, the Materials and Methods section outlines the experiment conducted to evaluate the proposed VR bushfire mitigation tool. This is followed by a discussion of the results of the research. Finally, the conclusions and future work are presented.

Background

This section will investigate the current standards and recommendations for bushfire mitigation. It will also investigate the advantages of using VR as a community consultation tool.

Building Standards in Bushfire Prone Areas

Currently in Queensland the method for determining the bushfire-prone areas is outlined in the State Planning Policy which requires an assessment based on Building Standard "AS3959-1999 Construction of buildings in bushfire-prone areas" (Australian Standards Limited, 1999). In February 2005 Standards Australia produced a draft standard called "DR05060 Construction of buildings in bushfire-prone areas" (Australian Standards Limited, 2005) as a possible revision of AS3959-1999.

The DR05060 contains bushfire mitigation recommendations that are derived from knowledge about the terrain slope, building proximity to vegetation and type of vegetation. DR05060 was chosen over AS3959-1999 for this study

because DR05060 was a more comprehensive standard and thus would better highlight the benefits of VR as a consultation tool. From these recommendations, the most suitable position for a building on a property parcel can be established. In addition, burning embers and sparks are the most frequent cause of buildings catching fire during bushfires (Queensland Government 1994). The planned use of trees and plants within the property will reduce this risk by: reducing the amount of available fuel, decreasing fire intensity; reducing wind speeds and turbulence; catching flying sparks and embers, and shielding radiant heat energy. There is a need to effectively communicate this important information to the general public.

Traditionally, web sites (e.g. Bushfireinfo.com 2003) have been used to communicate the benefits of the AS3959-1999 and DR05060, however, these sites lack any interactive participation on the user's part. The user must manually calculate the risk from the lookup tables of DR05060. There is an opportunity to improve information transfer of the standard by using a more interactive approach.

Benefits of using Virtual Reality as a Consultation Tool

Virtual reality (VR) can be described as a multi-sensory highly interactive computer-based environment, where the user becomes an active participant in a virtually real world (Ali and Ferdig 2002). VR is often described as a synthetic environment and is characterised by freedom of movement and interaction providing an extension of our natural experiences. The level of interaction can vary from simple navigation to an almost endless collection of tasks and actions that can be performed. Depending on the level, VR systems are often categorised as passive, explorative or interactive environments. For this research, a fully interactive environment was developed in order to provide the best possible form of education through VR.

The use of VR as a consultation tool in urban planning is a mature concept (Bucolo *et al*. 2003a). Bucolo's research concludes that a virtual walk or fly through can within minutes express the whole concept of an urban development (Bucolo *et al*. 2003b). VR has the ability to do this because it speaks to the user in a language that they are familiar with, that language being real-time 3D. We all live and interact in a 3D world, and VR technology can recreate that world as a 3D visualisation in real-time. Furthermore it allows the user to visit environments from angles impossible in the real world and take part in events that safety and physical factors make unavailable such as abstract concept, very large or very small scale environments, and in the case of bushfire, unsafe environments. Because users are actively involved interacting with an environment that is motivating, they can master and quickly assimilate the information being presented.

More evidence of the benefits of VR as a consultation tool can be found in a report that was based on the study of 26 examples of the use of VR for public consultation in the UK (Heame and Webster 2003). This study concluded the following advantages of VR as a consultation tool:

- VR is far more interactive and residents have become much more engaged in the consultation process;
- Users of VR could see what they were going to live in and interact with it, they did not have to build up a representation in their own minds from relatively abstract/codified documents; and
- VR draws in those who wouldn't normally get involved in community engagement.

The last point mentioned above from the Heame and Webster's study is also supported by other research (Mortiboys and Butt 2003). These authors show that VR has the ability to involve some of the hard to reach groups of the community such as people with disability, people living in remote areas, lacking English or with poor literacy, young people or people who feel excluded from society.

This project investigates VR's ability to stimulate users into changing their behaviour with regard to bushfire mitigation. It achieves this by simulating (in real-time) the effect certain fire mitigation procedures would have on reducing a user's risk during a bushfire attack. Similar use of VR to stimulate behavioural change is being conducted with the intention of reducing energy usage in buildings (Summerville *et al.* 2005). Consequentially, using a VR bushfire mitigation tool to represent the cause and effect relationships between mitigation and risk should lead to positive fire mitigating changes in users' behaviour. This makes VR the prime choice for developing a bushfire mitigation tool for community consultation.

Materials and Methods

A prototype VR bushfire mitigation tool was developed in c# .NET utilising the TV3D 6.2 visualisation engine (Truevision3D 2006). This prototype allowed the users to easily invoke the DR05060 standard. The implementation details for the development of this prototype are discussed in the remainder of this section.

3D Modelling

The fictitious terrain and property parcel were modelled using standard CAD software. Simple textures were added to the 3D meshes to make it more realistic. Various vegetation types, as defined in the DR05060, were added to the terrain. A number of buildings were added to the scene to create a better sense of immersion in the VR environment. Two buildings were modelled that represented timber and brick construction types respectively. These were the only type of buildings that could be added interactively by the users to the scene.

Classification of Vegetation and Slopes

The first step in calculating the risk is to classify the vegetation and slope of the terrain adjacent to the property parcel of interest. The classification was done manually in the prototype system and is shown in Figure 1 below.

Figure 1. Classification of Vegetation and Slope

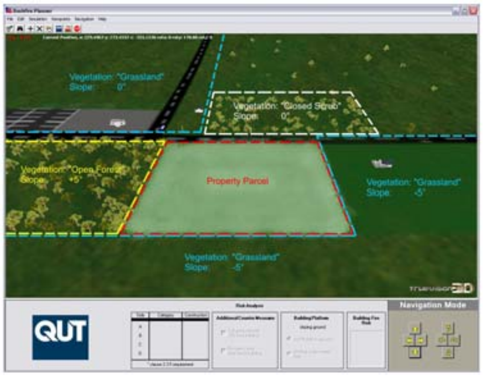
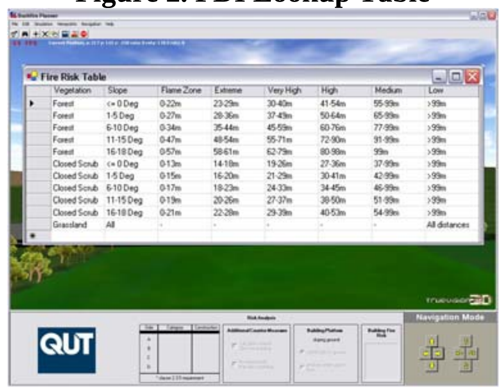


Figure 2. FDI Lookup Table



Fire Risk Table

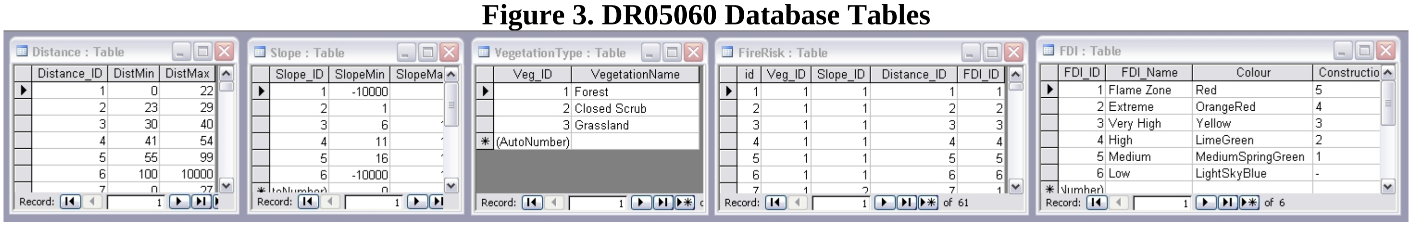
Vegetation	Slope	Flame Zone	Extreme	Very High	High	Medium	Low
Forest	<= 0 Deg	0-22m	23-29m	30-40m	41-54m	55-99m	>99m
Forest	1-5 Deg	0-27m	28-36m	37-49m	50-64m	65-99m	>99m
Forest	6-10 Deg	0-34m	35-44m	45-59m	60-76m	77-99m	>99m
Forest	11-15 Deg	0-47m	48-54m	55-71m	72-90m	91-99m	>99m
Forest	16-18 Deg	0-57m	58-61m	62-79m	80-98m	99m	>99m
Closed Scrub	<= 0 Deg	0-13m	14-18m	19-26m	27-36m	37-99m	>99m
Closed Scrub	1-5 Deg	0-15m	16-20m	21-29m	30-41m	42-99m	>99m
Closed Scrub	6-10 Deg	0-17m	18-23m	24-33m	34-45m	46-99m	>99m
Closed Scrub	11-15 Deg	0-19m	20-26m	27-37m	38-50m	51-99m	>99m
Closed Scrub	16-18 Deg	0-21m	22-28m	29-39m	40-53m	54-99m	>99m
Grassland	All	-	-	-	-	-	All distances

The 3D model of the terrain was built from known survey data including the slope, the location of roads, services and other land features. The different types of vegetation were easily communicated to the user through their graphical appearance.

Implementation of DR05060 Standard

The DR05060 was implemented as a lookup table in a database connected to the VR bushfire mitigation tool. This allows the parameters to be changed easily if the standard changes. The lookup relationship between slope, vegetation, distance and Fire Danger Index (FDI) are shown in Figure 2. From this figure you can see that only the vegetation types of forest, closed scrub, and grassland have been included at this stage. The underlying database tables that implement this lookup table are shown in Figure 3.

Figure 3. DR05060 Database Tables



Distance : Table

Distance_ID	DistMin	DistMax
1	0	22
2	23	29
3	30	40
4	41	54
5	55	99
6	100	10000

Record: 1

Slope : Table

Slope_ID	SlopeMin
1	-10000
2	1
3	6
4	11
5	16
6	-10000

Record: 1

VegetationType : Table

Veg_ID	VegetationName
1	Forest
2	Closed Scrub
3	Grassland
(AutoNumber)	

Record: 1

FireRisk : Table

id	Veg_ID	Slope_ID	Distance_ID	FDI_ID
1	1	1	1	1
2	1	1	2	2
3	1	1	3	3
4	1	1	4	4
5	1	1	5	5
6	1	1	6	6
7	1	2	7	1

Record: 1 of 61

FDI : Table

FDI_ID	FDI_Name	Colour	Constructio
1	Flame Zone	Red	5
2	Extreme	OrangeRed	4
3	Very High	Yellow	3
4	High	LimeGreen	2
5	Medium	MediumSpringGreen	1
6	Low	LightSkyBlue	-

Record: 1 of 6

The design can be easily adjusted for changes in the standard and is scalable if more slope or vegetation types are developed. The code uses an SQL query, as shown in Figure 4, to pass the distance and slope for each side of the building to retrieve the FDI. Not all of DR05060 could be implemented as lookup tables and consequently, some of the exception rules (like clause 2.3.5) were hard-coded into the program.

Figure 4. FDI SQL Query

```
oleDbDataAdapter1.SelectCommand.CommandText = "
SELECT
 FDI.FDI_ID, FDI.FDI_Name,  FDI.Colour, FDI.Construction
FROM
 (((FDI INNER JOIN FireRisk ON FDI.FDI_ID = FireRisk.FDI_ID) INNER JOIN Slope ON FireRisk.Slope_ID = Slope.Slope_ID) INNER JOIN VegetationType ON FireRisk.Veg_ID = VegetationType.Veg_ID) INNER JOIN Distance ON FireRisk.Distance_ID = Distance.Distance_ID
WHERE
 (((VegetationType.VegetationName)=\"" + vegType + "\") AND ((Slope.SlopeMin)<= slope.ToString()) AND ((Slope.SlopeMax)>= slope.ToString()) AND ((Distance.DistMin)<=" + distance.ToString() + ") AND ((Distance.DistMax)>=" + distance.ToString() + "))";
```

Bushfire Propagation Model

A cellular automata (CA) fire propagation model was used to simulate the effect of a bushfire on the terrain and to visualise the impact that the migration procedures had on the fire. Such a visualisation is useful in showing the advantages of certain mitigation and or building placement on the property.

CA have been used to model bushfires propagation by numerous researchers (Rothermel 1972, Sullivan and Knight 2004, Wainer 2004,). This CA model utilises local cell-based rules to determine the spread of fire over the landscape. These rules incorporated a fuel layer that was combined with a simple wind direction variable in order to control the propagation, speed and direction of the simulated bushfire.

The terrain used by the VR bushfire mitigation tool represents a 1km x 1km square. This terrain was split into cells of size 1m x 1m. Each of these cells was assigned a value between 0 and 10 to represent amount of fuel that a particular cell had available to a prospective bushfire. For example, all bitumen roads had a fuel value of 0 and would not burn, whereas the forest had a value of 10 and would burn with the greatest intensity and for the longest period. A wind direction variable was used to control to propagation direction and speed.

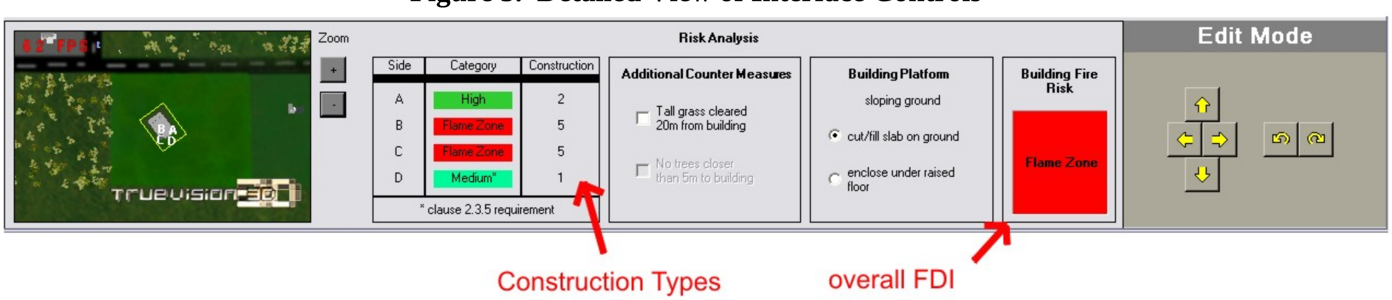
The CA continually updated each cell given the conditions of the cell's local neighbourhood. If a fire was started in any cell that had fuel, the fire could potentially propagate to any, if not all, of the 8 neighbouring cells. The fire propagation was controlled by the local function of the CA. In this study, the CA allowed the fire to propagate only in the direction of the wind and if the presence of fuel existed in that cell.

The bushfire propagation model was a very simple naïve model and was intended to be used as a proof of concept only. The effect of convection and wind interaction above the ground on the behaviour and spread of the fire was not addressed in this model. In addition, the model does not allow for spotting ahead of the fire front, and in fact a fuel-free region of just 1 m across with stop the fire. These are just some of the limitations of the current fire model. It was intended that as more comprehensive models become available they could easily be incorporated into the VR bushfire mitigation tool.

Results and Discussion

A demo VR bushfire mitigation tool was built and tested. Various screen shots of the demo application are shown in Figure 6. Once a new building is added to the property parcel the FDI and recommended construction material is calculated for each of the sides of the building. This information and the overall FDI of the building's position were displayed in the lower section of the application interface as illustrated in Figure 5. The VR interface remains in edit mode which allows the building to be rotated and move to any position of the property parcel. As location and/or orientation of the building changes, so too does the FDI and construction type values displayed to the user. Figure 6(a), (b) and (c) shows FDIs and construction types for three different locations and orientation combinations. The location and orientation is best observed by looking at the plan view section which can be found the bottom left section of the VR interface.

Figure 5. Detailed View of Interface Controls



The VR interface uses a typical first-person shooter style found in many popular computer games. All the controls for navigation and movement have been standardised with controls from this style of computer game. The advantage of first-person style is that the user can fly down to the building, change to walk mode and get an idea of the view the building would have at alternate locations. The user could also navigate to the adjacent street front and see what the street appeal would be again for alternate locations on the property parcel. The user also has the ability to show an

avatar to help get a sense of scale as shown in Figure 6(b). Other bushfire mitigation techniques that have be incorporated into the VR bushfire mitigation tool are clearing tall grass near buildings, cut/fill slab building platform and enclosing under a raised floor. Clicking "tall grass cleared 20m form building" option causes a change in colour of the grass rounding the building as shown in Figure 6(c). This option is not just visual eye candy, but will also update the fuel available in the area selected, this will in turn affect the fire propagation model and will limit the spread of fire in the area.

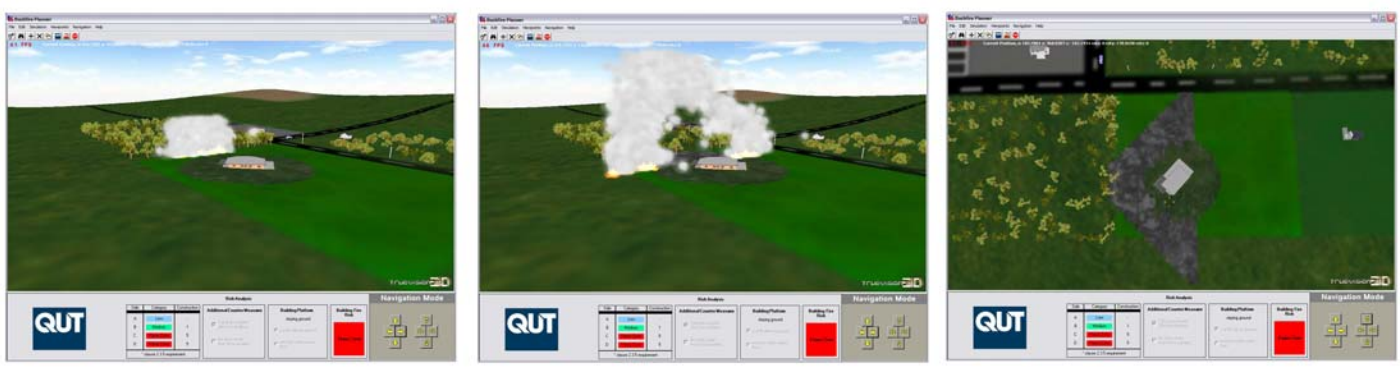
Figure 6. Screen Shots of Demo Application

(a) (b) (c)

The VR bushfire mitigation tool utilises Truevision3D's in built particle emitter to achieve the visual simulation of fire. This method was combined with the CA fire model to produce the visual impression of a fire front propagating across the landscape. As per the CA fire model rules, if the cell is burning then it will emit fire and smoke particles. Once the fuel for a cell is depleted no fire or smoke is emitted and the cell is changed to a charcoal colour to simulate the charred landscape left behind in the wake of the fire front. The results of this technique are shown in Figure 7, in this case the fire starts in the forest vegetation to the west of the building as seen in Figure 7(a). Note that the "tall grass cleared 20m around building" option has been selected in this example. As expected, the fire propagates in an easterly direction and splits as it encounters the cleared glass as demonstrated in Figure 7(b). Finally, the fire simulation can be stopped at any time and the resulting fire path, which is displayed as a charcoal scar on the landscape, can be analysed as per Figure 7(c).

Figure 7. Visual Simulation of Fire Model

(a) (b) (c)



The prototype VR bushfire mitigation tool was demonstrated to a group of approximately 50 people at a workshop organised by QUT and the Department of Public Works. This group was made up of representatives from fire services, fire research communities, local councils and state government. Feedback from this group showed that there is a high level of interest and potential for this type of application.

Conclusions

The virtual reality bushfire mitigation tool presented in this paper will facilitate community consultation, and thus stimulate behavioural change with regard to fire mitigation. The first-person shooter style is well known to computer gamers and will facilitate rapid uptake of the VR interface. The VR bushfire mitigation tool can show the advantages of alternate mitigation measures by allowing the users to run fire simulations on multiple configurations of the property

layout. The visualisation of the fire model's footprint (visualised as a charcoal scar on the landscape) could be useful in evaluating alternate fire models and comparing them against the existing damage done to actual terrain, where the terrain modelling is adequate.

The novelty of this research is the integration of bushfire modelling and DR05060 standard with a VR interface that will allow users to assess alternate bushfire mitigation scenarios. The significance of this work is its ability to improve community bushfire awareness and stimulate behavioural change which will directly reduce property damage and potentially save lives within the rural/urban interface.

Future Work

The current project has funding available for further development of the VR bushfire mitigation tool. In the near future, the product will be developed into two separate applications, which are aimed at non-expert and expert users respectively. The non-expert application will require the development of a web-based VR version. This web-based version will have a generic property and will allow users to edit the parameters such as building material, vegetation and terrain. The expert version will require the development of PC-based version, which interfaces with real GIS data to obtain vegetation and terrain information.

Acknowledgements

This research is supported by the Built Environment Research Unit of the Queensland Government.

References

Ali, N. and Ferdig, R. (2002) *Why not Virtual Reality?: The Barriers of Using Virtual Reality in Education*, Proceedings of Society for Information Technology and Teacher Education International Conference, Nashville, Tennessee, USA.

Australian Standards Limited (1999) *Building Standard AS 3959-1999 Construction of buildings in bushfire-prone areas*, www.standards.com.au accessed on 30 - Nov - 2005

Australian Standards Limited (2005) *Building Standard DR05060 Construction of buildings in bushfire-prone areas (Revision of AS3959-1999)*, www.standards.com.au accessed on 7-Feb- 2005.

Beringer, J. (2000) *Community fire safety at the urban/rural interface: The bushfire risk*, In Fire Safety Journal, **35,** pp. 1-23.

Bucolo, S., Ginn, S., Gilbert, D. and Hayes, J. (2003a) *Transit Oriented Sustainable Urban Developments – Enhancing Community Consultation through Web Based Virtual Environments*, Proceedings of 1st international conference on Computer graphics and interactive techniques in Australasia and South East Asia, Melbourne, Australia, pp. 271-272.

Bucolo, S., Ginn, S. and Gilbert, D. (2003b) *Using Virtual Reality Models to Better Communicate How Transport Infrastructure can Interface and Interact with the Built Environment*, Proceedings of 21st ARRB Conference, Cairns, Australia.

Bushfireinfo.com (2003) *Bushfireinfo.com - your essential guide to surviving another bushfire season*, www.bushfireinfo.com accessed on 30 Nov 2005.

Heame, W. and Webster, J. (2003) *A picture tells a thousand words*, http://www.housit.org.uk/vr/index2.htm accessed on 20 Mar 2006.

Mortiboys, W. and Butt, C. (2003) *Use of technology to aid the consultation process*, Staffordshire County Council.

Queensland Government (1994) *Reducing The Risks - Keeping Your Home Safe From Fire*, In Between the Leaves - The DPI Forestry & Department of Natural Resources Journal**,** pp. 18.

Ramsay, G. C., McArthur, N. A. and Dowling, V. P. (1996) *Building in a fire-prone environment: Research on building survival in two major bushfires*, Proceedings of Living in a Fire Prone Environment, Vol. 116 Linnean Society, Sydney, NSW, pp. 133-140.

Rothermel, R. D. (1972) *A mathematical model for predicting fire spread in wildland fuels*, In USDA Forest Service Research Paper INT-115**,** pp. 40.

Sullivan, A. L. and Knight, I. K. (2004) *A hybrid cellular automata/semi-physical model of fire growth*, Proceedings of 7th Asia- Pacific Conference on Complex Systems, Cairns, Australia.

Summerville, J. A., Buys, L., Ginn, S., Bucolo, S., Walker, A., Gard, S. and Bell, L. (2005) *Engaging people in environmentally sustainable behaviours using interactive Virtual Reality: a conceptual framework*, Proceedings of Social Change in the 21st Century 2005 Conference, (Eds, Bailey, C. and Barnett, K.) Brisbane, Australia.

Truevision3D (2006) *TV3D SDK 6.2 Visualisation Engine*, http://www.truevision3d.com accessed on 20 Mar 2006.

Wainer, G. A. (2004) *Modelling and simulation complex systems with CELL-DEVS*, Proceedings of Winter Simulation Conference, (Eds, Ingalls, R. G., Rossetti, M. D., Smith, J. S. and Peters, B. A.).