Effectiveness of VRML Building Models for Direction Finding

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Abstract

This paper describes an experiment which aims to examine the effectiveness of a Virtual Reality Modelling Language (VRML) building model compared with equivalent architectural plans, for direction finding purposes. The effectiveness issues being primarily investigated were task completion times and number of tasks completed overall. The experiment involved a series of tasks where participants had to find a number of locations/objects in a building unknown to them at the outset of the experiment. Statistically significant results are presented for the benefit of the research community, law enforcement officers and fire fighters where it is clear that in this context, the VRML model led to better task completions than the equivalent architectural plans. Regarding the task completion times, no statistical significance was found. This experiment is highly relevant to the research community, law enforcement officers and fire fighters. Given the current climate of security issues and terrorist threats, it is important that law enforcement officers have at their disposal the best information possible regarding the layout of a building, whilst keeping costs down. This also applies to fire fighters when rescuing victims. This experiment has shown that a VRML model leads to better task completions in direction finding.

1 Introduction

In the current modern world emergency services play a constant and important role in safeguarding security and dealing with general emergencies. Fire fighters have to deal with various situations involving fires in buildings of all kinds. Law enforcement officers are constantly being challenged by new threats and new extreme terrorist acts.

Concerning fire fighting, fire crews have the problem of finding unconscious people in a building full of smoke. While they are well equipped to deal with this situation it would be of benefit to them to always use the latest technology available.

Concerning law enforcement personnel, they unfortunately have to sometimes deal with extreme terrorist acts. One of these is the holding a building under siege with hostages. While such personnel are highly trained and make use of various technologies it would benefit them to always use the latest equipment or techniques available to aid their job.

One of the technologies available is the use of Virtual Reality (VR) to model buildings, such as public buildings or buildings of strategic importance. Having an accurate VR model of a building could help fire fighters ‘learn’ in a short period of time the layout of a building and positioning of key items in a building. Alternatively law enforcement personnel could ‘learn’ the layout a building along with the positioning of key items for the unfortunate situation of a building being under siege. Sometimes terrorists have spent considerable time and effort in learning all they can about the layout of a building. This can possibly disadvantage law enforcement personnel who do not know the layout of a building. Currently various techniques are used to counter this situation, e.g. consulting floor plans and having ‘resource officers’ visiting certain schools on a daily basis (Scallan, 2004). Further the use of VR in helping to train personnel in the kinds of situations mentioned above (and other contexts, e.g. (Li et al, 2000)) is being investigated/used by other organisations, e.g. the Sandia National Laboratories are using VR to ‘familiarise law enforcement teams with scenarios’ involving hostage rescues (‘Sandia National Laboratories’, 2005). Also in (Querrec, 2003) virtual environments are being used for training fire fighters. Further work in such training contexts can be seen in ('PoliceOne.com', 2005) and ('Virtra Systems', 2005).

Most of this kind of work centres around scenarios etc. However there does not seem to be much work going on to address the basic situation of direction finding in an unfamiliar environment using basic equipment and software (i.e. not specialist hardware/software). This paper makes a contribution to the issue raised. Hence the results of an experiment, conducted using a VRML (Virtual Reality Modelling Language) model of a university campus building are presented in this paper. The main aim was to determine if the VRML model led to better task completions in direction finding within the building and shorter time completions for direction finding, compared with an architectural drawing of the same building. The results are of interest to anyone involved with direction finding, particularly in the areas of fire fighting or law enforcement.

2 Design and execution of experiment

2.1 Background issues

The experiment was carefully designed to ensure the conditions under examination were biased as little as possible.

The first step was to find a suitable building to model. The building used in the models was a campus building that was considered by the authors to be of a suitable size. This meant that it was not too large for both the purposes of modelling and experimental testing. Further, the experiment required a building unfamiliar to the prospective users. The building used fulfilled all these criteria.

The second step was to visually analyse the internal aspects of the building and to catalogue various features of the building, e.g. location of fire extinguishers (for the purposes of future task design).

The third step was to obtain accurate architectural diagrams of the building and then develop accurate external and internal models of the building, using the Virtual Reality Modelling Language (VRML).

2.2 Task design

The next aspect considered was the design of appropriate tasks that would elicit the information the experiment was trying to achieve. This was mainly to discover if a VRML model was more effective than an architectural diagram for direction finding tasks. Effectiveness was defined as leading to a quicker overall task completion time and higher score (see next paragraph for details on the scoring mechanism).

A series of 16 tasks were designed which involved finding various locations and items within the chosen campus building. The particular locations/items were building evacuation refuge locations, fire escapes, fire extinguishers, fire alarm panels and fire hoses. Users finding specified locations/items would accrue a series of points. Some locations/items, due to where they were located in the building were considered to be easier to find and were therefore given fewer points than other locations/items considered to be more difficult to find. The points system used was also weighted to take into account the fact that with certain locations/items finding one item would make it easier to find the next item. In these particular cases, the first find accrued more points than the second find. Also the particular locations/items used for the tasks were ones where finding them required some 'searching'/'recall', i.e. they could not be found by simply standing at the entrance of the building and visually scanning the immediate environment. An example concerning the building evacuation refuge locations is that the ones used in the experiment were on the first floor and second floor middle staircases. Whichever of the two was found first (thus allowing for different user direction finding strategies), 4 points were allocated with 2 points allocated if the second refuge location was found. The points assigned to each location as explained above were to do with the overall difficulty of finding these locations.

Having decided on the tasks users should perform, the overall scores of the tasks would be used to see which of the modes being tested was better, i.e. each user's score would be summed to get one score and then all the scores would be analysed to see if one mode (VRML model or architectural drawing) led overall to higher scores. Also users would be timed and the aim would be to see which mode would lead to faster completion times.

2.3 Experiment procedure

Thirty participants were recruited to take part in a between users experiment. Each participant was given a pre-experiment questionnaire which aimed to determine their personal experience and characteristics. Various questions were included in the questionnaire. The main questions dealt with issues of the participant's experience with computers, Virtual Reality and knowledge about building fire procedures. Participants were also asked if they had ever been in the campus building that was to be used in the experiment. Clearly, if a prospective participant had prior knowledge about the building, it would invalidate any results for the experiment.

Having received completed questionnaires, the participants were then asked to take part in a pre-experiment screening. This aimed to determine/add to their current skills in either using VRML controls at the user interface or the reading of architectural plans in general. It also allowed the participants to see the kind of interaction they would have to be involved with when the experiment was started. The pre-experiment screening involved using a different VRML model and architectural plan to the ones used in the actual experiment. The VRML model used for this purpose was the main example used in (Hartman & Wernecke, 1996). The architectural plans used were John Adams' Courthouse MS USA ('The Historic Renovation of the John Adams Courthouse', 2004).

The participants using the architectural plans were given 20 minutes to study these. Then the plans were removed from the participants and subsequently were given 5 minutes to complete a multiple choice test, which covered various locations and characteristics of the Courthouse. If the participants obtained a score of 50% or more in the multiple choice test, they were considered to be suitable participants. This criterion was applied because in the real world individuals such as law enforcement officers etc, are expected to have certain skills to an appropriate level. Also this means that there should not have been extreme wide ranging levels of skill, which could have biased the final results.

The participants using the VRML model were selected as having a moderate amount of computer experience, as stated on the pre-experiment questionnaires they completed. They were given the VRML model and were asked to explore the model over a 20 minute period. During this time the participants were informally observed to ascertain their competence with the VRML navigational controls at the user interface. All participants in this group demonstrated competence in using the VRML controls.

As indicated above each participant was assigned to one of two groups. The first was the architectural plans group and the second was the VRML model group, dependent on the criteria described above.

The 15 participants selected for the architectural plans group were then given the diagrams for the campus building. Each participant was given 25 minutes to study the plans, which covered four floors in total. Relevant locations/items were clearly marked on the diagrams.

The 15 participants selected for the VRML model group were then asked to explore the VRML world of the campus building using the same VRML browser they had used during the pre-experiment screening process. Each participant was given 25 minutes to study the model. The model included the locations/items of relevance to the experiment. Further, locations were 'marked' in the model by means of white cubes containing location names.

The information presented in both modes (i.e. architectural plans and VRML model group) was identical. However the manner of the information presentation was different.

Once all participants (i.e. both groups) had completed the study of the campus building, each participant was briefed concerning what would happen in the next stage of the experiment. The following briefing points were made clear to each participant:

1) Participants would be physically accompanied/followed to the campus building (the technique of actually taking a participant to a real location was considered to be more realistic and has been successfully used and described in (Murano, 2003)) and be asked to find a series of locations/items based on their study of the campus building.
2) Participants would be asked to locate a subset of the locations/items they had seen on their preparatory study for the experiment.

3) Depending on the type of locations/items involved, the set of tasks would be divided into related sections. Thus the experiment would take place by completing a series of sections.
4) Participants would be timed with a stopwatch.
5) Participants would have 2 minutes for each individual task. If this time was exceeded the particular task in question would be stopped and the next task would be started.
6) Participants would not be allowed to ask questions to aid their direction finding. Further, only 1 answer per task would be allowed.
7) If a location/item could not be found by the participant they could either attempt an answer or move to the next task.
8) Data would be recorded by the experimenter as the experiment tasks proceeded.
9) Participants would be able to ask clarifying questions regarding the briefing instructions described above.

At the end of the experiment all participants were asked to complete a post-experiment questionnaire. Certain questions were identical for both groups. However the VRML model group had a supplementary set of questions regarding the use of the VRML browser.

Both groups of participants were asked several subjective questions concerning how the participants felt they had ‘learned’ the locations for the tasks. They were also asked if in their opinion they had been given enough time to ‘learn’ the locations and actually find them during the experiment.

The VRML model group were also asked several subjective questions regarding the model itself, e.g. accuracy of the model in relation to the real building and also questions regarding the ease of use of the model. Further, they were asked their opinions regarding the issue of ‘learning’ locations by the specific use of the VRML model.

2.3.1 Pilot study

Before the actual experiment took place a small pilot study was undertaken to test the experimental design for soundness. One of the reasons for having included a pre-screening stage to the experiment was that the pilot study revealed that in the VRML model condition a usage of time was incurred in becoming familiar with the particular VRML browser used in the experiment. Thus the pre-screening process gave the participants the opportunity of familiarising themselves with the VRML controls thus lessening the possibility of bias during the actual experiment.

Also, being able to run through the experiment allowed the maximum times to be established for each task. These were set to 2 minutes and based on what was observed during the pilot study, this was considered to be a reasonable amount of time for each task. The time of 2 minutes was actually more than was required for the completion of a task. This would allow for participants who may have been naturally slightly slower in nature.

3 Results

Some interesting and useful results were obtained. Firstly, regarding the times taken to complete the tasks, no statistically significant results were obtained. A t-test was used, based on the overall time taken for all the tasks, to determine the significance or lack of significance concerning how quickly the tasks were completed. The times under the VRML model condition were compared with the times for the architectural plans group. Table 1 below shows the actual figures obtained for the t-test:

Table 1: T-test - Task Times - VRML World and Architectural Plans Conditions

t-Observed	0.61
t-Critical (5%)	2.05

However the rate of success in the task completions was higher under the VRML model condition. Participants achieved higher scores under the VRML world conditions, i.e. the tasks were more successfully completed under this condition. This was a statistically significant result. A t-test was used, based on the overall scores obtained for all the tasks, to determine the significance or lack of significance concerning the success of task completions. The scores under the VRML model condition were compared with the scores for the architectural plans group. Table 2 below shows the actual figures obtained for the t-test:

Table 2: T-test - Task Completion Success - VRML World and Architectural Plans Conditions

t-Observed	2.29
t-Critical (5%)	2.05

Secondly, subjective opinions were elicited from the participants by means of a post-experiment questionnaire. The questionnaire was designed as a series of questions accompanied by a set of answers on a Likert scale, where 1 was a completely negative response and 5 was a completely positive response.

The most interesting aspects concerned the participants' impressions of how they 'learned'. The users of the VRML model reported not actually memorising the items/locations. They grouped the items/locations together and did not pay any attention to compass directions. The users of the plans instead reported learning the positions of items/locations one floor at a time. They did not group items/locations together and they actually used the compass directions on the plans. The mean participants' responses and accompanying standard deviations (SD) are shown below in Tables 3 and 4:

Table 3: Participants' Subjective 'learning' impressions (VRML Model Group)

	Mean	SD
Locations Memorised	2.13	1.13
Locations 'Automatically' Remembered	4.00	1.00
Locations/Objects Learned on Floor-by-Floor Basis	2.60	1.30
Locations/Objects Learned by Grouping Each Type Together	4.00	1.20
Locations/Objects Learned by Use of Compass Directions	2.13	1.53

Table 4: Participants' Subjective 'learning' impressions (Architectural Plans Group)

	Mean	SD
Locations Memorised	4.70	0.49
Locations 'Automatically' Remembered	1.90	0.64
Locations/Objects Learned on Floor-by-Floor Basis	4.90	0.40
Locations/Objects Learned by Grouping Each Type Together	2.00	0.70
Locations/Objects Learned by Use of Compass Directions	4.60	0.51

Finally, most users felt that they had been given enough time to study the architectural plans/VRML model and carry out each task. In addition, the VRML model group indicated clearly that the accuracy of the VRML model in relation to the real building was to a very good standard and that the VRML model was easy to use.

4 Conclusions

As can be seen from the previous section there is no statistically significant evidence to suggest that the VRML model group was faster than the architectural plans group with respect to task completions.

However the task completion rate was higher under the VRML model group with statistically significant results.

The aspect concerning speed of task completions and the lack of statistical significance simply shows that the two groups were well balanced in terms of ability to travel around an environment on foot. This had not been a specific requirement for the experiment. However no user taking part in the experiment was physically impaired in any way.

The interesting aspect concerns the evidence which suggests that a VRML model, in this context, leads to better task completions. This is a very important finding as a higher rate of task completions in a real world could potentially save lives, particularly in the context of fire fighting and/or law enforcement.

The other interesting aspect concerns the way the participants reported their manner of learning. Tables 3 and 4 in the previous section show interesting participant self-reported learning mechanisms. These all have either quite low or very low accompanying standard deviations. These show a high consistency in the participant responses. This suggests that participants in each of the two groups were using similar ‘learning’ strategies, dependent on the mode of information presentation.

The uses for this experimental finding are that it could help fire fighters improve their direction finding skills. Also if models were widely available for public buildings, it could help law enforcement personnel to deal with a worst case scenario of a terrorist siege. The suggestion being made is not to abandon current training/practices. However, these should be augmented by the use of VRML models as they give the user a valuable insight not available with architectural plans and the experiment indicates that the internals of a building are learned in a more useful way than with architectural plans on their own. VRML models of key buildings should be available for fire fighters and law enforcement officers.

One drawback of this suggestion is that VRML models would have to be constantly kept up to date as sometimes the internal configuration of buildings can change due to refurbishment etc.

A further aspect this experiment has shown is that powerful useful visual information can be conveyed to users with basic equipment and software (i.e. not specialist hardware/software). It would be simple to have a model on a laptop PC and carry this to any appropriate location. Linked to the issue of costs is the fact that VRML models can be built in different ways. One way is from first principles, which requires more specialist knowledge. However, VRML building tools are also available thus making the building of a VRML world accessible to non-computer scientists.

5 Further work

The experiment generated some interesting results. However the experiment also raised issues requiring further investigation. The first issue concerns the campus building modelled in VRML. As stated above, the campus building was not a huge intricate building, even though it was big enough to conduct the experiment. It would therefore be interesting to find out if the same results would be obtained with a larger more intricate building, such as a public government building.

The second issue would be to involve real fire fighters and law enforcement officers in another experiment, perhaps including an emergency scenario.

The third issue involves the scores obtained concerning the participants’ perceived self-learning mechanisms. As can be seen in the results section above, users in each of the two groups consistently showed themselves to be adopting similar learning strategies depending on which group they had been assigned to. It would be useful to find out if this effect was due to participants subconsciously adjusting their manner of learning depending on the mode of presentation of the information. This issue could also involve screening users concerning their own particular learning strategies. This in turn would require linking with existing learning theories and/or other issues of human cognition. If it could be determined that certain styles of learning affect the recall of an ‘environment’, fire fighters and law enforcement officers could be screened in advance so that in an emergency situation they could be given a particular type of visual information based on their learning style.

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7 References

Hartman, J. & Wernecke, J., (1996) The VRML 2.0 Handbook Building Moving Worlds on the Web. Addison Wesley.

The Historic Renovation of the John Adams Courthouse, (2004) Architectural Plans, http://renovation.socialaw.com/archplans.htm, Accessed 2005.

Li, Y., Brodlie, K., Phillips, N., (2000) Web-Based VR Training Simulator for Percutaneous Rhizotomy, Medicine Meets Virtual Reality, Edited by Westwood, J.D., Hoffman, H.M., Mogel, G.T., Robb, R.A. and Stredney, D., IOS Press, p. 175-181.

Murano, P., (2003) Anthropomorphic Vs Non-Anthropomorphic Software Interface Feedback for Online Factual Delivery, 7th International Conference on Information Visualisation (IV 2003) An International Conference on Computer Visualisation and Graphics Applications, London, England, 16-18 July, © IEEE

PoliceOne.com (2005), New Virtual Reality Training Targets Homeland Security Advanced Interactive Systems, Inc., Expands Ability to Develop Synthetic Environments. http://www.policeone.com/police-products/training/simulator/press-releases/75123/ Accessed 2005.

Querrec, R., Buche, C., Maffre, E., Chevallier, P., (2003) SecuReVi: Virtual Environments For Fire Fighting Training, VRIC 2003 (Colloque Laval Virtual 2003 Cinquième Conférence Internationale Sur La Réalité Virtuelle) p. 169-175, Laval, France, 14-16 May.

Sandia National Laboratories, (2005) Hostage Rescues Honed in Virtual Reality Simulation, http://www.sandia.gov/media/vr.htm – Accessed 2005

Scallan, M.M., (2004) Terrorist Threat Poses Challenge for Mississippi Schools, Biloxi Sun Herald via Associated Press http://www.officer.com/article/article.jsp?id=16882&siteSection=8. 10.9.04 – Accessed 2005

Virtra Systems, (2005) http://www.virtrasystems.com. Accessed 2005.