Guiding user navigation in virtual environments using awareness of virtual off-screen space

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Abstract

Navigation in virtual environments can be difficult. One contributing factor is the problem of user disorientation. Two major causes of this are the lack of navigation cues in the environment and problems with navigating too close to or through virtual world objects. Previous work has developed guidelines, informed by cinematography conventions, for the construction of virtual environments to aid user comprehension of virtual "space" to reduce user disorientation. This paper describes the validation of these guidelines via a user study involving a navigation task in a virtual "maze". Results suggest that the use of the guidelines can help reduce the incidences of user disorientation. However, the guidelines seemed to have little impact on users' abilities to construct 'cognitive maps' of the environment.

1 Introduction

Usability problems associated with navigation and exploration of virtual environments are attributable to many causes. These include, the lack of navigation or wayfinding cues to guide users around the environment [1], problems when the whole display screen is reduced to one colour or texture whilst navigating too close to [3][4] or through virtual objects [5], the cognitive load that is placed on the user [10] and the restricted field-of-view seen through the display screen [9]. Any one or a combination of these may result in user disorientation. This is problematic as navigation is typically the central and most frequently performed activity in a virtual environment.

In this paper, we present the results of a study to test guidelines [6] for the construction of virtual environments that promote user-centered navigation. This work is being carried out as part of the INQUISITIVE project [2], a three-year research project funded by the UK EPSRC between groups at the University of York and the CLRC Rutherford Appleton Laboratory (RAL). The aim of the project is to develop methods and principles that can be used to improve the design of interfaces for virtual environments. The work described in this paper focuses on one common usability problem in the navigation and exploration of virtual environments - user disorientation.

2 Background

Marsh and Wright [6] propose the use of design guidelines, informed by cinematography conventions, for the construction of virtual environments to aid users' comprehension of "virtual off-screen space" in order to reduce user disorientation. "Virtual off-screen space" is the space that exists beyond the confines or borders of a user's current view port that is seen within the restricted field-of-view of the display screen, e.g. desktop, Head Mounted Display (HMD), projection screen, etc. It is anticipated that the application of the guidelines will provide users with visual cues to unconsciously predict the contents and/or shape of the immediate surrounding space in addition to that seen within the display screen's restricted field-of-view. That is, the space that is seen on-screen – within the display screen – implies additional space that is not seen through the current view port and is in off-screen space. Hence, users are provided with a greater knowledge of their immediately surrounding virtual space and we propose that this will aid navigation of virtual environments (VE).

Two of the guidelines defined by Marsh and Wright [6] involve the cinematography conventions for *exit and entry points* and *partially out of the frame*. In the context of virtual environments, they identify *exit and entry points* as doors, paths, roads etc. that lead out of the screen and *partially out of the frame* as familiar objects shown partly in the current view frame. The proposed guidelines for these two conventions are:

- *exit and entry points:* wherever possible, it must be clear to the user that there exists the option to exit the area contained within the confines of the display screen.
- *partially out of the frame:* the placement of objects in the virtual environment should be such that there is always more than one object partially in the user's field of view.

This paper describes a study to investigate the validity of these guidelines. In the current work this focuses on the latter guideline and to a lesser degree the former. That is, the guideline *partially out of the frame* will be manipulated. It is anticipated that the guidelines will appear natural and transparent, support user navigation by reducing the number of usability problems (wall collisions and walking through virtual objects) and hence, reduce user disorientation. This work is part of a larger effort to develop design principles to help maintain the users' illusion of interacting within 3D virtual space and thus, to increase the users' virtual reality (VR) experience [7].

3 Study

A study was developed to test the effectiveness of Marsh and Wright's [6] guidelines in an attempt to reduce usability problems associated with navigation and exploration within virtual environments, and in particular, to reduce user disorientation. The study consisted of two groups. Both were required to carry out a navigation task in a virtual environment; one with the design guidelines implemented and the other, in the same virtual environment without the guidelines. The test desktop-based virtual environment used in the study is a “virtual corridor” or maze implemented in the Windows version of GNU MAVERIK [8]. In this study, collision detection was turned off, that is, subjects are able to walk through virtual objects. The maze with guidelines consisted of pictures, picture frames, wall panels, and dado rails, etc. mounted along the walls of the virtual corridors. Their placement was in accordance with the guideline for *partially out of the frame*. The maze had neither windows nor doors, had one entrance, one exit and a corridor or pathway connecting them; these are the *entry and exit points* according to this guideline. As the *entry and exit points* were the same for both mazes, any future reference to the guidelines will therefore apply to those *partially out of the frame*. An example of a point-of-view with and without the guidelines is shown in figure 1.

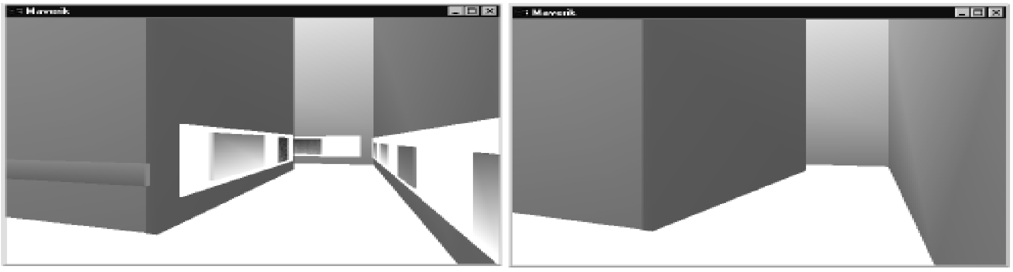


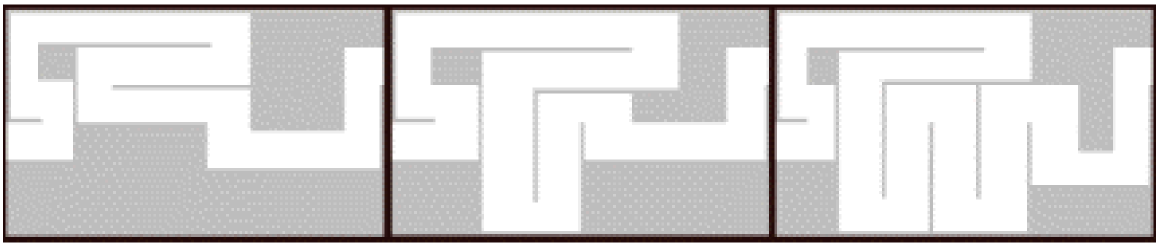
Figure 1. A portion of the virtual corridors/maze with and without the guidelines

The study will attempt to answer the following questions - do the guidelines:

- appear natural and transparent, that is, are not identified as guidelines
- provide visual cues to help guide participants through virtual space
- imply to users the existence of space other than that which is seen within the confines of the restricted field-of-view, that is, imply virtual off-screen space
- aid in the construction of a ‘cognitive’ or mental map
- re-enforce the illusion of interacting within virtual space
- increase a participant's virtual reality experience

3.1 Method

Eighteen paid volunteers recruited through University notice boards and an internal web site took part in the study. These consisted of five females and thirteen males with ages ranging between eighteen and thirty-five. All had previous experience of computer games, describing themselves as 9 novices and 9 experienced users. Three had VR experience, two of desktop and one of HMD VR. Subjects were allocated study time slots and alternately placed in one of the two groups, with and without guidelines. From a first person perspective (field-of-view as if one was in the environment) subjects were asked to move through the “corridors” of a virtual building controlling their movements using the cursor/arrow keys on a standard keyboard until the exit was reached. Immediately following the navigation task, subjects were asked to identify a 2D plan or birds-eye view of the “virtual corridors” from either of three different maps. The three maps can be seen in figure 2; map ‘B’ is a plan-view of the “corridors” or maze used in the study. A video recording of the study was made for further analysis.



(A) Simplified maze **(B) Actual maze** **(C) Complex maze**

Figure 2. 2D plan-view of corridors (maze) within the virtual building

3.2 Results

Twelve subjects rated the speed of movement through the corridors to be acceptable – neither too fast nor too slow. Three novice and two experienced subjects thought the movement was a little too fast, and one experienced subject found the movement a little slow. Sixteen subjects found the keyboard control easy to use and three novice users found it to be a little difficult. As shown in table 1, eight subjects out of each group collided with walls and this occurred a similar amount of times. Only three subjects with guidelines walked through the walls, in contrast to six without guidelines. Nine subjects chose the correct map B, only three of these had guidelines. Nine chose incorrect maps and of these, eight opted for map C (five with guidelines).

	Guidelines	*Without guidelines*
collided with walls	8	8
walked through walls	3	6
map: A	1	0
map: B	3	6
map: C	5	3
disorientated	3	6
awareness of activities external to study task	1	3
breaks in attention	4	3

Table 1. Summary of study results

In the debriefing questionnaire nine subjects acknowledged feeling disorientated at some point moving through the VE - three with guidelines and six without. Identifying the cause as walking through walls for all three with guidelines and for those without: three identified walking through walls, two the colours of the walls, and one moving in a 'closed environment – i.e. unable to get bearings' because there are no 'windows or pillars, etc'. Four subjects (one with guidelines) said that they were aware of activities external to the study navigation task (e.g. people walking past/close to the study laboratory, the sound of typing in the distance and awareness of the study evaluator). Seven subjects acknowledged breaks in their attention or concentration from the study navigation task. Five identified the cause as walking into or through walls (three with guidelines and two without), one the colours of walls (without) and one subject with guidelines took time out of the study task to admire the pictures on the walls.

4 Discussion and Conclusions

Although the same number of subjects from each of the two groups momentarily collided with the corridor walls and this occurred a similar number of times for subjects from both groups, those without guidelines however, walked through walls twice as many times as those with guidelines. This demonstrates that the guidelines used in the study were more effective in guiding subjects through the virtual corridors and thus, aided navigation in the virtual environment used in this study.

In the two dimensional (2D) maze recognition test, subjects with guidelines surprisingly scored lower than those without guidelines. Of the nine subjects who chose the correct maze ‘B’, only three had guidelines. One likely explanation for this is that the guideline, *partially out of the frame*, provides visual cues to imply the contents and/or the shape of the off-screen virtual space that immediately surrounds the display screen. Although this helps to guide subjects through the virtual corridors, by allowing them to anticipate or predict the space outside the display screen’s field-of-view on a small-scale, this however, seems to play little part in the construction of users’ knowledge of the spatial layout of the environment on a large-scale. Additionally, the majority of subjects with guidelines (five) opted for the more complex map ‘C’. This suggests that the use of the guideline for *partially out of the frame* (with additional objects, textures, etc.) implies a more complex environment.

Only one subject acknowledged that the guidelines had momentarily caused them to break their attention from the study navigation task to admire the pictures on the walls. That is, the pictures used as guidelines evoked interest and/or curiosity, and although it is reasonable to suggest that the subject’s concentration was momentarily broken from the study navigation task the subject, however, remained attached to the illusion created within the virtual environment. Neither of the remaining subjects with guidelines mentioned that the guidelines and their placement had broken their concentration to the study task nor were they identified as having been the cause of disorientation. This suggests that the guidelines appeared transparent to most subjects and blended naturally with the study virtual environment.

Of the nine subjects who felt disorientated at some point within the virtual environment, only three had guidelines and all of these identified the cause as walking through walls. Those without guidelines identified various reasons: three identified walking through walls, two identified the colours of walls, and one subject identified the cause of disorientation as moving in a ‘closed environment’ with no windows or pillars to get bearings. Finally, only one subject with guidelines acknowledged being aware of activity external to the navigation task during the study (awareness of the study evaluator) in contrast to three subjects without.

5 Further Work

A further study has been carried out in the virtual corridors with collision detection applied. Analysis of the results is currently underway and a comparison with the work presented in this paper (i.e. with no collision detection) will be made.

6 Acknowledgements

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