

Manipulating the Future: Predictor Based Feedback for Velocity Control in Virtual Environment Navigation

Dale Chapman and Colin Ware

Faculty of Computer Science
P.O. Box 4400
University of New Brunswick
Fredericton, N.B.
CANADA E3B 5A3
Address correspondence to Ware
at above address or cware@UNB.ca

Abstract

This paper introduces a predictor based visual feedback aid for navigating through virtual environments using velocity control. The predictor indicates to the user where and how fast he or she is travelling and has a direct manipulation feel to it. Experiences using the predictor to navigate over digital terrain maps are discussed, which show it to be an aide in learning to use velocity control and in creating smooth flight paths over thinned wire frame representation of a scene for subsequent single frame animation. Measurements of performance in using the predictor to fly through a tube scene show a benefit for the less experienced users.

Introduction

For the past six years our work has focussed on methods for exploring "fishtank" virtual environments. These are not the full-blown environments with head mounted displays, coupled to head position (Sutherland, 1968; Blanchard, et al, 1990), but rather the (currently) far more useful environments where the virtual 3D world is perceived to be behind the monitor window. Given this common configuration, the user requires a means to move through the virtual environment and manipulate objects within it - both of these are 6 degree of freedom (6DF) tasks. Previous work on viewpoint manipulation in our laboratory using the Bat input device has established that control over viewpoint velocity to be a preferred exploration mode (Ware and Osborne, 1990). The Bat (like a mouse that flies or *fledermaus*) senses the user's hand position and orientation. We use the button as a kind of engagement device and while the button is held down relative position

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and orientation is converted to viewpoint velocity; translational position is converted to translational velocity and orientation is converted to rotational velocity. We use a quadratic function to map hand displacement to both translational and rotational velocities and this gives control through changes of scale of up to four orders of magnitude.

The hand position is computed relative to the 6D coordinates of the initial change to the button down state. Using relative position in this way has advantages and disadvantages. It allows the user to work comfortably. If the user finds a position awkward, letting go of the Bat button instantly stops motion; the hand can be then moved to a more convenient position, usually fairly close to the body without undue arm extension, and motion can be resumed relative to this new position. The disadvantage of the relative mode is that the user is not likely to remember the starting position of the hand (button down transition). If you knew where your hand was you could infer your velocity. As it is there are only visual cues available from the virtual environment about the current viewpoint velocity and these are often not adequate, especially when the environment has little texture.

The present project was initiated to develop a viewpoint navigation aid by providing the user with feedback on his or her current velocity. The most important source of inspiration came from experimental heads-up cockpit displays designed to illustrate the aircraft attitude in the pilot's field of view. In some experimental studies it has been found useful to display the aircraft's predicted attitude in addition to the current aircraft attitude (Gallagher et al, 1977; Kelley, 1968). Taking this a step further is the "quickened" display which only shows the aircraft's future position (for a discussion see Wickens 1984).

The notion of quickening was especially attractive to us since we felt it might give a direct object manipulation feel to the interface. Even though the user is in fact directly manipulating the current velocities, he or she may feel that it is the predictor that is being manipulated and the predictor shows a future position and orientation based on extrapolation. Assuming success, the user will feel in control over the predictor and, in a sense, control over the future view point with a guaranteed

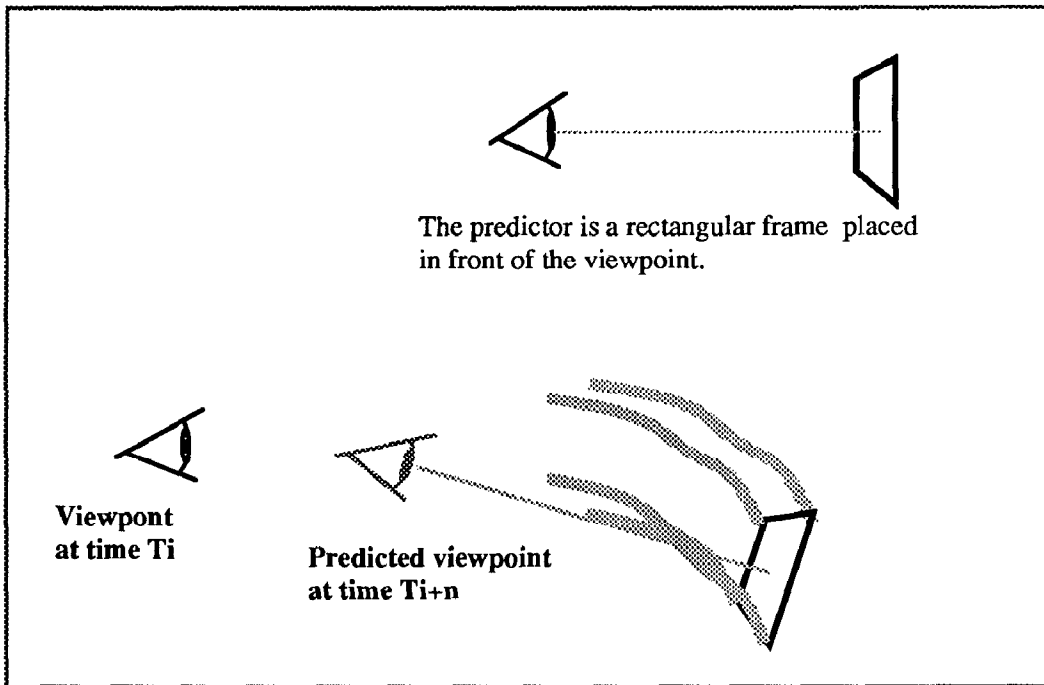


Figure 1. The predictor which is perceived at time T_i is based on the predicted position of the viewpoint at time T_{i+n} . The streamers from the corners of the predictor trace out the path of the predictor over the previous frames.

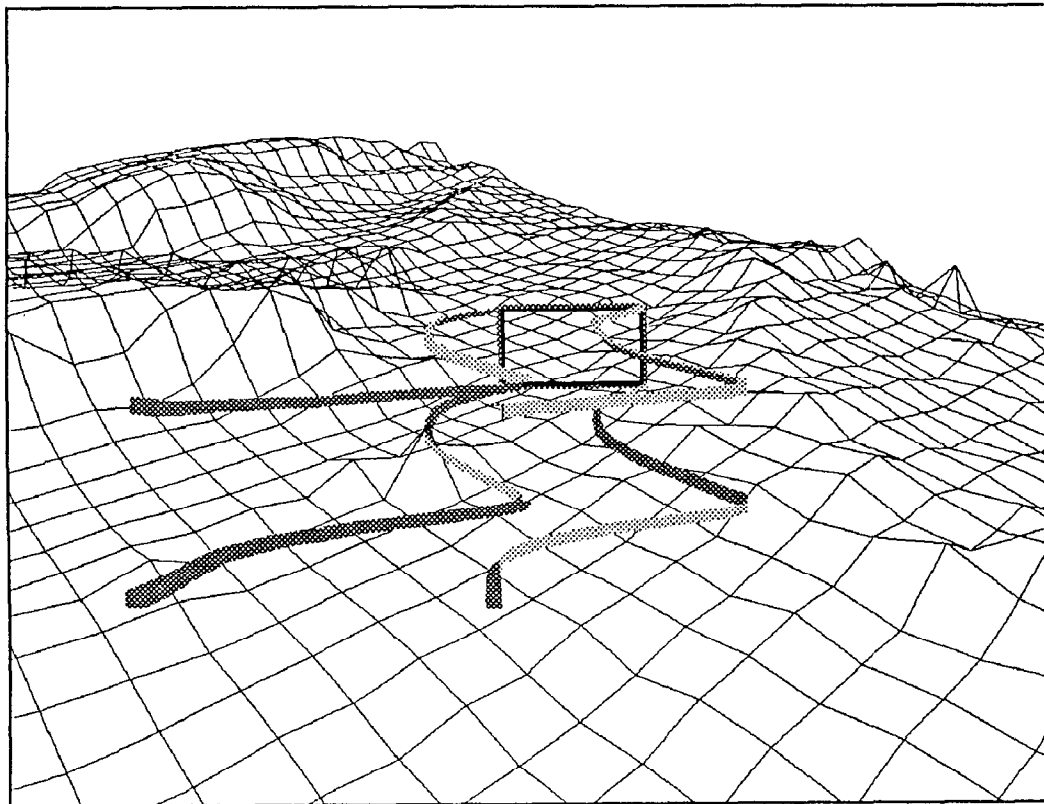


Figure 2. The predictor is seen in use over a digital terrain map representing the North Atlantic

smooth transition from the current viewpoint. To arrive at a particular location it will be only necessary to point the predictor at it, and changes of orientation may be achieved in a similar fashion. In this respect the display would be like Mackinlay et al's (1990) technique for viewpoint navigation relative to specified points on the surfaces of objects, only without the necessity of tying navigation directly to objects.

Predictor design

The aircraft problem and the fishtank interaction problem are not exactly isomorphic. An aircraft has complex flight dynamics whereas our interface was designed for complete freedom of motion with ease of use being the only consideration. We are able to move up down forwards, backwards and sideways with equal facility. Because a conventional predictor will not be visible except in the case of forward motion we gave our predictor a neutral point in front of the viewpoint, as illustrated in Figure 1. To add velocity and trajectory feedback we added tails to the four corners of the predictor frame. Although these tails actually look like ribbons, they behave like smoke trails. That is, they mark the course of the predictor frame through space. Figure 2 illustrates the predictor being used to create a motion path over a digital terrain map.

Uses

Our first real application of the predictor is in virtual camera control. We are involved in a major Canadian ocean mapping project at UNB and we have created part of an animated videotape for the Canada pavilion in the upcoming World's Fair in Seville Spain. We used the predictor with the velocity control interface to create a motion path in real-time over a thinned wire frame representation of the topographic data. We can then reuse the saved motion path with single frame animation and high quality rendering techniques to create the required movie.

We are also building the predictor into a data visualization and editing system for oceanographic research.

Evaluation

Our experience in using the predictor to explore various kinds of terrain data suggest that the predictor tails help in providing feedback about velocity, smoothness and direction of travel which is invaluable in the specification of a motion path for a flyby animation. In this kind of scene the terrain consists of a wire mesh which means that the tails were always visible to the user. In addition, the visual feedback from the predictor tails are especially useful in graphically impoverished scenes, they make up for the lack of visual motion parallax information (Gibson, et al, 1959)

The first stages of predictor design were an iterative process without formal evaluation. However, it is obvious to us already that it is a valuable navigation aid and as anticipated it has a direct manipulation feel to it. It has had additional benefits which were not anticipated. Because our system uses the standards Z buffering for hidden elimination, it gives a collision cue. The predictor can be seen to enter an object, leaving it's tail still visible allowing for avoidance action.

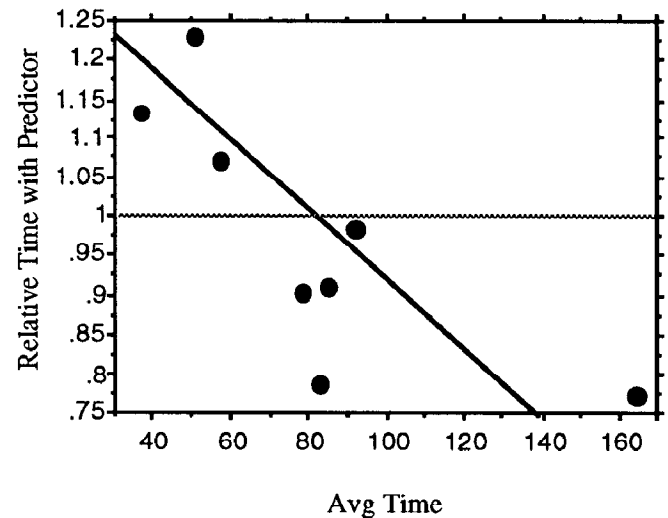


Figure 3. At a particular time setting, the presence of the predictor allows inexperienced subjects to perform better. Experienced subjects perform worse. See text for explanation

We are beginning a series of formal studies to evaluate various predictor parameters such as optimal extrapolation time and streamer length. The results we have thus far come from a task in which subjects navigate through a tunnel which is made up of a sequence of eight curves each having a different radius. Each time the subject does the task a different randomly connected sequence of curves is used. The subject's task is to navigate the tunnel as fast as possible without flying through a wall. We measure both time to completion and errors under the three conditions:

- No predictor
- Predictor without tails
- Predictor with tails.

The most interesting results obtained to date are plotted in Figure 3 which shows data from eight subjects. The relative time to completion for the predictor without tails condition is plotted against average time to completion. The negative correlation shows that subjects who did the task slowly (on average) were did significantly better with the predictor - they are represented by the five points below the line, while subjects who did the task fast were actually hindered in their performance of the task. The subjects who

did the task slowly were ones with no prior experience with our velocity navigation system and they clearly benefited from the presence of the predictor. The reason for the degradation of performance with the more experienced subjects became clear on detailed analysis. The speed with which they navigated through the tube was such that the predictor was projected right out of sight beyond the next bend, most of the time. Because of this the subject only occasionally obtained glimpses of the predictor which proved to be a distraction rather than a help. It appears likely that for experienced subjects the predictor should be projected a shorter time into the future.

The data obtained we have obtained thus far with the tails give a confusing picture which suggest that some subjects benefit while other subject find them to be a hindrance, irrespective of experience. We are continuing our investigation.

What has been achieved

We feel that the combination of Bat, fishtank environments and predictor has immediate utility for Scientific visualization and Cad systems. It lacks many of the motion constraints of full blown, head mounted virtual reality while it allows for almost as much functionality, although, of course the feeling of immersion in the graphical environment is absent - but this saves on Graval. There are now three Bat devices in or close to production: the SimGraphics Flying Mouse™, the Ascension Technologies Bird™, the Logitech™ 3D mouse, and the Gyration GyroPoint™. In other studies we have found that Bats are good for object manipulation (Ware and Jessome, 1988, Ware, 1990) and superior to the SpaceBall™ for 3D navigation (Ware and Slipp, 1991)

Acknowledgements

Thanks are due to Pat Cavanaugh for part of the code used to display the digital terrain model and to Kevin Marinelli for software support.

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Videotape

The videotape that accompanied this paper showed sequences are shown:

- 1) The predictor is seen in use in the Duct Maze environment used to evaluate performance. The manouvers being carried out show how the predictor behaves when it is flown in and out of walls.
- 2) The predictor is used in an interface which allows the exploration of a digital terrain map of the North Atlantic and the west coast of North America. When motion stops the surface is rendered at successive levels of detail. The colour coding of the surface illustrates gravity anomalies.

In the version illustrated in the videotape, the predictor tails extend from 20 frames in the future to 10 frames into the past. At a frame rate of 20 frames/second this yields a one second predictor which seems about right