Adaptive Navigation Support in 3D E-Commerce Activities

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Abstract. Advances in the delivery of complex graphics via the Web make 3D models and Virtual Environments available as a viable medium for e-commerce activities. Similar to hypermedia systems, personalized navigation support in these environments can be useful by directing customers' attention to significant features. This can be achieved by integrating ideal viewing parameters with the navigation of a virtual environment. This technique, known as Attentive Navigation is used to demonstrate several types of Adaptive Navigation Support.

1 Introduction

The power of adaptive hypermedia (AH) makes it an attractive technology for enhancing the functionality of various Web-based systems from information kiosks to e-commerce. However, a hyperspace of connected pages –the context of existing AH techniques – is not the only kind of virtual space that is available for Web users. With advances in delivering complex graphics through the Web, users can also access 3D models and Virtual Environments (VEs) online. Although the hyperspace and VEs support different applications, they are both targeted for user-driven navigation and exploration. Starting from adaptive hypermedia and exploring similarities between hypermedia and VEs, it is possible to develop interesting recommendation technologies for VEs. By extending this support, an adaptive virtual environment can help the user to work more efficiently and avoid common problems such as navigation in the wrong direction, overlooking an important part of the space, and being lost. This paper explores the development of adaptive navigation support for VEs in the context of e-commerce applications. A technique known as Attentive Navigation provides the infrastructure for embedding navigation and recommendation information into the VE. This technique is used to provide a framework that can power several types of navigation support.

2 Virtual Environments for E-Commerce Activities

Finding appropriate applications for VE e-commerce remains an open issue. Shortly after VRML 1.0 was released in 1994, a major effort in the e-commerce community focused on creating virtual storefronts. Given the ability to transmit 3D images over the web, consumers could leverage their knowledge of physical shopping in an interface on their computer. Unfortunately, the benefits of familiarity with a physical store do not always outweigh the rapid retrieval and aggregation abilities afforded by hypermedia. For example, online bookstores instantly fetch books and put them in a list, *saving* the viewer from wandering around a warehouse of bookshelves to find relevant books. Nonetheless, investigation in virtual storefronts continues. Chittaro and Ranon suggest that viewers might also be able to benefit from social interactions in the virtual storefronts or that the development of hi-fidelity models may be better able to appeal to a customer's emotional style of purchasing [1]. This type of appeal can be seen in the automobile industry. The web sites for nearly all major automobile manufacturers feature some form of 3D model that allows the customer to view the car from multiple points of view and see the effects of adding custom options. Intuitively, virtual 3D models give customers the ability to experience (visually inspect, manipulate, customize) products before executing a transaction. Extending this ability to e-commerce is vital because that people have grown accustomed to it in the physical world. Now that the technical capabilities are maturing, serious attention must be given to developing suitable applications

The effectiveness of VE e-commerce may also depend on the commodity itself. The spatial nature of virtual environments may prove to be a valuable interface if the products were inherently spatial. For example:

- Real Estate brokers could present detailed models of properties, allowing viewers to narrow the options that they want to physically visit.
- Resorts could offer a preview of their facilities before customers commit to an expensive vacation package.
- Furniture stores could allow customers to "test drive" their products by allowing the viewer to insert a model of the furniture into a model of their home.

The above examples rely on spatial fidelity for their success. Unlike a virtual storefront that can be rearranged to support the interests of the viewer, these scenarios call for the user to direct their attention to features within a predefined structure. An Adaptive Navigation system could help focus the customer on important features while remaining true to the context of the environment.

3 Extending Hypermedia Adaptive Navigation Support to 3D

An understanding of the navigation space is critical before any attempts can be made to guide a viewer through it. Hypertext has the convenient feature of being made of discrete nodes. Travel to the different nodes is accomplished by simply selecting the desired node from a relatively small collection. Travel in VEs is not that simple; there are often numerous positions compounded by multiple orientations that can lead to a virtually infinite array of navigation choices facing the viewer. For the purposes of this paper, discussion is limited to desktop systems that adopt a first-person perspective. These systems often rely on a camera analogy to describe the potential viewpoints that can be displayed. The camera is described in terms of its position (X,Y,Z) as well as the orientation or what direction the camera faces (Yaw, Pitch and Roll). Additional properties of the camera can sometimes be considered part of the navigation (e.g. amount of zoom), but this paper will limit discussion to the basic six parameters listed above.

Many of the techniques that are employed for adaptive navigation support in hypermedia systems can be extended for 3D visualizations. Brusilovsky provides a taxonomy of several popular technologies for adaptive hypertext navigation including direct guidance, sorting, hiding and annotation [2]. Descriptions of each of these techniques for hypertext and a suggested corresponding 3D approach are described below.

Direct Guidance: This is achieved when a strict linear order can be determined through the navigation space. Instead of giving the user options to navigate, the "best" choice is selected by the system. In terms of hypermedia systems, pages are presented with only one link, usually labeled as "next". For 3D environments, direct guidance is accomplished by presenting a predetermined sequence of viewpoints to the viewer. This is equivalent to viewing a movie where the director has determined both the camera position and orientation. Several research projects have produced programs that automatically generate purposeful camera paths through virtual environments including [3-5].

Hiding: This approach involves restricting the number of navigation options to a limited subset. Irrelevant paths are concealed, leaving the viewer to choose only from alternatives that are consistent with the task at hand. Hypertext systems accomplish this by simply disabling links to inappropriate pages. In VE systems, this is done by restricting the possible positions or orientations for the camera. This is often achieved by modifying the way that the system interprets the user input to the system. For example, if the environment is representing a single object or a centralized collection of objects, navigation can be limited to a sphere surrounding the object. The camera is not allowed to be positioned off the sphere and the orientation is limited to points that are internal to the sphere (usually fixated to face the center point). Another approach is commonly used if the viewer needs to discover a configuration of objects. The viewer may be restricted to "walking" through a scene. This is accomplished by keeping the viewpoint position a fixed distance from a surface in the environment. In this case, the viewer has direct control over the X and Y Position, but the Z values are fixed. While walking, the orientation of the camera is usually in complete control of the viewer although some systems may also deny movement in Pitch and Roll.

Sorting: This technique applies to altering the order in which navigation decisions are presented to the viewer. In terms of hypertext, this is accomplished by compiling the links into a list arranged by relevance. Clearly this approach cannot directly be transferred to 3D environments. One of the hallmarks of VE systems is the attempt to capitalize on consistency with the real world. Altering the structure of the navigation options could seriously compromise the fidelity of a model. However, the intent of sorting as an adaptive technique is to facilitate the selection of a particular option while still presenting the alternatives; it is easier to select an option from the beginning of the list. In this spirit, it is possible to accomplish "sorting" in a VE by making easier at the control level for a viewer to take a particular navigation step. Mackinlay et. al. introduce *Point of Interest* navigation that adjusts the viewer's motion speed logarithmically in relation to the distance from an object of interest [6]. Thus if the viewpoint is far away from an interesting feature, only a small movement is required to bring the viewer closer to the goal. Conversely, if the viewer is nearby relevant artifacts, it takes more effort to move away from it.

Annotation: Another method for recommending navigation options is to display supplemental markup near the desired outlet. Annotation can be used to provide statements of relevance as well as better indications of the content that lies along that path. Several methods of annotation can be found in hypertext systems, including changing the color of links or placing additional icons near the links. Adding this supplemental material is just as easy in 3D environments. For example, Satalich designed a system to help guide people through an architectural structure that consisted of drawing lines on the floor that connected points of interest [7].

As described above, the study of interaction with 3D environments has yielded a collection of techniques that can be used to achieve adaptive support for navigation. However, each of these approaches is unique, requiring a separate implementation. In the next section, a framework is proposed that can be used to achieve each of these types of adaptation using the same underlying dataset. Moreover the supplemental guidance information is relatively compact and thus well suited to delivery over the Web.

4 Attentive Navigation Techniques

The basic premise of Attentive Navigation is to provide a mechanism for computing ideal viewpoints in the environment based on a user model and the user's context within the environment. The construction and use of these ideal viewpoints can lead to the different classes of adaptation described above.

Attentive Navigation is a derivation of Constrained Navigation proposed by Hanson and Wernert in an attempt to facilitate 3D navigation using 2D controllers [8, 9]. In those papers, the authors divide the navigation space into its two components. The Constraint Surface defines the range of positional values that the camera can assume. The Camera Model Field (CMF) describes the ideal viewing parameters for each point in the constraint surface. As the viewer controls motion through the constraint surface, the system determines the corresponding values in the CMF and presents them to the viewer.

Practically speaking, the CMF is not explicitly represented; as the number of points that comprise the constraint surface can be arbitrarily large. Hanson and Wernert proposed sampling the CMF at a fixed resolution and then ensuring smooth transitions by interpolating the viewing parameters using a bicubic Catmull-Rom spline. Even given this abstraction, the generation of the CMF is not a trivial task.

A tool is currently being developed to assist with CMF generation. The authors have produced a simple drag-and-drop interface that allows markup of a projected 2D map of the environment. While this tool simplifies the task, it still requires human interaction, and thus it is not sufficient for creating dynamic CMFs. This means that the current implementation can only support navigation for predefined stereotypes and does not provide for real-time adaptation. Ongoing work is being done to automate the tool to overcome that limitation, and the authors do not see any major technical obstacles to achieving this. Another drawback to the current design is that it relies on a 2D projection. This immediately restricts the navigation space to 2 degrees of freedom for position and 1 degree of freedom for orientation. This is consistent with the "walking" metaphor described above and is sufficient for a large number of environments. The dependency on a 2D projection is strictly a function of the interface that is used for the mark-up, and is not inherent to the technique itself. Again, once a batch tool can be completed, this restriction should evaporate.

5 Adaptive Navigation Support Through Attentive Navigation

Different effects can be accomplished by changing the way the CMF viewing information is used during viewer interaction. An extensive taxonomy of these interaction techniques can be found in [10]. This section discusses how the CMF can be used to provide adaptive navigation support from the taxonomy presented above.

Direct Guidance provides the best path through the environment without any decisions required from the viewer. The system can adopt the navigation strategy: "Always move forward in the direction that you are looking". Using this strategy, the movement through the navigation is deterministic and based on the configuration of the viewing vectors. The path generated by following these vectors with either contains a cycle or a terminal point, as shown in Figure 1. This translates nicely into the idea that direct guidance in a VE is equivalent to a movie. The movies that are generated will either continue to show the same pathway repeated infinitely or there will be a clear terminus where the movie ends.

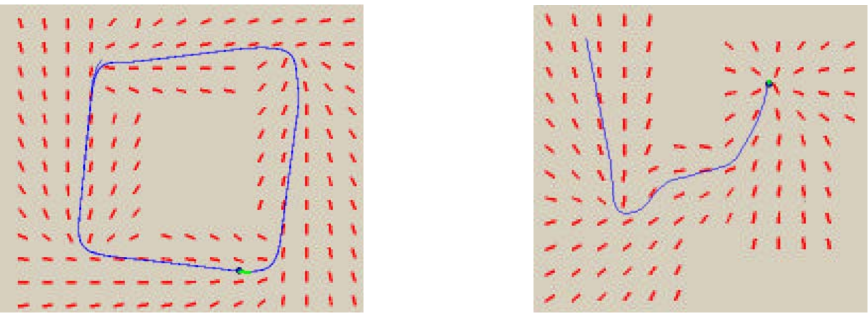
(a) (b)

Fig. 1. Direct Guidance CMF to generate (a) repeating movie (b) terminal movie

The navigation model described above may seem restrictive in terms of the types of movies that this system can generate. Clearly, the rules of cinematography allow for the camera motion and the direction of gaze to be disjoint. This is also possible with a simple addition to the general guidelines of Attentive Navigation. An ideal camera placement vector can be stored in the CMF as well as an ideal viewing vector.

This new vector simply defines the best position for the camera to move to in the next segment, and motion through the environment is computed from an interpolation of this vector rather than the gaze vector.

Hiding: As described in the previous section, hiding is the result of pairing down the navigation space accessible to the viewer. Recall that the number of camera positions multiplied by the available camera orientations defines the total array of navigation options available to the viewer. Most common forms of hiding in VE applications work at a very broad level. For example, adopting the walking metaphor eliminates any position variation along the Z-axis. Using attentive navigation, it is possible to work at a more granular level. Since each position in the environment has an associated ideal orientation, it is possible to hide all of the irrelevant orientations from the viewer for each point on the constraint space. The viewer retains control of the position, but the system dictates the orientation. This allows the system to force the viewers to fixate on a certain object as they walk past it. For example, in Figure 2, as the person walks along the path defined by the dark gray arrows, his gaze is fixated on the star.

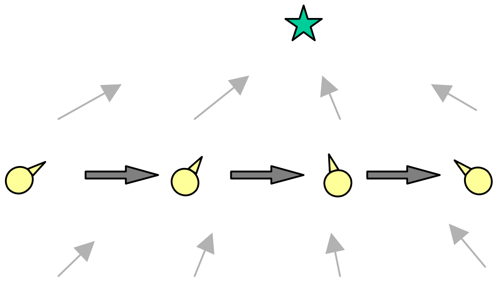

Fig. 2. Navigation Hiding: Gaze Fixation**.**

Sorting: To extend Attentive Navigation to the implement sorting, the same approach is taken as with Hiding. The viewer can manipulate the camera position through the environment, while the system automatically redirects the viewer's gaze to align with the ideal viewing vector for the current position. Unlike the hiding approach, the alternatives should still be accessible. This means that additional control must be afforded to the viewer that allows them to explicitly manipulate the orientation. Under these guidelines, as the viewers travel through the environment, their gaze will become fixated on the suggested objects. However, they are free to explore alternate points of view if desired.

The strength of the recommendation is variable to the degree that the control of the orientation is shared. Some modifications to the basic approach above may include:

1. Automatic Gaze Redirection: As the viewer moves through the environment, the orientation of the camera is aligned to the ideal gaze vector by default. If the viewer wishes to examine something other than what the system recommends, they must take explicit action to alter the orientation of the viewpoint to their intention.
2. Redirect Gaze Modulated by Speed: If the viewer is traveling very quickly through the environment, they may not want to be distracted unless by a very

important feature. In addition to the viewing orientation parameters, the CMF may contain a scalar that represents the strength of the attraction, proportional to the importance of the object. If the motion speed is less than the threshold, then the viewer's gaze could be redirected to align with the ideal vector. If the motion speed exceeds the threshold, then the object may be ignored.

3. Voluntary Request: The ideal viewing vector is used only when explicitly requested from the viewer. This has the effect of the viewer asking for directions.

Annotation: Finally, a form of annotation can also be achieved using the Attentive Navigation. Instead of using the ideal viewing vector to adjust the viewpoint, it is used to power external imagery. Two possibilities are outlined below.

1. Projected Vector: The most basic annotation that can be realized is to simply project the ideal viewing vector on the floor of the environment. This will allow the viewer to get a sense of a direction that is given to them. This may be used to tell them either the direction they should be looking or perhaps a direction they should travel. This approach is represented in Figure 3a.
2. Attentive Flashlight: Another approach is to use the ideal viewing vector to control the direction of a spotlight traveling through the scene. With this condition, as the viewer moves through the environment, the flashlight will shine on relevant objects, leaving unimportant features in the dark. This technique may be more effective at selecting particular objects, as opposed to showing directions. An example of this treatment is shown in Figure 3b.

(a) (b)

Fig. 3. Annotation powered by Attentive Navigation

6 Discussion

Extensive user evaluation is still needed to validate the effectiveness of attentive navigation as a tool for providing adaptive navigation support. However, several preliminary studies have promising results. Hanson et al found that using hiding and sorting both resulted in better recall of objects encountered in the environment [9]. This was attributed to the fact that the viewer could devote more attention to the display because they did not need to concentrate on controlling multiple degrees of freedom. Viewers using a sorting implementation were able to develop a better understanding of the global configuration of the elements of the scene according to Hughes and Lewis [11]. Equipped with this improved mental map of the environment, viewers are better able to make decisions about subsequent motion. Finally, Hughes and Lewis used sorting and annotation implementations of attentive navigation to facilitate searching an environment [12]. The assistance provided to the viewers resulted in quicker, and more accurate searches and the users had to exert less effort to accomplish the task.

The attentive navigation system provides a solid engine for bringing adaptive navigation support to Virtual Environments. It is capable of supporting the same major types of adaptation that are seen in adaptive hypermedia through by marking up the environment with ideal viewing vectors. Making it easier to navigate Virtual Environments in a web setting can foster development of 3D e-commerce applications and expedite their acceptance by the consumers.

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