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Knowledgeable Navigation in Virtual Environments

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INTRODUCTION

Virtual environments provide a computer-synthesized world in which users can interact with objects, perform various activities, and navigate the environment as if they were in the real world (Sherman & Craig, 2002). Research in a variety of fields (i.e., software engineering, artificial intelligence, computer graphics, human computer interactions, electrical engineering, psychology, perceptual science) has been critical to the advancement of the design and implementation of virtual environments. Applications for virtual environments are found in various domains, including medicine, engineering, oil exploration, and the military (Burdea & Coiffet, 2003).

Despite the advances, navigation in virtual environments remains problematic for users (Darken & Sibert, 1996). Users of virtual environments, without any navigational tools, often become disoriented and have extreme difficulty completing navigational tasks (Conroy, 2001; Darken & Sibert, 1996; Dijk et al., 2003; Modjeska & Waterworth, 2000). Even simple navigational tools are not enough to prevent users from becoming lost in virtual environments. Naturally, this leads to a sense of frustration on the part of users and decreases the quality of human-computer interactions. In order to enhance the experience of users of virtual environments and to overcome the problem of disorientation, new sophisticated tools are necessary to provide navigational assistance. We propose the design and use of navigational assistance systems that use models derived through data mining to provide assistance to users. Such systems formalize the experience of previous users and make them available to new users in order to improve the quality of new users' interactions with the virtual environment.

BACKGROUND

Before explaining any navigational tool design, it is important to understand some basic definitions about navigation. Wayfinding is the cognitive element of navigation. It is the strategic element that guides movement and deals with developing and using a cognitive map. Motion, or travel, is the motoric element of navigation. Navigation consists of both wayfinding and motion (Conroy, 2001; Darken & Peterson, 2002).

Wayfinding performance is improved by the accumulation of different types of spatial knowledge. Spatial knowledge is based on three levels of information: landmark knowledge, procedural knowledge, and survey knowledge (Darken & Sibert, 1996; Elvins et al., 2001). Before defining landmark knowledge, it is important to understand that a landmark refers to a distinctive and memorable object with a specific shape, size, color, and location. Landmark knowledge refers to information about the visual features of a landmark, such as shape, size, and texture. Procedural knowledge, also known as route knowledge, is encoded as the sequence of navigational actions required to follow a particular route to a destination. Landmarks play an important role in procedural knowledge. They mark decision points along a route and help a traveler recall the procedures required to get to a destination (Steck & Mallot, 2000; Vinson 1999).

A bird's eye view of a region is referred to as survey knowledge. This type of knowledge contains spatial information about the location, orientation, and size of regional features. However, object location and interobject distances are encoded in terms of a geocentric (i.e., global) frame of reference as opposed to an egocentric (i.e., first-person) frame of reference. Landmarks also play a role in survey knowledge. They provide regional anchors with which to calibrate distances and directions (Darken & Sibert, 1996; Elvins et al., 2001).

The quality of spatial knowledge that a user has about a virtual environment determines his or her performance on a wayfinding task. Any navigational assistance provided by a tool is aimed to assist the user to gain spatial knowledge about the environment. Therefore, a key element to the success of any navigational tool is how effective it is in representing and providing spatial knowledge that is easy to understand and useful from the perspective of the user.

In the past, different navigational tools and techniques to improve wayfinding have been included in the design of virtual environments. Maps and grids have been introduced to bring legibility to virtual environments and to improve wayfinding performance (Darken & Sibert, 1996). Personal agents have been used that can interact with the user and provide verbal navigational assistance (Dijk et al., 2003). Due to their popularity, there also has been tremendous focus on the use and design of landmarks to aid in wayfinding (Elvins et al., 2001; Steck & Mallot, 2000; Vinson, 1999). The achievement of previous researchers has been significant, but the area of navigation in virtual environments still remains an open research topic.

WAYFINDING: THE DATA-MINING APPROACH

Data mining is the process of discovering previously unknown patterns, rules, and relationships from data (Han & Kamber, 2001). A Knowledgeable Navigational Assistance System (KNAS) is a tool that employs models derived from mining the navigational records of previous users in order to aid other users in successfully completing navigational tasks. For example, the navigational records of previous users may be mined to form models about common navigational mistakes made by previous users. A KNAS could be designed to use these models to help users avoid backtracking and making loops. Another example would be to derive models of frequent routes taken by previous users. These frequent routes may defy traditional criteria for route selection but have hidden advantages. A KNAS could be designed to use these models and recommend these frequent routes to users (Kantardzic et al., 2004).

The process of designing a KNAS involves three distinct steps. The first step is recording the navigational data of users. Selection of the group of users that will have their navigational behavior recorded is dependent upon the application. Ideally, this group of users should be experienced with the system (Peterson & Darken, 2000; Peterson, et al., 2000). The data that are recorded can include both spatial and non-spatial attributes pertaining to the navigation of users. Examples of recorded data could include the landmarks and objects visited, routes traversed by users, as well as information on longitude, latitude, elevation, and time (Shekhar & Huang, 2001; Huang et al., 2003).

The second step is the actual mining of data. In most cases, data will need to be preprocessed before applying the mining algorithms (Kantardzic, 2003). The data-mining process will result in models that will be used by the KNAS.

The third and final step is actual implementation of the KNAS and the corresponding interface. The interface of the KNAS needs to allow the user to issue navigational queries, and the KNAS must use the derived data-mining models in order to formulate a reply. Figure 1 depicts the three steps necessary for construction of a KNAS: recording of the navigational data, the data mining process to form models, and the implementation of the KNAS.

To better demonstrate the concepts and ideas behind a KNAS, the construction of a KNAS is discussed, which is capable of recommending routes of travel from one landmark to another landmark. As previously discussed, landmarks are an important component in wayfinding and commonly are found in various virtual environments (Steck & Mallot, 2000; Vinson, 1999). Some may argue that relying on knowledge extracted from the records of previous users to derive routes is an overhead. After all, there are already tools that can produce route directions

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