VISUALISATION AND INFORMATION

Case Study

WHAT ABOUT THOSE ANTS? SWARM INTELLIGENCE FOR VIRTUAL ENVIRONMENTS

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ABSTRACT

The use of 3D virtual worlds has spread rapidly in recent years. These worlds have various uses ranging from computer games to urban design simulation systems. However, the spread of 3D virtual worlds has been impeded due to the problem of users not being able to find their way in and around virtual worlds. Hence improving wayfinding has become a crucial area of research. As virtual worlds become more advanced, they will be better equipped to run complex design scenarios highlighting potential design faults and areas for improvements. If virtual worlds technology is to become an effective and reliable design tool for the construction industry, wayfinding must also be developed to minimise wastage and inefficiency that may arise out of users not being able to find routes to their destinations. Swarm intelligence, with its distributed information gathering crawlers, points to a promising area of research for those who seek to broaden the capacity of wayfinding aids.

Keywords: **Virtual Environments, Wayfinding, Swarm Intelligence, Construction Industry**

1. INTRODUCTION

The use of 3D virtual worlds has spread rapidly in recent years. These worlds have various uses ranging from computer games to urban design simulation systems. However, the spread of 3D virtual worlds has been impeded due to the problem of users not being able to find their way in and around virtual worlds. Improvements in graphics technology have enabled the virtual worlds to become more realistic and detailed than previously possible. Hence improving wayfinding has become a crucial area of research. Attempts to improve wayfinding thus far assume the world to remain static over the course of the interaction, and hence offer no dynamic adaptivity. This paper begins by outlining current wayfinding efforts in the literature. This is followed by the ideas behind swarm intelligence. I propose to employ swarm intelligence to address the problem of wayfinding in virtual environments.

2. BACKGROUND

2.1 WHAT IS WAYFINDING?

No widely accepted definition for wayfinding exists in the literature. Various definitions focus on different aspects of wayfinding, and researchers have not yet reached a consensus. However one general definition is provided by Gluck (Gluck, 1990) who defines wayfinding as “the process used to orient and navigate.” He argues the fundamental goal of wayfinding is “to accurately relocate from one place to another in a large-scale space” (Gluck, 1990). Arthur and Passini (Arthur and Passini, 1992) concur as they describe wayfinding as “finding one’s way to a destination.” They further explain wayfinding to be a “spatial problem solving” which comprises of “three interdependent processes: decision making, decision executing, and information processing” (Arthur and Passini, 1992). Similarly, Peponis et al. (Peponis et al., 1990) describe wayfinding as “the ability to find a way to a particular location in an expedient manner and to recognize the destination when reached.”

Wayfinding, therefore, simply means knowing where you are, where you want to go, and how you get there. In order to achieve this, researches in wayfinding have used, to name a few, landmarks, maps, thumbnails, visual cues, multiple views, guided tours, and queries. Wayfinding efforts can be roughly categorised into two categories: environment focused and user focused. Environment focused approach aims to aid wayfinding by manipulating the environment in order to enable users to gain spatial knowledge. User focused approach, on the other hand, allows users a limited control over their interaction with the virtual world. What is lacking in both approaches is dynamic adaptivity. Both approaches assume the environment to remain static. Hence when the world changes, the wayfinding aids—whether they be maps or a some kind of knowledge-rich database—also need to be updated. The changes can only be made while the user is not using the environment. A brief overview of current research in wayfinding is given below.

2.2.1 Environment Focused Approach

The environment focused approach improves wayfinding by manipulating virtual environments to aid users (Elcacho et al., 2001; Ramloll and Mowat, 2001; Todd Elvins et al., 1997; Vinson, 1999). The areas of improvements in the virtual environment include:

- Landmarks/Visual cues (Chittaro and Scagnetto, 2001; Elcacho et al., 2001; Noser et al., 2003; Raubal and Winter, 2002; van Luin et al., 2001b; Vinson, 1999)
- Maps/Thumbnail (Barkowsky et al., 2000; Casakin et al., 2000; Kitamura et al., 1998; Ramloll and Mowat, 2001; Saretto, 2001; Todd Elvins et al., 1997)
- Multiple views (Kitamura et al., 1998; Ramloll, 1997)

2.2.1.1 Landmarks

Landmarks are distinctive environmental features that function as reference points (Vinson, 1999). These landmarks are critical in providing visual information for wayfinding (Evans, 1980; Golledge et al., 1985; Lynch, 1960). The landmarks also influence the search strategies used by users (Todd Elvins et al., 1997). Without a priori knowledge of a destination and its surroundings, a user performs an exhaustive search of the region. Landmarks are used as directional cues with which to steer such a search. Even with a posteriori knowledge of the destination and its surroundings, the user navigates to the destination by survey, procedural, and landmark knowledge (Todd Elvins et al., 1997). Vinson (Vinson, 1999) presents design guidelines for landmarks for use in virtual worlds. In it, Vinson argues that only those landmarks which are both noticeable and helpful to the navigators to remember their positions in the environment should be created. Any attempt to improve user's orientation skill is ideal. The problem with this type of solution is that every time the world changes, new landmarks also have to be created in order to distinguish the newly created objects from the rest.

2.2.1.2 Maps

Just as there are maps available in the real world, there also are maps for the virtual worlds. Most 3D environment browsers provide functionalities to view the world in miniature for the users to gain survey knowledge (Todd Elvins et al., 1997). Stoakley et al. (Stoakley et al., 1995) extend this idea by creating a miniature world and embedding it within the main world as shown in figure 1. From WIM given in the browser, the user can reposition the contents of the virtual world as well as themselves. The main world updates to reflect the changes made in WIM. This solution helps users to orient themselves within the environment. However this solution still leaves the wayfinding task to be undertaken by the users.

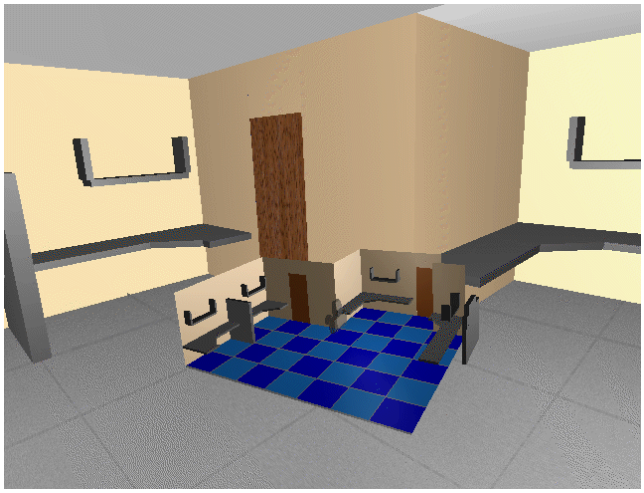

Figure 1 World in Miniature (WIM) shown within (Stoakley et al., 1995)

2.2.2 User Focused Approach

The user focused approach overcomes the problems identified with the environment focused approach by employing various means. They include:

- Guided Tours (Chittaro et al., 2003; Gaylean, 1995; van Luin et al., 2001a)
- Queries (van Ballegooij and Eliëns, 2001; van Luin et al., 2001a)
- Agents (Bertoletti et al., 2001; Maes, 1995; van Dijk et al., 2003; van Luin et al., 2001a; Zwiers et al., 2000)

2.2.2.1 Guided Tours

Guided tours offer the opportunity for users to experience whatever the virtual environments offers. This is the first genuine attempt at solving the problem of getting 'lost-in-cyberspace'. Being gently guided around the worlds, the users are no longer 'lost-in-cyberspace'. Gaylean (1995) implemented this notion of a guided tour with the use of "the River Analogy". In this, users are restricted to follow a predefined navigational path and follow it "like a river flowing through a landscape" (Gaylean, 1995). Gaylean describes it as the user being in a boat "floating down this river with some latitude and control while still being pushed and pulled by the pre-defined current of the water" (Gaylean, 1995). The user still has the control over what is seen on the screen.

Figure 2 A Virtual Guide presenting an object (Chittaro et al., 2003)

Another implementation of guided tours is developed by Chittaro et al. (Chittaro et al., 2003), as shown in figure 2. They adopted the use of an avatar, called the H-Anim character, to be both a wayfinding aid and an information aid. This H-Anim character leads the user on a tour of the world that includes all the specified objects and/or places in a predefined order. At each specified object/place, the avatar stops the user possibly to present pre-recorded information as shown above. For each world, a new touring path needs to be generated with information regarding tour items.

2.2.2.2 Queries

Van Luin et al. (van Luin et al., 2001a) present an ongoing research where the users query an interface agent, called Karin, in a natural language. The system is built around a virtual theatre. This is where the difference ends compared to the examples mentioned above. In this system, Karin accesses three different databases. The first database stores information relating to physical objects that are present in the theatre such as objects, names, locations, and sizes. The second database stores information relating to imaginary objects such as performances. The third database contains knowledge about the relationship between objects. These databases are queried according to the questions asked by the users.

Querying is an adequate method of giving a complete control to the user of his/her interaction with the system. However, it should be noted that the kind of spatial knowledge displayed as a result of a query is highly dependent on the kind of data stored in the databases. If the information stored in the databases is out dated or limited, then querying will not be so effective in aiding wayfinding. Moreover, giving directions to a destination in terms of any landmark present might not be sufficient for users to navigate smoothly, especially if users are not aware of the very landmarks the directions mention.

2.3 SWARM INTELLIGENCE

Swarm intelligence is defined as “any attempt to design algorithms or distributed problem-solving devices inspired by the collective behaviour of social insect colonies and other animal societies” (Bonabeau et al., 1999). In this paradigm, two concepts are of concern: self-organisation, and stigmergy. However I focus only on the notion stigmergy.

2.3.1 Stigmergy

Stigmergy is a type of communication which is conducted “by altering the state of the environment in a way that will affect the behaviours of others for whom the environment is a stimulus” (Kennedy and Ebergart, 2001). Bonabeau et al. (Bonabeau et al., 1999) explain stigmergy as an indirect interaction between two individuals “when one of them modifies the environment and the other responds to the new environment at a later time” (Bonabeau et al., 1999). Ants communicate via sign-based stigmergy using pheromones. Pheromones are chemicals used by ants as a method of communicating with others.

Figure 3 Ideal path travelled by ants to food source

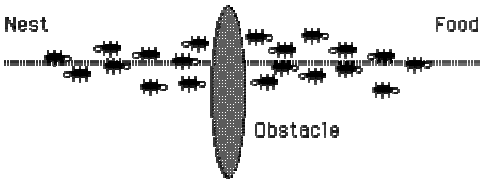

Figure 4 An unexpected obstacle laid on the path

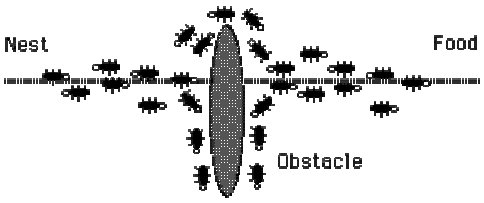

Figure 5 Initial direction of travel chosen by ants

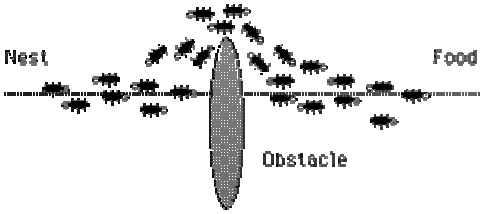

Figure 6 Shortest path chosen by ants

Interacting with each other, ants can perform complex tasks even when their behaviours are unsophisticated. Trails of pheromones are laid down by a given ant, which encourages other ants to follow. The stigmergy is illustrated by an experiment which is summarised as follows. The researches on live ants illustrate that “when food is placed at some distance from the next, with two paths of unequal length leading to it, they will end up with the swarm following the shorter path” (Kennedy and Ebergart, 2001) as shown in figures 3 to 6 (Dorigo, 2003). This observation is made possible by the fact that the shorter path to the food source will have a higher concentration of pheromones deposited on it compared to the longer path. Hence an individual ant tends to follow the path with stronger scent.

3. WAYFINDING SWARM OF CRAWLERS

In order to solve this problem in wayfinding, I employ swarm intelligence with the emphasis on the use of stigmergy and the design of pheromones. The overall system features, as shown in figure 7, a personal agent that interacts with a user in various ways. Using simple natural language processes, the user can query the location of a particular destination. This allows the agent to control macro-level behaviour of crawlers which move about in the world to discover different routes to the destination.

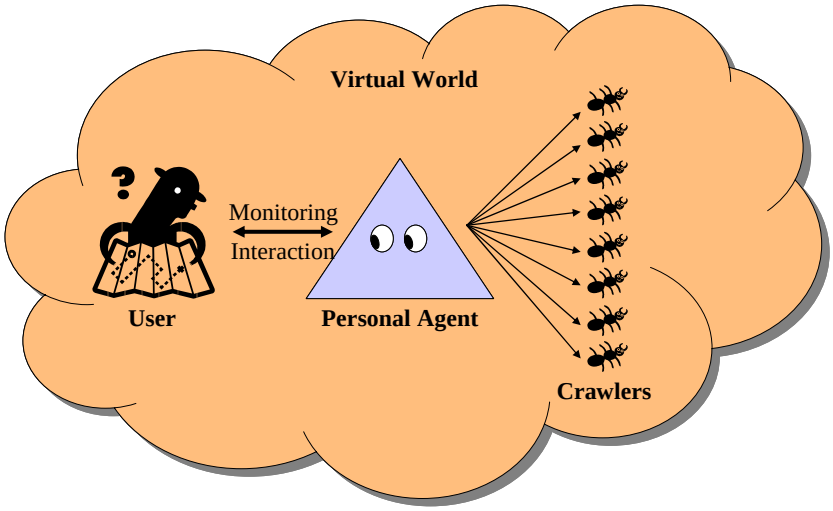

Figure 7 Overall system architecture

The information retrieval crawlers are the most critical component in the overall system, shown in figure 8. They are effective information gatherers and I utilise them in order to gather wayfinding information in the virtual world. Each crawler is a simple rule-based agent having a localised knowledge of the world around it. Crawlers have the capacity to construct the needed knowledge in order to find the best wayfinding route without relying on an already existing knowledge base. Hence as the virtual world changes, the crawlers simply move about in the world to gather new wayfinding information.

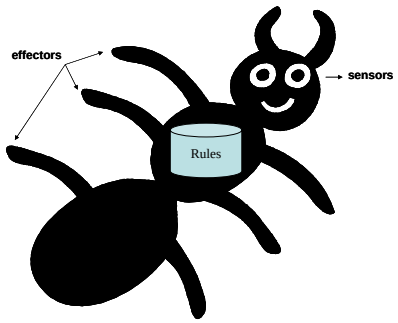

Figure 8 Wayfinding crawler

Typical foraging ant models assume one of the randomly moving ants find a food source, the path to which is marked with pheromones. Since the ants do not communicate directly with each other, they use pheromones dropped on the trail to the food source. The pheromones then become the stimuli for other ants to follow the trail. This process of indirect interaction by ants is called stigmergy. I employ this method of indirect communication through the environment in my design of crawlers with one important difference. Pheromones which are used among ants to attract other ants are used among crawlers as repellents. Electronic pheromones will encourage other crawlers to find alternative routes to the destination.

This is a novel approach to wayfinding which eliminates the need for a database containing information about the world that needs to be updated whenever the world changes. The use of crawlers allows the world to be changed without limiting wayfinding capacity as crawlers continuously search

for alternative routes to a destination within a dynamically changing complex virtual environment.

4. THE WAY FORWARD

The nature of stigmergy in virtual environments needs to be examined further as well as the composition of electronic pheromones. Swarm intelligence offers an exciting opportunity to enhance wayfinding without having to rely on a previously composed database. As virtual worlds become more advanced, they will be better equipped to run complex design scenarios highlighting potential design faults and areas for improvements. If virtual worlds technology is to become an effective and reliable design tool for the construction industry, wayfinding must also be developed to minimise wastage and inefficiency that may arise out of users not being able to find routes to their destinations. Swarm intelligence, with its distributed information gathering crawlers, points to a promising area of research for those who seek to broaden the capacity of wayfinding aids.

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