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Design of a Semiautomatic Travel Technique in VR Environments

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ABSTRACT

Travel in a real environment is a common task that human beings conduct easily and subconsciously. However transposing this task in virtual environments (VEs) remains challenging due to input devices and techniques. Considering the well-described sensory conflict theory, we present a semiautomatic travel method based on path planning algorithms and gaze-directed control, aiming at reducing the generation of conflicted signals that may confuse the central nervous system. Since gaze-directed control is user-centered and path planning is goal-oriented, our semiautomatic technique makes up for the deficiencies of each with smoother and less jerky trajectories.

Index Terms: Human-centered computing—Human computer interaction(HCI)—Interaction paradigms; Human-centered computing—User interface design—Interaction devices;

1 INTRODUCTION

In response to the quickly increasing virtual reality (VR) applications, travel interfaces in virtual environments (VEs) have been recognized as the most fundamental feature to provide user satisfaction, sense of presence, reduced cybersickness and entertainment when designing a product, a building, or when showing reconstructed places to the public. These tasks have to deal with increasingly complex and unknown scenes with numerous objects sequentially.

Considering different travel tasks to be performed, current travel tasks can be divided into two main subcategories [3]: 1) *Exploration*. Typically implemented for users to gain information about objects and build up knowledge of the environment, this task is not required to explicitly specify a goal to be reached; 2) *Search*. This task involves travel techniques where users have to specify a specific goal or target location within VEs.

To achieve successful navigation in VEs, appropriate navigation devices and techniques should be intuitive. For instance, devices such as joysticks or head orientation tracking based devices using gyro in VR headsets are widely used for navigation in VEs. This kind of navigation devices is easy to use and effective for novice users to control movements in VEs. However, joysticks are unable to provide smooth movements towards a target location but rather cause sudden and irregular motion. Such travel technique fails to provide natural movements and is more likely to induce cybersickness [5]. With the intention of developing a navigation interface to enhance user comfort and reduce cybersickness, we present in this paper a new semiautomatic technique to navigate in immersive VEs.

1.1 Related Work

Igarashi et al. designed a path drawing technique to navigate in virtual 3D spaces [2]. This method allows users to draw the desired

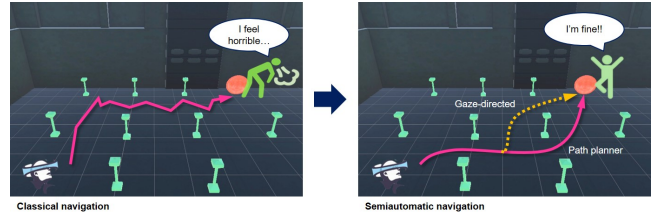


Figure 1: Left: with classical travel techniques, e.g., joystick-based techniques, irregular unsmooth trajectories lead to cybersickness. Right: with our semiautomatic travel technique, optimized smooth trajectories can be achieved thanks to automatic path generation, allowing reduced cybersickness.

path with a free stroke, then the system automatically projects the stroke onto the walking surface to generate the final moving path. The avatar and the view point move to the target position along the tangents of the path with a controllable speed. A user study found that path drawing is preferred and more intuitive compared to both driving and flying travel methods. Since users do not have to hold on a controller's button all the time for travel, it is possible for novice users to focus on other tasks.

Instead of drawing a path, automatic path planners from the humanoid robotics field which has focused on the evolution of humanoids in real environments was also proved to be better [4]. Developing a system to plan automatically an optimal path from a starting point to a target point with an improved A* algorithm, Yao et al. introduced the application of path planning to travel in VEs and they managed to control the motion of an avatar to conduct tasks such as *search* or *maneuvering* [6].

1.2 Contributions

Very little work was proposed to combine path planning algorithms from humanoid robotics and spatial steering techniques to design travel techniques in VR. Therefore, to alleviate cybersickness and increase user comfort, we propose to adapt path planning methods to VEs and design a new travel method especially to perform the *Search* and the *Maneuvering* tasks whose procedure shows strong similarities with that in a path finding process which requires fixed initial positions and targets (Fig. 1). The adapting process is designed based on gaze-directed control. Here we stick to the design of our technique while user assessment is left for another publication.

2 DESIGN OF SEMIAUTOMATIC TRAVEL

The original idea of semiautomatic travel is that a virtual reality system provides basic control rules and dynamics during travel while still allowing users to control the system [1]. Among manual travel techniques, we chose gaze-directed control as it is close to real situations: we usually look to a specific position when walking.

One general issue of gaze-directed control is that it couples gaze direction and travel direction, which means that users cannot look in one direction but move to another direction simultaneously. In addition, if complete 3D motion is enabled in VEs, gaze-directed control has to tackle two issues: a) users may navigate up and down when they travel in a horizontal plane since it is difficult to keep the

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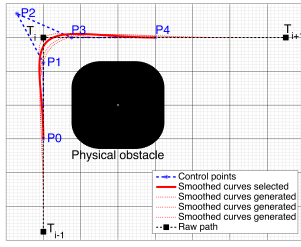


Figure 2: Application of a 4th degree ($n = 4$) Bézier curve to smoothen an intersection.

head at the same level precisely; b) it is awkward to correct the travel trajectory vertically up or down by looking straight up or down.

In order to overcome these two deficiencies of gaze-directed control, we added a path planner that can control the trajectory and avoid the “up or down” effect. The user firstly specifies a target to the VE platform, the system reads the current states of the avatar position and orientation and the destination. The path planning algorithm connects the avatar position to the target position with the shortest trajectory using the A* path planning algorithm by taking into account environmental constraints simultaneously. In order to smoothen the trajectory generated by the A*, we used the Bézier curve fitting to define the final shape of the path, as it enables real time fitting compared to other fitting methods,

$$\mathbf{B}(t) = \sum_{k=0}^n P_k \binom{n}{k} (1-t)^{n-k} t^k \quad (1)$$

where n is an integer related to the degree of the Bézier curve, P_k is the selected control point from the original A* trajectory, and t is a parameter, $t \in [0, 1]$. In a real case, the control point computed on the raw path generated from the A* algorithm is given in Equation 2,

$$\begin{cases} P_0 = T_i + l_1 \frac{T_{i-1} - T_i}{\|T_{i-1} - T_i\|} & P_1 = T_i + l_2 \frac{T_{i-1} - T_i}{\|T_{i-1} - T_i\|} & P_2 = T_i + l_3 \frac{R - T_i}{\|R - T_i\|} \\ P_3 = T_i + l_2 \frac{T_{i+1} - T_i}{\|T_{i+1} - T_i\|} & P_4 = T_i + l_1 \frac{T_{i+1} - T_i}{\|T_{i+1} - T_i\|} \end{cases} \quad (2)$$

where, as shown in Fig. 2, T_{i-1} , T_i and T_{i+1} are the raw path points coming from the path planner; P_0 , P_1 , P_3 as well as P_4 are set to lie in the raw path; l_1 is the distance from T_i to P_0 and P_4 ; l_2 is the distance from T_i to P_1 and P_3 ; l_3 is the distance along the angular bisector (obtuse angle) of the intersection; R is a point on the angular bisector. l_1 , l_2 and l_3 can control the shape of the smoothed path. The transition between two modes of control is achieved by changing the way to act on the travel interface: taking as an example a gamepad, path planning is set by pressing one button but pressing another button activates gaze-directed control.

Fig. 3 presents two different examples of application of the semi-automatic technique: users can accept the default and optimized (shortest) path to navigate, but they may manually modify the generated path at any time using gaze direction. If users get lost in the VE during travel, they can activate the path planner again.

A very first test on 13 VR-novice participants (4 females) comparing our approach with a traditional joystick-based navigation technique in a large virtual environment with points of interest displayed in an HTC Vive head-mounted display, showed that the cybersickness level measured from the Simulator Sickness Questionnaire decreased of about 34% while general feedback from the participants regarding efficiency, likability, accuracy, learnability, immersion, consistency and concentration was significantly more positive with our approach.

3 CONCLUSIONS AND FUTURE WORK

We designed a semiautomatic travel method that can generate smooth travel trajectories. The motion planner in the automatic mode may help users navigate in a VE with less unnecessary and jerky visual stimuli, providing better VR experience.

The path planner requires users to specify the initial and final positions to generate the path, especially in random exploration situations, which is not possible in the present work. Accordingly, in future work, a natural way for users to specify the destination will be taken into consideration. In addition to the optimization of trajectories, the optimization of the travel speed will also be taken into consideration. In-depth user tests will finally be conducted to fully assess our approach.

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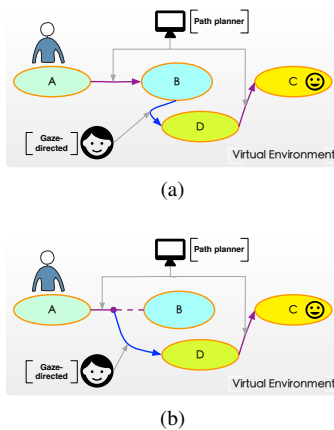


Figure 3: A, B, C and D are different locations in the VE. Our semiautomatic travel technique is used to navigate from position A to C: the purple line is the trajectory generated from the path planner while the blue line is the trajectory generated from the gaze-directed control: (a) the user firstly arrives at B with the path planner but then, rather than going to C, she/he decides to go to D with the gaze-directed control; finally she/he uses the path planner to arrive at C. (b) the user initially decides to go with the default path planner but she/he changes her/his mind before arriving at B and decides to go to D, so the gaze-directed control enables her/him to move to D. Then, she/he moves to C with the path planner.