An Approach to Redirect Walking by Modifying Virtual World Geometry

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ABSTRACT

We present an approach to redirect a user's walking path by dynamically modifying the geometry of a virtual environment. This method allows real walking through environments that are much larger than the physical tracking area without requiring rotational or translational gains. We demonstrate this technique using a proof-of-concept example environment and explain the modifications at each stage of a walking path through the virtual world. We also discuss the potential advantages of this method and outline several open questions for future investigation.

Index Terms: H.5.1 [[Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

Keywords: virtual environments, real walking, locomotion

1 INTRODUCTION

Studies have shown that real walking provides a greater sense of presence, more efficient navigation, and cognitive benefits over other travel techniques [9] [11] [13]. While locomotion achieved entirely through real walking is now practical for many applications, the size of the virtual environment is ultimately limited by the physical tracking space available. A number of methods have been introduced to overcome this limitation, allowing the use of real walking in virtual environments that are much larger than the physical tracked area. Redirected walking is one such technique that introduces a continuous rotation to guide the user along a modified path [6]. This method introduces a visual-proprioceptive conflict which has been the subject of several recent studies [1] [8]. Alternatively, translational gain techniques have been proposed to increase the step size of the user without modifying rotation [2] [12]. Peck et al. noted that all these methods can be augmented by introducing reorientation techniques to handle failure cases and showed that visual distractors resulted in less awareness of the reorientation [5].

We propose a method to redirect the walking path of the user while maintaining natural rotation and translation. This technique relies on modifications to the geometry of the virtual environment that will cause the user to walk along a path that conforms to the boundaries of the physical tracking area. As a result, it is highly dependent on the particular structure of the environment in question. This method is not a generalized solution that will automatically work with all environments; rather, it is best conceived as a strategy to employ *during the design phase* for the virtual environment. Thus, the goals of this project are twofold: (1) implementing a proof-of-concept environment to evaluate this technique in a controlled study; and (2) developing guidelines for designing environments that employ this technique and/or methods to transform existing environments automatically.

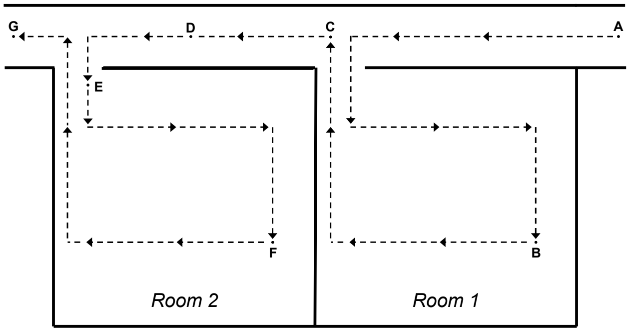

Figure 1: A static model of an example environment which is used as a proof-of-concept of this technique.

2 TECHNIQUE OVERVIEW

Environmental spatial knowledge is usually categorized into three levels: (1) landmark knowledge; (2) route knowledge; and (3) survey knowledge [10]. By manipulating the geometry of the environment, we present the user with conflicting spatial layout information, which could negatively influence formation of survey knowledge. This, in turn, could make it more difficult for users to orient themselves, which is particularly concerning given that spatial orientation is already difficult and error-prone in virtual environments [7]. However, recent research has shown that users tend to orient primarily using landmarks when this information conflicts with spatial layout [4]. Thus, it is important to preserve qualities of the environment which will contribute to landmark and route knowledge as much as possible when altering the layout. Specifically, we attempt to preserve the locations of salient objects (and relationships between them) and the direction of turns when the user is given a choice between two or more paths. We hypothesize that users will tend to ignore inconsistent spatial information and will instead orient using the salient objects in the scene.

This technique relies on modifications to the environment geometry which switches the orientation of doorways so that the walking path stays within the available tracking area. The overall environment is not rotated; instead, the environment dynamically changes around the user, but these modifications are always applied ”behind the scenes” when the user is looking away. This is comparitively easy in a head-mounted display due to the low field of view of these devices relative to the real world. This method seems well-suited for interior environments where the transitions between rooms can be exploited for this purpose.

Figure 1 shows a static model of a proof-of-concept example environment - a corridor with several rooms, such as one would find in a typical office building. A virtual walking path is shown in which the user visits each room as he/she travels down the corridor. This example is intended to be used with a square tracking area that is slightly larger than one of the single rooms. Figure 2 demonstrates the process of modifying this virtual world at each stage of the walking path through the environment. Initially, the corridor and the first room of the environment are fitted within the available tracking area (State 1). When the user is inside the room, the ori-

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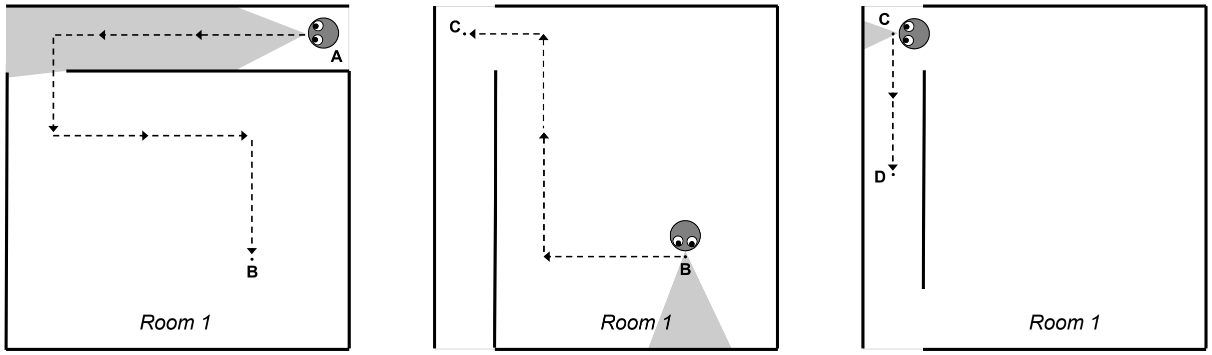
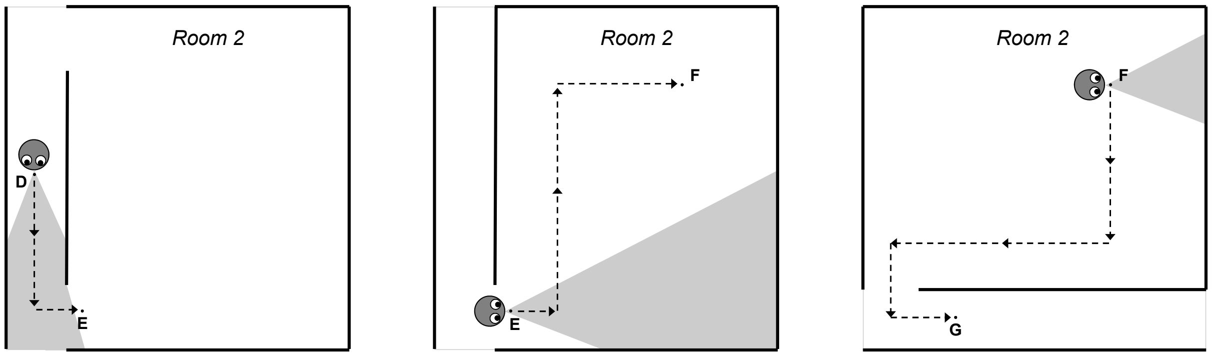


(a) **State 1**: Initially, the corridor and the first room are fitted to the tracking area.

(b) **State 2**: When the user is inside the room, the direction of exit is changed and the corridor is realigned along the perimeter.

(c) **State 3**: As the user transitions to the corridor, the next door is added.



(d) **State 4**: As the user approaches the door, the first room is replaced by the second room.

(e) **State 5**: As the user enters the second room, the first door is removed.

(f) **State 6**: When the user is inside the room, the direction of exit is changed and the corridor is realigned along the perimeter.

Figure 2: A step-by-step explanation of the dynamic modifications to the virtual environment geometry. The visible area of the environment, calculated using a 45 horizontal field of view, is shown in gray. This measurement is approximately the field of view provided by the Virtual Research VR1280 head-mounted display.

entation of the door is changed, the corridor is realigned along the perimeter of the area, and the geometry of the room is adjusted to maximize the remaining usable area (State 2). Though the dimensions of the room are altered to allow space for the corridor, the overall area of the room is preserved. This transformation allows to the user to exit the room and continue down the seemingly long corridor while remaining within the boundaries of the tracking area. The next three transformations are necessary to support the gradual transition into the next room, which lies within the same physical boundaries in the tracking area. As the user enters the hallway, the doorway to the second room is opened (State 3). As the user walks down the hallway, the geometry for the first room is replaced by the second room (State 4). When the user enters the room, the original doorway out of the room is removed (State 5). Finally, when the user is inside the second room, the orientation of the door and the geometry of the room changes again, allowing the user to proceed back out to the corridor and continue (State 6). This method can be repeated for an arbitrary number of rooms along the corridor, allowing a large environment to be represented.

3 DISCUSSION

The strategy of dynamically modifying the environment geometry at runtime has several potential advantages over existing techniques. We believe that to provide a realistic and natural interaction, it is beneficial to maintain a direct mapping of the user's physical position and orientation without introducing any discrepencies in translation or rotation. We also hypothesize that this technique will be less noticeable when used in tracking areas that are large enough to use real walking, but too small to easily support redirected walking without becoming perceptible to the user. As we do not yet have the data to back up these claims, we plan on conducting studies to formally evaluate this method against existing techniques.

It should be noted that this technique fails when the user chooses to skip visiting a room along the corridor or attempts to backtrack and revisit a room. In this case, a reorientation technique should be employed as suggested by Peck et al. [5]. At best, if the user follows the predicted path, no reorientations will be necessary. This technique may be more easily applied when the user's path can be reasonably predicted, especially if cues can be given to guide the user along the intended path (such as opening and closing doors). Virtual tours are one such application which fit this constraint and may work well with this technique.

In our example, we did not directly address the question of how objects in the environment, such as tables or chairs, should be repositioned when the dimensions of the room are modified. Given that the landmarks in the environment are important for orientation, especially when altering the spatial layout, we believe that these objects should only be repositioned to preserve important conceptual relationships between them (for example, a chair to the left of the door should remain in that relative position after the door orientation is switched). One potentially interesting question would be whether this technique could be combined with passive haptic feedback for objects in the environment, which has been previously explored in conjunction with redirected walking [3].

This technique introduces a number of open questions:

- To what degree are the perceptual ”tricks” used by this technique noticeable to the user?
- How does this strategy influence user’s ability to spatially orient and form a cognitive map of the environment?
- How important is it to preserve landmark information when employing this technique?
- How does this technique compare against existing methods, such as redirected walking?
- What strategies can be used to automatically apply this technique to existing environment geometry?

We are currently implementing the example environment using a 224 square foot tracking area and are in the beginning stages of designing a user study to investigate some of these questions.

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