

# A Realistic Walking Model for Enhancing Redirection in Virtual Reality

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## ABSTRACT

Redirected walking algorithms require the prediction of human motion in order to effectively steer users away from the boundaries of the physical space. While a virtual walking trajectory may be represented using straight lines connecting waypoints of interest, this simple model does not accurately represent typical user behavior. In this poster we present a more realistic walking model for use in real-time virtual environments that employ redirection techniques. We implemented the model within a framework that can be used for simulation of redirected walking within different virtual and physical environments. Such simulations are useful for the evaluation of redirected walking algorithms and the tuning of parameters under varying conditions. Additionally, the model can also be used to animate an artificial humanoid “ghost walker” to provide a visual demonstration of redirected walking in virtual reality.

**Index Terms:** H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

## 1 INTRODUCTION

The creation of immersive virtual environments is heavily constrained by the limited physical space in which the user operates. In recent years, the desire to enable real walking in virtual reality has led to the development of redirected walking. Redirected walking imperceptibly alters the mapping between real world and virtual motion to allow a user to explore a large virtual space within a confined physical area. Currently, several methods for redirection exist and research focuses on combining various redirection techniques [5]. The end goal is to develop an algorithm that applies redirection effectively and efficiently, maximizing the utility of redirection while keeping perceptual manipulation within acceptable thresholds. In order to achieve this goal, the system must be able to reasonably predict the user’s walking motions. Additionally, redirected walking algorithms are often evaluated using computer simulations of virtual users to demonstrate and test new developments, as shown in Figure 1. While it is possible to model simulated walking paths using straight lines connecting waypoints in the virtual environment, this is not a realistic approximation of human motion in the real world.

This paper presents a walking model for use in the development and evaluation of redirected walking algorithms. Given that exploiting user motion is a critical component of redirected walking, a more accurate model of human walking will enable virtual reality systems to more accurately predict users’ walking trajectories. Additionally, this model can also be used to improve evaluation capabilities achieved via simulation.

## 2 GOALS FOR THE MODEL

The scientific community is not lacking for models of natural walking. Biomechanical models are highly accurate, and some models

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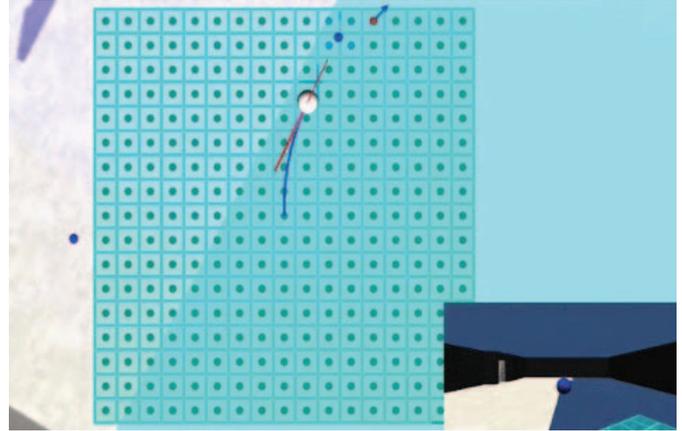


Figure 1: An example of a simulation environment for testing a redirected walking algorithm. The sphere represents the user, while the red line represents trajectory, and the blue line is the path after the application of redirection.

have been extended for use in animation or video games. However, the degree of accuracy seen in these models is unnecessary and cumbersome. Therefore, this model aims to provide the necessary basics to be useful in simulation without impacting the performance of the program. Considering path generation, multiple tools exist that focus on the most efficient path, which is an inaccurate approximation of the actual walking paths that would be taken by a user in a virtual environment.

This work is based in part upon previous research at the University of Virginia, which developed realistic path planner that was validated against real world data. The development of this simulated walking sought to expand upon this research and apply it within the framework of redirected walking and virtual reality. There were four main requirements that were considered during the development of the model. Foremost, it must be computationally efficient. The focus of test simulations is on the path taken by the user; a biomechanically accurate model is not necessary to accomplish this. Second, the walking model should generate a realistic walking path. Humans do not take the most efficient route between two points, so to maximize the “redirectability” of the subject, this needed to be replicated. The third requirement was that the model be able to visually replicate salient components of human motion to provide a “ghost walker” for use in demonstration. The walker would be beneficial in illustrating the concept of redirection for those unfamiliar with the technique. Finally, we wanted the walker to offer various configurations faithful to the differences exhibited between men and women when walking. This mainly pertains to variations in step length and velocity.

## 3 THE MODEL

The walker was designed around a waypoint mode of travel to align with current redirection techniques used and was developed in Unity to allow compatibility with existing simulations.

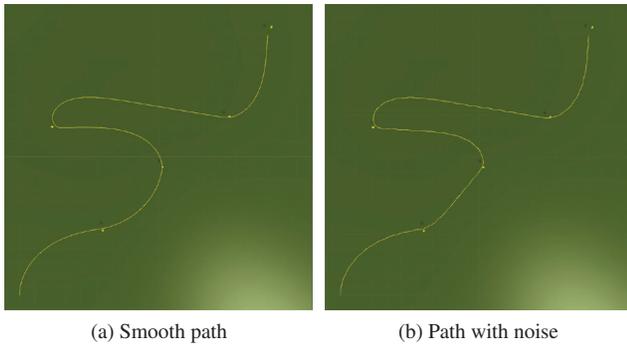


Figure 2: The two paths generated by the model between five arbitrary waypoints. Noise from head motion does not effect the overall trajectory of the path.

### Walking Paths

Two components of human walking paths were considered while developing the model: the global shape of the walking path and deviations that occur on a minute level due to gait cycles and head motion.

The global shape of the path is determined based on the location of the current waypoint and initial heading. From [1], humans gradually adjust their heading to align with the desired heading at the target. Additionally, at higher velocities, the shape of the path is initially strongly curved, followed by a more linear segment to the final target. The model continually adjusts the current heading against the desired heading to generate the trajectory. This results in paths such as the one seen in Figure 2a.

Upon closer inspection, walking paths exhibit slight jitter. These deviations result from natural gait cycles combined with the positioning of the head. In general, during each gait cycle the head travels in a sinusoidal path along each axis. Using data collected from [2] and [4], these deviations were quantified and applied to the paths to replicate the jitter. The result can be seen in Figure 2b, where the amplitude of the deviation has been magnified to illustrate the motion along the path. The overall trajectory did not change with the addition of a parameter accounting for noise from head motion.

### Humanoid Walker

In addition to developing a tool that accurately modeled human walking paths, we also sought to create a realistic humanoid walker. As mentioned before, we wanted to consider the impact of variables such as height and sex. While these do not drastically alter the shape of the path, they are all known factors that determine characteristics of walking such as stride length and step frequency. Based on informal testing and anecdotal evidence from the creation of walking in place models, stride length was identified as one of the most important elements in faithfully replicating an individual's stride pattern. Therefore, transitioning between male and female alters this variable to change the projected path.

Regarding speed variables, from [1], the maximum observed velocity was 1.36 meters/second, and when approaching a marked turn (not the final target) the observed speed was 1.10 meters/per second. When approaching the final target, deceleration began 1.63 meters from goal, and maximum speed was attained 1.82 meters from the origin. These parameters were applied to the humanoid model to replicate typical speed features during walking.

To animate the walker, open source, unedited motion capture data was applied to a humanoid skeleton to create a 'ghost walker', shown in Figure 3. For consistency, some of the raw motion capture

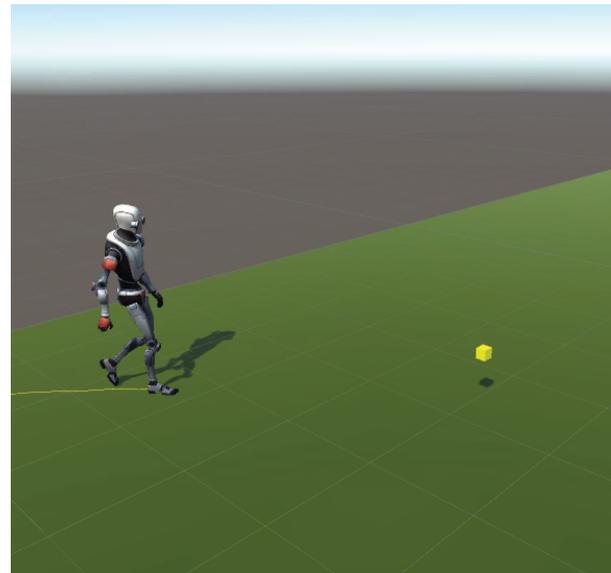


Figure 3: A humanoid walker navigating the same set of waypoints as shown in Figure 2.

data was edited to mirror the average values for head motion.

### 4 CONCLUSION

This walking model has the potential for numerous applications involving the development and simulation of redirected walking techniques. Work is currently being done to incorporate the model with existing research that seeks to evaluate the performance of different redirection algorithms under varying physical and virtual environments. Regarding future work, [3] proposes a standardized framework for evaluating the accuracy of virtual walking paths. This framework would be a useful metric for validating the path composition aspect of the model using motion tracking data collected from actual users.

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