Suspended Walking:
A Physical Locomotion Interface for Virtual Reality

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Abstract. We present a novel physical locomotion interface for virtual environments. It suspends the user in a torso harness so that the feet just touch ground. Low friction materials allow walking motions with ground contact similar to real walking, while maintaing the user in the same position. We detail the hardware and motion tracking setup and outline results of a first user study.

Keywords: physical locomotion interfaces, virtual environments, games.

1 Introduction

We propose a novel physical locomotion interface for virtual reality that enables more natural walking by suspending the user so that the feet just touch the ground. The user rests in a harness that is mounted to the ceiling or a frame, and stands upon a low friction surface wearing special slippers. This allows for a high degree of freedom of movement, most importantly a full walking motion, while still maintaining the sensation of touching the ground and remaining in the same location.

Torso harnesses are used in healthcare and rehabilitation for walking-impaired patients. They are designed for maximum comfort while giving optimal support. In addition to a torso harness, our technique requires two leg-mounted 3-axis accelerometers for the detection of walking-patterns.

Suspended walking has advantages over existing physical locomotion techniques. It does not require large area tracking space and technology like actual walking techniques do. Unlike many devices simulating walking, the harness allows full freedom of movement for the legs, and does not suffer from device lag (unlike, for instance, a treadmill, which requires time to stop). It also enables turning motions and can be extended to support jumping.

The application areas for suspended walking are diverse. Apart from general physical locomotion in virtual realities for increased presence, it can be used for specific applications requiring "natural" full-body motions from the user or it can be employed in the context of games for health. From a therapeutic perspective, suspended walking opens up intriguing perspectives for rehabilitation and physical therapy. It can make the capacity of motion-based virtual environments for motivation, feedback and guidance available to people who suffer from impaired mobility.
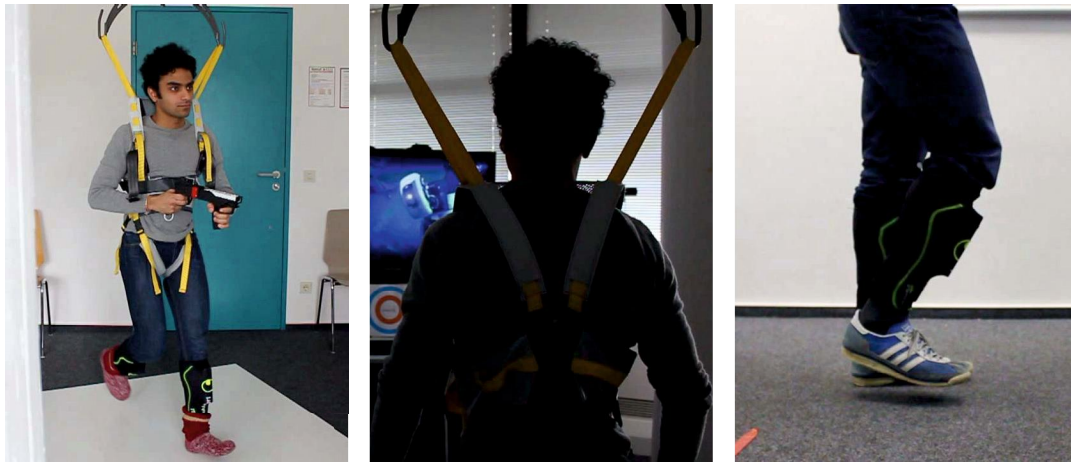
Fig. 1. Suspended walking (left, middle); walking-in-place (right)

2 Related Work

Physical locomotion techniques employ the user's body motion to facilitate moving through virtual environments. The physical exertion of the user has been shown to increase the self-perceived sense of presence in comparison to sedentary techniques [1]. Virtual reality research distinguishes three categories: walking, walking-in-place (WIP) and devices simulating walking. Virtual travel interfaces using actual walking transfer the user's physical locomotion directly into the the virtual space. These can only be used for small areas, due to the restricted tracking range of sensing devices. WIP techniques require the user to imitate a walking motion on the spot. Although this does not require the full leg motions of real walking, it is a good compromise between completely virtual travel and real walking, supporting presence better than the former but less than the latter. Keeping recognition latency to a minimum poses a challenge for WIP interfaces. State of the art algorithms approach this matter with prediction heuristics based on biomechanics [6]. Simulation devices address the tradeoff between area constraints and natural motions by mechanically supporting the user in making full walking motions without actually moving. These devices range from treadmills to spheres [2] or low friction surfaces [3,4]. However, such devices often suffer from balance problems, lag or limiting the freedom of movement of the user.

Our technique enables a high freedom of movement and the sensation of natural walking. Since it does not spacially translate the user, the tracking requirements remain confined to tracking the user's actions in a specific location.

3 Technique and Setup

The harness was originally developed for aiding walking-impaired patients in therapy. It consist of straps for the lower torso and loops for the thighs, which are attached to a yoke above the head. It requires a suspension that should safely carry at least twice the maximum weight expected for users. We experimented with low friction materials for the floor and feet, wool slippers or socks and a PVC sheet provided good characteristics.

The suspension setup works with both vision-based as well as accelerometer sensing, and we experimented with both. Our goal was to match our suspension setup with state of the art, low-latency walking recognition. Although skeleton recognition with the Microsoft Kinect worked well with the harness setup, we did not find it accurate enough for our purposes. We thus employed the signals of two 3-axis accelerometers (in the form of Nintendo WiiMotes), each attached to one lower leg of the user via shin guards.

Our walking detection is based on a state-of-the-art low-latency walk phase detection algorithm [6], which we have already successfully used for a WIP technique [5]. The recognition algorithm identifies the current step section of the leg movement using a series of optional conditions that need to be matched. These conditions include a min/max acceleration in each cardinal direction, a maximum amount of time the previous step section is valid, a masking time in which no next step section may be detected and a min/max difference between the two most important accelerations: Y (vertical) and Z (depth). A step is only completed, when each of the step sections occur consecutively. Step frequency is then transformed to walking speed using the heuristics of the gait-understanding-driven (GUD) WIP technique [6]. With small adjustments, we utilised the resulting predictions to implement a very low latency starting, stopping and walking speed detection. Although initially developed for WIP, this algorithm works with our suspended walking as well. Due to the "floating" movement in our suspended setup however, the pattern recognition algorithm does not deliver the same accuracy as for WIP, since distinct accelerometer spikes that normally occur when the feet touch the ground or are lifted from it are missing.

Suspended walking can be used with any kind of display setup. Since the user remains stationary, a heads-up solution is not required. In our working prototype, we achieved reasonable immersion with one large planar display. However, this only allows relative orientation gestures. In order to allow absolute orientation, a more immersive cave setup or heads-up display would be necessary.

4   Evaluation

To get first insights on our approach, we evaluated suspended walking in a user test against walking-in-place and the default keyboard and mouse setup. 18 test persons aged between 22 and 30 (average 26.3) took part in the experiment. 7 of the participants were male, 11 of them were female. Each participant used each technique to play an exergame adaptation of the action game *Portal 2* [5]. The treatment consisted of an obstacle course specifically designed for the experiment with a level editor. While none of the participants found the suspension setup most comfortable, which was attributed to a not well fitting harness, 6 of them would use it again and 3 rated it to be the most natural and intuitive user interface. However, none of the users found that suspended walking is easier to use than walking-in-place and the combination of keyboard and mouse. Some of the test persons criticised that contrary to walking-in-place, the suspension setup did not allow walking backwards. Others suggested to use a treadmill instead of a harness.

5   Conclusion

We presented a novel physical navigation technique for virtual environments. Like walking-in-place and walking simulation devices, it does not require large-scale tracking spaces. It enables the user to perform a whole step cycle and approximates real haptical feedback from touching the ground, while providing more freedom of movement than simulation devices. We adapted a state-of-the-art low-latency WIP algorithm for the full walking requirements. Results of a qualitative study indicate its potential as a natural walking device, but also point out the importance of a correct harness adjustment. While the harness setup was not perceived as the most comfortable solution when compared to walking-in-place and sedentary keyboard and mouse controls, we argue that the potential to make motion-based games with walking elements accessible to previously excluded player groups, as well as the potential that lies in the implementation of additional motion patterns, such as high jumping, warrant further explorations. As future work, we intend to add support for jumping and crouching by integrating springs into the suspension setup. We will also assess the quality of omnidirectional walking with a swivel and heads-up-display.

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