Virtual Locomotion System for Large-Scale Virtual Environment

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Abstract

Omni-directional locomotion systems are yet of little advantage in virtual environments (VEs) with limited large display system, where users may experience visual-less situations when they move in a direction that is not covered by the large screen. This paper presents a new omni-directional locomotion interface based on step-in-place movement and a smart-turntable system to impart users with the ability to move freely in any direction within VEs without loosing sight of the displayed image despite its projection on a limited large screen that do not provide surrounding or 360° visual feedback. The novelty of the interface is that a) it uses a smart-turntable with embedded sensors as walking platform that compensate users’ rotations rather than their displacements b) no cable attachments are made to the user body c) user can make many full body rotations without loosing sight of the environment, virtually providing a surrounding display despite the use of limited size screen.

1. System Overview

The developed system as illustrated in figure 1, is composed of 3 main parts: a walking platform, sensing system, and large display system. The interface employs a turntable as walking platform on top of which users will stand and interact with the virtual environment that being projected on the large screen. Initially users will stand at the center of the turntable and face the center of the large screen. Users can engage into a virtual walking experience by stepping in place without propelling their body. Step-in-place movement will be detected by the sensing system and treated as a gesture of moving forward in the VE. To change the moving direction or to explore the surrounding environment in general, users are required to turning their body about its vertical axis while remaining at the same position, the same natural turning action they perform in real life. The turn-in-place action is treated as a gesture changing the direction of the viewpoint. However, as the large screen provides a limited projection area, a large turning action will put the displayed image outside users’ visual field of view. To overcome such limitation and keep users continuously oriented toward the screen and provided with enough visual display, the turntable platform will smoothly and passively rotate in the opposite direction of users turning. The passive compensation of users’ active turning will continue until users regain their initial orientation.

At the front side of the system a large display is provided for graphical projection of the VE. For the experimental prototype the screen was 2.5 m wide and 2.5 m high.

2. Walking Platform

The usage of a turntable as walking platform is intended to compensate users turning movement by passive and smooth rotations, hence keeping users oriented toward the screen and avoid them a visual less situation even when they perform large turns. However, turntable rotations should not in any case disturb user’s walking behavior or threaten their stable posture. It is suggested that passive rotation and acceleration should be kept under some threshold values to ensure its transparency to the user. Otherwise users attention may be shifted time to time from the VE to safety or body’s balance concerns.

To provide a smooth and well-controlled passive rotation we designed and developed, in collaboration with Cyverse Company - Japan, a new kind of high performance turntable platform based on linear motor technology. To hide the passive rotation from being perceived at least in its early stage, it is essential that the turntable delivers quite and stable rotation and fine acceleration to guarantee a smooth compensation of users’ turning.

The developed turntable is 70 cm wide and 10 cm high and it has the following features and technical characteristics:

a) Noise less: No hearable noise is delivered during turntable rotation. The presence of such auditory cues may help users to perceive their passive rotation or its direction.
b) Jolt less: the surface of the turntable remains stable during stepping and turning movements. It does not deliver any perceptible vibrations, jolt, or tilting that may increase user’s awareness of the passive rotation.

c) The turntable is directly controlled from a remote personnel computer interface.

However, during stepping-in-place movements users may unintentionally step away from the center of the turntable [4], leading them to step close to the edge or totally outside of the platform. To prevent users from stepping outside the platform and maintain their position at its center, we delimited the walking area where users are required to step and turn by a cylindrical ring with 37 centimeters in diameter and 1 cm thick, which can be haptically sensed by feet, figure 4. User will be required to adjust their standing or stepping position whenever their feet fall on the ring.

3. Sensing system

In respond to user stepping and turning movements the system have to move and orient users in the VE according to their expressed locomotive behavior by updating the viewpoint. A proper updating of the visual feedback will create the sense of linear and circular vection that impart users of the feeling of being really moving and present within the virtual world. A mismatch between user’s movement and visual feedback may user’s ability of spatial orientation. Therefore, a reliable stepping and turning sensing system is necessary to keep the integrity between proprioceptive action and their visual effect.

We propose a new approach for tracking user stepping by embedding load sensors under the walking platform. These load sensors are used to monitor the different ground reaction forces (GRF) between users’ stepping and the walking platform. To reliably gather the generated GRF, we have embedded four FlexiForce load cells on the bottom side of the turntable. The load cells are integrated into a force-to-voltage circuit. The signals from all four load cells are then converted from analog to digital by mean of a national Instruments data acquisitions board loaded in a standard computer. By analyzing the received data the system is able to recognize users actions as they step in place on top of the turntable.

To track user turning, two-colored markers are attached to the backside of the body or to the head, it depends on the application. The two markers have a spherical shape with light reflecting surface. An infrared camera placed back behind the user at a higher position will capture the overall image of the system including the markers. By using our image-processing algorithm, the system can extract from the captured images, and in real time, markers’ position, which determine users’ orientation.

4. Performance

Walking performance and traveling accuracy of the system were tested through various experiments. Below is a comparison of traveling accuracy between joystick device and our locomotion interface. It is shown that step-in-place locomotion kept accurate displacement and smooth turns during sharp corners without loosing sight of the visual display.