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OmniWalker: Omnidirectional Stroller-based Walking Platform

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Abstract—**In virtual reality, locomotion is a key factor in making a simulation immersive. Actually walking is the most intuitive way for people to move about, providing a better sense of presence than walking-in-place or flying. We have built a locomotion system with a ball-bearing platform that allows the subject to walk in a natural fashion in any direction. In this paper we present further development of our walking platform: a three-camera system to improve tracking accuracy, improved calibration using Svoboda's calibration method, and use of glowing multi coloured orbs as markers. Postural information is captured and analysed in real-time using mid-tier hardware computer and webcams. Results comparing the system to an earlier prototype are also presented.**

Locomotion interface, walking, camera triangulation, mean-shift algorithm, virtual reality, omniwalker

I. INTRODUCTION

Locomotion is one of the most important factors in building a truly immersive simulation. Real walking produces a substantially higher sense of presence and learning than virtual walking [1]. The aim of this project is to develop a locomotion device to improve the subject's sense of walking in a multi-user virtual environment, where users can see and interact with each other. The system must also be robust enough to be deployed in an actual training simulation.

Our system is based on an omni-directional ball-bearing disc platform (OBDP) [2], a design which allows the subject to perform a natural walk. However, the OBDP is costly to construct and maintain due to the use of hundreds of custom-made ball bearing sensor switches. Instead, our system employs standard ball transfer units and uses cameras to track user motion resulting in a robust and relatively inexpensive locomotion system. However, our earlier system [3] suffered from a high noise rate due to the use of a parallel two camera tracking scheme.

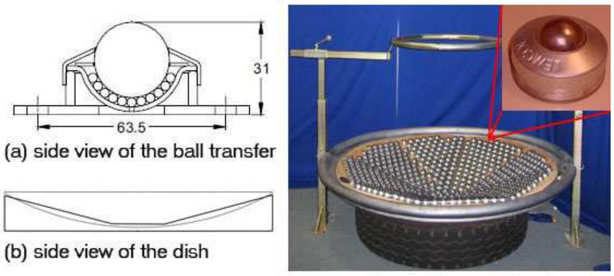

Figure 1. Dish platform

In this paper we describe some improvements being made on the system.

II. SYSTEM OVERVIEW

The platform disc is shaped like a cone with a flattened center (refer to Fig. 1). It uses heavy duty ball transfer units laid on its surface. We use a flat 15 degree inclination angle to provide better footing for the feet to slide. We also placed a rubber support under the dish to provide a more comfortable dampening force. Tracking is done using three Logitech webcams capturing at a resolution of 320x240 pixels with a frame rate of 30 fps.

III. 2D TRACKING AND MARKERS

We use 10 LED orbs attached using Velcro and flexible bands to the subject's body joints. Each LED orb consists of a diffuser and red, green, and blue LEDs. Hence, it can produce a range of colours. In our system we used five different colors for upper and lower body parts to reduce the complexity of the matching and searching problem. Our previous system used reflective markers that required bright lighting which reduced immersiveness by washing out the display screen.

These markers are then tracked in 2D using a mean-shift algorithm (refer to Fig. 2). The input to this algorithm is the result of bit-wise conjunction of two grayscale images from intensity thresholding and histogram backprojection. Intensity thresholding is used to obtain the 2D position of the markers regardless of its color. It applies fixed-level thresholding to the maximum

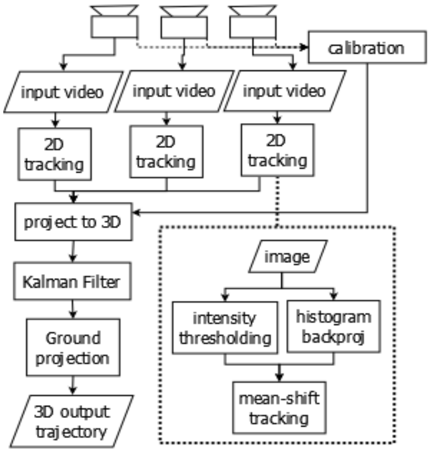

Figure 2. System flow diagram

value of the three-channel RGB image array.

Histogram backprojection generates the intensity image from the hue channel based on similarity to a color histogram. This color histogram is generated automatically during the initialization phase which is described below. To initiate tracking, the subject adopts a T-stand stance. In order to improve the performance, heuristic matching is only done on one camera view. Once a match is found the intensity threshold and histograms are generated for each view.

IV. 3D TRACKING AND CAMERA CALIBRATION

Camera calibration is done using the multicamera self-calibration toolkit [4]. Scene registration is done using three right-angled LED lights attached to the frame of the platform to compute the transformation from camera to world space. We used Hartley and Zisserman's [5] method of Direct Linear Triangulation to get the 3D position of the markers. The selection as to which pair of 2D feature points to use is sequential from the first two views (left and top cameras). If any of the first two views has lost track of the markers, we then use the 2D feature point from the third view. A Kalman filter is used in the last stage to reduce the noise in the reconstructed 3D data.

V. CONTROL OF AVATAR

The upper body model (including hands and forearms) is controlled using 3DOF motion capture. We manipulate the avatar's hand and forearm to match the position of the tracker relative to its parent.

With the lower body model, we cannot use the 3D tracking information data to directly control the animation of the legs because the movement of the legs (sliding down an inclined plane) is not the same as in a normal walk. To synthesize a robust and natural-looking walk, we use a similar mechanism to that of [6]. Referring to Fig 3. transition between states is triggered by the velocity of the foot. Each state represents interpolation of animation time (t) between 0 to 1.0. This also takes into consideration the rendering update time in order to prevent jerky movement.

Change of walking direction is via a sidesliding gait that is similar to the natural way of turning while walking (refer to Fig. 4-right). For example, for turning left the walker would swing forward the right foot then slide it to the right and then slide it back again. Instead of continuing with the animation, we run the animation in reverse so that the back foot acts as the pivot point.

VI. RESULTS

During a number of preliminary tests, we found the new technique generates much better data at a very low error rate. The jitter generated in the previous prototype is almost non-existent with the new method.

In a few cases, the left camera lost track of one or two markers due to occlusion, but since the user does not need to rotate or move around, these markers are always visible from the other two cameras. Consequently, no loss of tracking ever occurs in the 3D tracking. In the 2D tracking, when a view loses track of a marker, it can recover instantly when the marker become visible again. The system has been tested in single hardware with a 2.4GHz Intel Core2 Duo processor, 3GB DDR2. The system usually perform in real-time with an image acquisition rate of around 30fps. There are still occasional time when it lags when a marker is occluded.

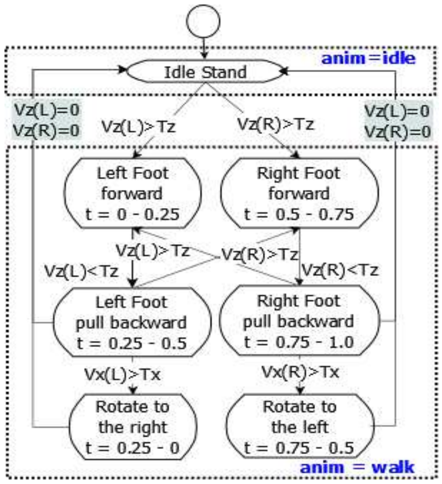

Figure 3. Walking animation states

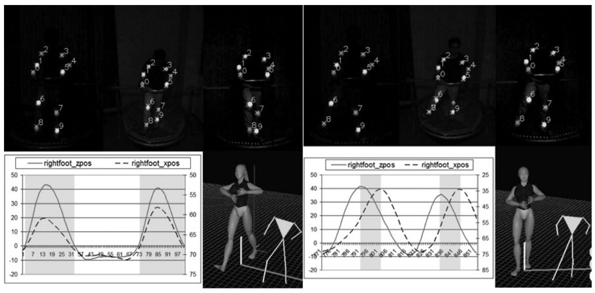

Figure 4. X-axis and Y-axis position of the right foot during forward walking (left) and left rotation gait (right)

VII. CONCLUSION

Using the improved tracking mechanism the system allows more accurate tracking at slightly less computational cost compare to the first prototype. The system is still capable of real-time performance on mid-tier hardware. Assessment of the use of the system in underground coal mine safety training is in progress.

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