



INTERACTION IN VIRTUAL MANUFACTURING ENVIRONMENTS BASED ON LOW-COST LIGHT WAND

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Abstract. *Virtual Reality is known as one of the most advanced form of interaction between man and computer. Visualization, simulation, information provision and telerobotics are just some of the fields that have been explored in the interaction with virtual manufacturing environments. When used with multi-screen projection systems, this technology provides a significant improvement to the perception of realism and accuracy of a synthetic world. There are several commercial devices available for human-computer interaction in virtual manufacturing applications. However, the cost of these devices is still quite high. Thus, this paper presents a light wand-like detection mechanism for CAVE-like systems based on low cost computer devices. Through the use of a regular webcam and image processing techniques is possible to detect light wand-like devices as a form of interaction in an immersive multi-projection environment.*

Keywords: *virtual manufacturing, multi-projection system, image processing*

1. INTRODUCTION

Interaction and immersion are two important fields of research on VR applications and techniques. Research on Virtual Reality (VR) involves studies of several different aspects on development of immersive and semi-immersive virtual environments. Moreover, it includes also the development of new interaction techniques different from common desktop application approach.

With the improvement of computer hardware through the years, VR applications grew considerably as well as the need for interaction techniques such as force feedback devices, other sensory information, head trackers, light wands etc (Cruz-Neira et al, 1992).

Kelner et al (2006), states that the user interaction with virtual reality must be fairly natural, in such a way that the virtual world is just an extension of the real world. Nonetheless, usually these powerful interaction techniques for virtual reality applications are implemented in a proprietary and expensive way and bound for specific target platforms, requiring exclusive hardware and software, which holds back portability even though several virtual reality libraries are prepared for hardware abstraction practices.

This paper presents a low-cost way of interaction in an immersive multi-projection system based on light wand like devices. Through the use of a regular webcam and image processing techniques it is possible to detect light points from wand like devices to perform look around, zoom and object selection operations in an immersive virtual environment.

The remainder of this paper is organized as follows: in Section 2, a brief introduction to the immersive multi-projection system is done. The interaction based on light wand like devices is described in Section 3. The results and discussion are presented in Section 4. The conclusion is stated in Section 5 and references in Section 6.

2. IMMERSIVE MULTI-PROJECTION SYSTEM

Schuemie et al (2001) cite that the factors that differentiate the virtual reality technologies from other visual interfaces are the presence or the user immersion and interaction with the elements.

An immersive multi-projection system has a set of features that allow the user a deep interaction with the virtual environment, which is a valuable tool for scientific visualization and exploration of very large datasets.

The Multiuser Laboratory of Immersive Visualization (MLIV) of the University of São Paulo (USP), located in São Carlos-SP, has an immersive multi-projection system with three projected surfaces (two walls and floor) as described in section 2.1.

2.1 MLIV Infrastructure

The immersive multi-projection system of the MLIV consists of three projection surfaces (two walls and a floor) with dimensions: 3.2 x 2.4 meters (front wall), 2.4 x 2.4 meters (right wall) and 3.2 x 2.4 meters (floor) as shown in Figure 1.

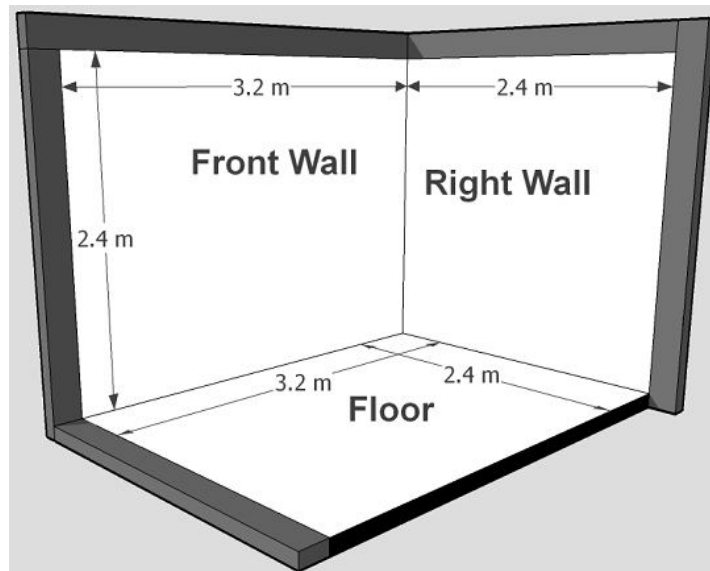


Figure 1. Immersive Multi-projection surfaces

For each projection surface there are two Christie DS +60/DW30/Matrix 3000 projectors, a personal computer with an Nvidia Quadro FX4500 video card and 4GB of RAM. Each computer is connected to the projectors through DVI cables. There is a main computer where one can access or control the three computers responsible for the projection surfaces. The mounted system allows the passive stereo visualization mode, where each projector is responsible for the image visualization of one of the user's eye.

The images for the right and left eyes are projected superimposed on the screen so that the use of stereoscopic glasses is possible to obtain the feeling of immersion in any virtual environments. The stereoscopic glasses used in MLIV are INFITEC filters. This type of system allows the immersion of multiple users within a virtual environment, as long as each user wears a pair of stereoscopic glasses. A complete description of the multi-projection system was already presented in Oliveira et al (2009).

2.2 MLIV Development Tools

The main development tool used in the MLIV system is VR Juggler 3.0, a free virtual platform for the creation and execution of immersive applications, that provides a virtual reality system-independent operating environment. The construction of virtual environments is developed by importing 3D models and creating scene graphs through OpenSG 2.0, a free portable scene graph system to create real time graphics programs for virtual reality applications.

For light wand like device detection the OpenCV 2.4 was used. OpenCV is an open source computer vision library which focuses mainly on real time image processing and allows people to easily write programs for such tasks as finding specific individuals in images and detecting motion of objects or gesture detection (Sugano & Miyamoto, 2009). The OpenCV library runs parallel to the functions of VR Juggler and OpenSG libraries by monitoring the input data in the video capture through the use of threads. The input video device is a regular webcam found in most of pc computers.

3. INTERACTION BASED ON LIGHT WAND LIKE DEVICES

3.1 Light wand like devices

Some of the low-cost light wand like devices we tested are based on laser pointers and small flash-lights. In order to correct the light noise captured by the camera, a translucent white plastic material was attached at the tip of the devices, as shown in Figure 2.



Figure 2. Laser pointers and small flash light

We also built another light wand like device with three different colors of led lights and three buttons to turn each color on and off. Therefore, besides calculating the movement of a point of light in each frame of the camera, the color (red, blue and green) of the light is also taken into account to perform an action in the virtual environment. As with the laser pointers we used a plastic filter to smooth and focus the brightness of the led lights, as shown in Figure 3.

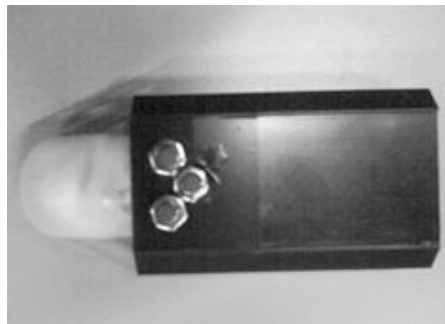


Figure 3. Light wand like device

The user movement detection was performed through the use of one or more laser pens within the field of view of a webcam.

Through the movement of the light point of the device it is possible to move 3D objects in an immersive virtual world.

To capture the light wand movement, a low-cost webcam was used. The webcam was set to capture an image as dark as possible, so the light of the device could be highlighted in the image. To reduce the processing time, just one webcam was used.

In order to capture all the user movements with just one webcam, different positions of the camera were tested and the best position found was on the floor wall, at the point where the three walls meet each other.

The webcam was pointed to the eyes of the user as shown in Figure 4.

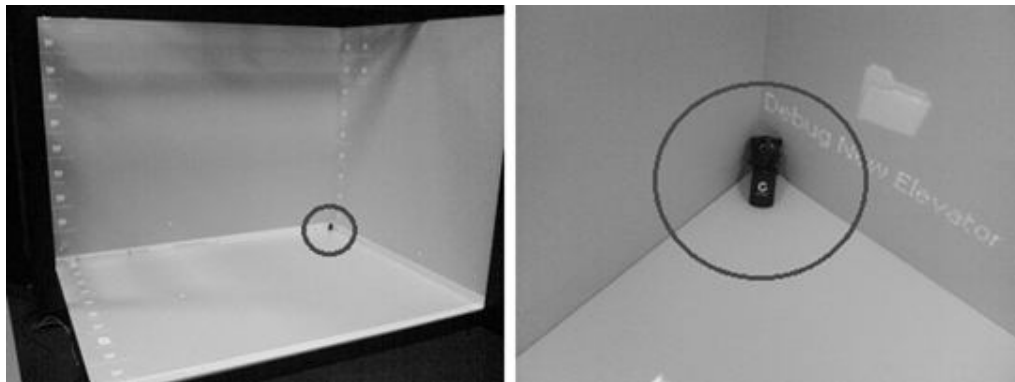


Figure 4. Web camera position on the multi-projection system

3.2 Image processing

Initially, using the OpenCV library, each frame of the webcam stream is converted from RGB color space to gray scale. Then a threshold is used to generate a binary image, where the white pixels are the light point (if the light device

is on) and the black pixels are the background. If there is no white pixel in the image, it means the light device is off. Figure 5 shows the sequence of 3 images which illustrate the process just described.

The light point was segmented and some morphological properties were extracted, such as its area and its center.

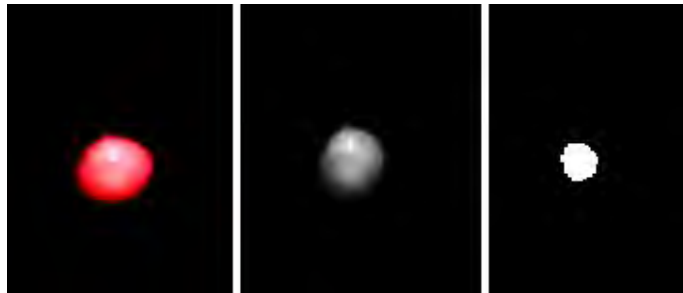


Figure 5. From RGB to binary image of the light point

3.3 Look around function

For each frame of the image, the x and y coordinates of the point light were stored and then the difference between the current position (current frame) and the previous one (previous frame) was calculated.

The difference between the last two coordinates was multiplied by a constant that determines the speed of the movement of the 3D objects and the result was used to adjust the x and y coordinates of the 3D objects in the virtual world, as shown in Equation 1.

$$\begin{aligned} \Delta x &= speed \left| x_{current_frame} - x_{last_frame} \right| \\ \Delta y &= speed \left| y_{current_frame} - y_{last_frame} \right| \end{aligned} \quad (1)$$

By adjusting the x and y coordinates of the 3D objects while the z coordinate value is kept, it is possible to obtain the look around function inside the virtual environment with the use of a light wand like device.

3.4 Zoom function

As the zoom function needs the z axis and the webcam image provides just two dimensions, two light wand like devices are used simultaneously to get the proper data to adjust the position of the virtual world.

When the user moves the two light points towards each other, that is, the light points get closer in the image, zoom out is performed. On the other hand when the two light points move far away from each other, zoom in is performed in the virtual world, show in Figure 6.



Figure 6. Two light wand like devices used to perform zoom in the virtual world

Through the use of image segmentation, the system gets the distance between the two light points on each frame and compares the current distance with the last distance to obtain the zoom parameter of adjustment, as shown in Equation 2.

$$\Delta z = s \left(\left| x_{light1} - x_{light2} \right|_f - \left| x_{light1} - x_{light2} \right|_{f-1} \right) \quad (2)$$

The s parameter controls the intensity of zoom and the f and $f-1$ are the current and last frame.

The system identifies if the user intends to perform either the look around or the zoom function inside the virtual environment, based on the number of light points detected in the image.

3.5 3D object selection

To allow the selection of specific 3D objects in the virtual world a 2D pointer was developed, as shown in Figure 7.

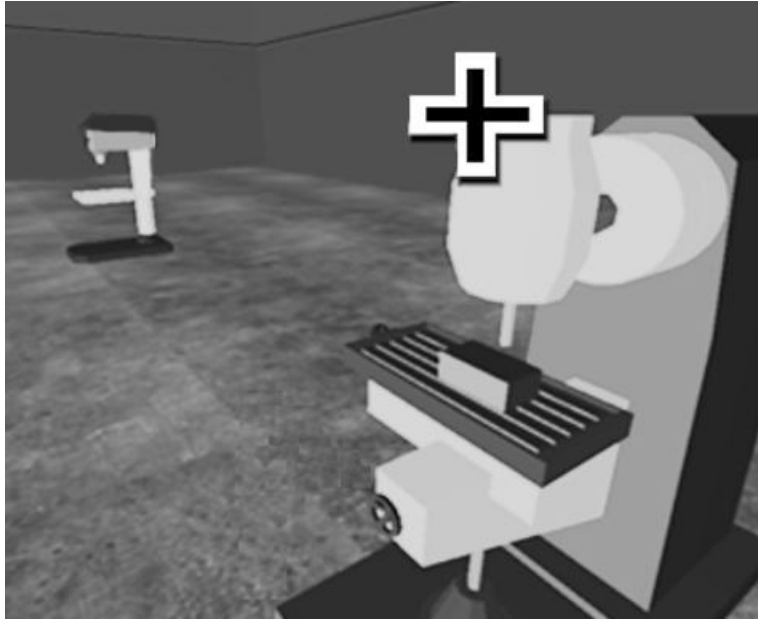


Figure 7. Two dimensional pointer to select 3D objects.

The 2D pointer is an object model added in the OpenGL scene graph as any other virtual object. Nevertheless, its movement is restricted to the xy-plane, as a mouse pointer on a desktop computer screen.

A light wand like device is used to move the 2D pointer throughout the scene. When the user wants to select a specific 3D object, the light device must be turned on and off twice in a row, simulating the click of a mouse. If the 2D pointer is over the specific 3D object then this object is selected. Once the object is selected, the user moves the light point device and both the 2D pointer and the object are moved through the virtual world.

In order to find whether the light point is on the object or not, it is necessary to get the screen coordinates of the object and compare with the screen co-ordinates of the pointer. The screen coordinates of the objects are gotten through OpenGL library functions.

As the user turns on and off the light in a very short interval, the system interprets this blink as a “double-click” of the light device and the object selection is performed.

4. RESULTS AND DISCUSSION

During the tests performed with the light wand like devices inside the immersive multi-projection system, the users could explore the virtual worlds by just moving the light devices in front of the camera. The look around, zoom and selection functions were successfully achieved in practical use. However, the 2D pointer worked better when it was used in just one of the projection surfaces at a time. When the 2D pointer moves from one wall to the other the user loses the intuitive control of the pointer due to the ninety degrees angle between the walls.

The fact that the user needed no wire, fancy and expensive devices to interact with the virtual world besides a simple webcam and a pair of laser pens allowed great user mobility inside the multi-projection system through low cost technology, as well as the reuse of such solution to any virtual world application.

The tests performed showed that there were almost no delay between the user movement and the 3D environment response. The interaction feedback was highly satisfactory compared to other proprietary solutions.

For future work a 3D menu can be developed so that the user can choose many other functions to be performed through by handling the light wand like devices.

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5. CONCLUSION

With the improvement of computer hardware through the years, VR applications grew considerably as well as the need for interaction techniques such as force feedback devices, other sensory information, head trackers, light wands etc. Nonetheless, usually these powerful interaction techniques for virtual reality applications are implemented in a proprietary and expensive way and bound for specific target platforms, requiring exclusive hardware and software, which holds back portability even though several virtual reality libraries are prepared for hardware abstraction practices.

This paper presented a satisfactory low-cost solution to interact with an immersive multi-projection system based on light wand like devices. Through the use of a regular webcam and image processing techniques it was possible to detect light points from wand like devices to perform look around, zoom and object selection operations in an immersive virtual environment. The fact that the user needed no wire, fancy and expensive devices to interact with the virtual world besides a simple webcam and a pair of laser pens allowed great user mobility inside the multi-projection system through low cost technology, as well as the reuse of such solution to any virtual world application.

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