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3D Input Interface via Hand Motion Using Stereo Camera System for Wearable PC Environment

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Abstract

Research on wearable computing has recently been studied for providing new information environment with computing devices worn on human body. In this report, we propose a 3D desktop environment for wearable computer system, in which a stereo camera is equipped on the user's body, and a display is attached beside a glasses. In this system, disparity image and color image are used for robustly extracting the user's hand, of which the 3D position enables 3D manipulation in the 3D desktop environment. We develop such wearable system, and implement some applications in the 3D desktop environment, so that the efficacy of the system can be demonstrated.

1 Introduction

Research on wearable computing has recently been studied for providing new information environment with computing devices worn on human body. For example, wearing the camera and use user's hand as mouse[1][2], wearing the keybord, wearing the device with user's hand and using user's voice as command. It is necessary for wearable computing to develop interface by which a user can operate the system in efficient and easy manner. Interface system that enables the user three dimensional control has also been extensively studied, in which human's gestures are generally used for the system input. For example, in the system[3],user can control in 3D.

In this report, we propose a 3D desktop environment for wearable computing system, in which a stereo camera is equipped on the user's chest, and a display is attached beside a glasses as shown in figure 1. In this system, a user operates computer with the user's hand 3D position and posture. A human usually uses hand's gesture to convey an intention to other person, therefore, controlling computer by the hand is one efficient way. In Most systems about 3D hand mouse, camera is put on the fixed position. In our system, the stereo camera is attached on his chest, because the relative geometrical relationship between the user's hand and body does not change much, so that stable detection of 3D position and posture of the hand can be realized.

In most of related systems [1], user generally equips a camera on his head so that the camera can capture the same information as the user's observation. The camera can not always capture the hand in such a system, however, because the user does not always watch the hand when operating computer with hand's gesture, but may watch some other objects. In our proposed scheme, the camera can always capture the hands motion because the camera is attached on the chest area.

Figure 1: Appearance of the developed wearable system

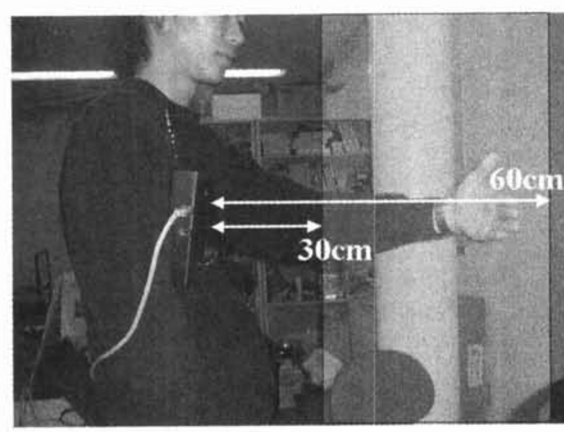

Figure 2: Disparity threshold

2 Appearance

For detecting the user's hand motion, a stereo camera system that can get disparity image and color image is employed. We use Digiclops camera system (Point Grey Research Inc.) as the stereo camera system for capturing hand motion. It has three cameras and can get disparity image and color image. We equip the camera on the user's chest. We also attach the Clip-

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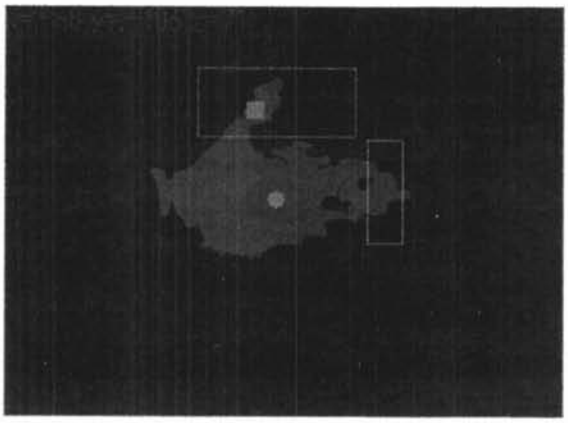


Figure 3: Hand region extraction.

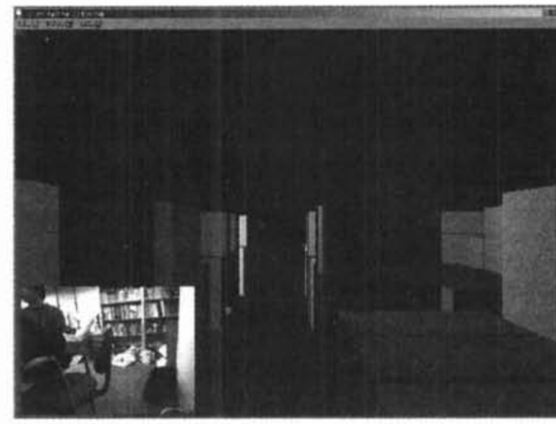


Figure 5: 3D Map Viewer

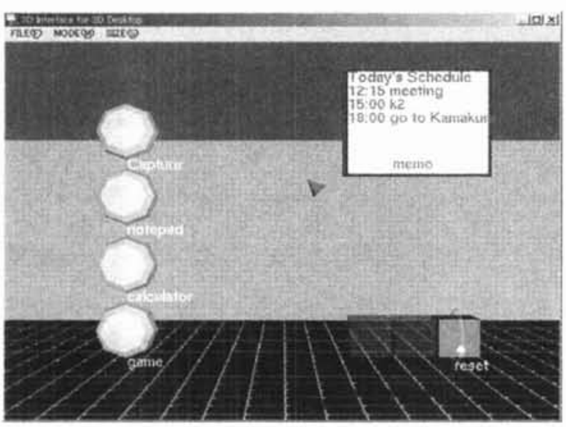


Figure 4: 3DDesktop

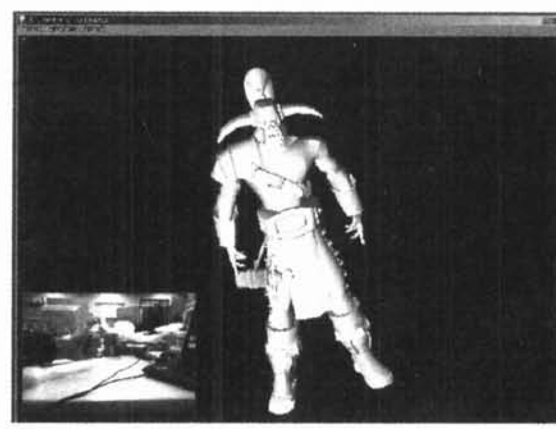


Figure 6: 3D Model Viewer

on Monitor (Micro Optical) on the user's glasses. The user can see the 3D desktop through this monitor. The camera and the monitor are connected to the laptop computer which is in the rucksack of the user. The user can manipulate the 3D desktop by moving hands in front of the camera which is equipped on the chest.

3 Hand motion detection using stereo camera system

First of all, we adjust white balance to remove the influence of lighting condition. We put the white object in front of the camera, then the system adjust white balance automatically.

3.1 Hand region extraction

First, hand 's region is roughly extracted from disparity image by thresholding the disparity image, according to the fact that the hand can be moved in restricted space ($30cm$-$60cm$) in front of the chest (figure 2), on which the camera is attached.

Second, thresholding hue value from the color image limits the hand's region. Such thresholdings of disparity and color images make the extraction more robust. Figure 3 shows an example of the hand extraction. Finally, we extract the largest region as hand region.

3.2 Controlling 3D position and 3D rotation via hand motion

For controlling 3D position, the position of the thumb is detected. We assume that the thumb is always pointing up when user move his hand. We set the rectangle thumb region above the center of the extracted hand region to decide the position of the thumb. We define the center of the hand region as (Xc, Yc), and then place the center of the thumb region at $(Xc, Yc + Y1)$. $Y1$ is the distance between hand's center and the center of the thumb region. We define D as the disparity of hand's center and a,b,c as constant, then $Y1$ is defined like following equation.

$$Y1 = a(D - b) + c \qquad (1)$$

where $Y1$ is proportional to D, because the size of the hand region can be regarded to be proportional to the disparity of the hand region.

After that, we select the extracted hand region inside the the rectangle thumb region. The center of the selected region is regarded as the thumb position.

We also detect the position of middle finger by the similar way.

In this way, we can robustly determine the position of the thumb and the middle finger in the disparity image, because we take into account the depth of the hand.

We can get the orientation of the palm from disparity of thumb, middle finger and center. The orientation of the palm is used for inputting 3D rotation. When the palm is open, the orientation of the palm can be calculated from the relation among disparities of three points, which are the center of the hand region, the thumb, and the middle finger. However, the calculated orientation in this way is not enough accurate to specify the accurate angle. Therefore, we do not use the rotation angle of the palm for controlling the 3D hand motion interface, but just use the direction of the rotation. Thus, the rotating angle in the 3D hand motion interface is specified by the length of the time. The 3D position and posture are detected as shown in figure 9 for 3D input.

We define palm is closed (figure9 a) as "click" operation of the general purpose mouse.

If the user uses the mouse, the user can input only 2D coordinate and click. But in this system, user can input 3D coordinate and 3D rotation intuitively.

4 3D desktop environment

We develop a 3D desktop environment that is composed of 3D objects in virtual 3D space as shown in figure 4, in which the hand's motion is used for controlling 3D objects in the desktop. We extend the desktop from 2D to 3D, so we can use the desktop more intuitively. We can also use the desktop widely, because icon is arranged in 3D space. In the 3D desktop environment, we developed some utility applications, such as 3D Map Viewer, 3D Model Viewer, Capture, Calculator, Notepad, Game, etc. In such applications, 3D Map Viewer and 3D Model Viewer employ the 3D input interface for controlling the viewpoint and model's orientation in 3D.

4.1 3D Map Viewer

In this system, the user can control the 3D position and direction for viewing the 3D map by the hand's 3D position and 3D rotation as shown in figure 5. If the user uses the conventional interface such as a mouse for such a 3D controlling, the user can't move their view in 3D space easily because he/she can't input 3D coordinate directly. By using hand's motion for inputting such 3D information, it is easy to move and rotate the viewpoint in the 3D space because hand's 3D position can directly control the viewpoint.

4.2 3D Model Viewer

Figure 6 shows the application in which user can move the 3D Model with the 3D position of the hand. If the user uses the conventional interface such as a mouse for such a 3D controlling, he/she can't input 3D coordinate directly. So many application, the position of the depth is assumed by 2D coordinate and the position of the depth is assumed always plus value. For that reason, the user can't move the 3D object in 3D space correctly using a mouse. In this system, we can move the 3D Model correctly and easily, because we know 3D coordinate of the thumb.

By developing such wearable system, and implement some applications in the 3D desktop environment, the efficacy of the system can be demonstrated.

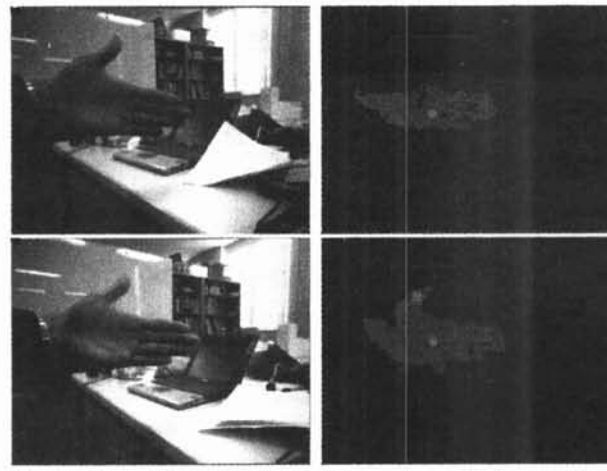
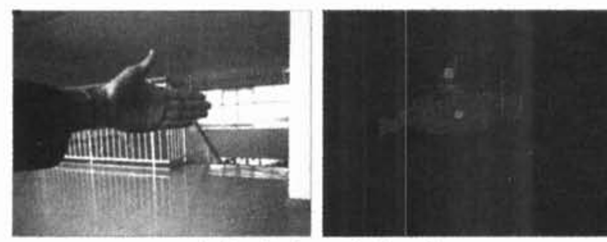
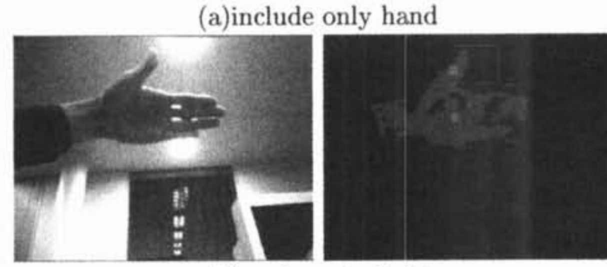


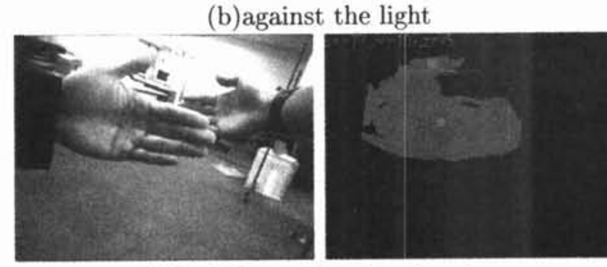
Figure 7: adjust white balance (up : before adjust, down : after adjust)



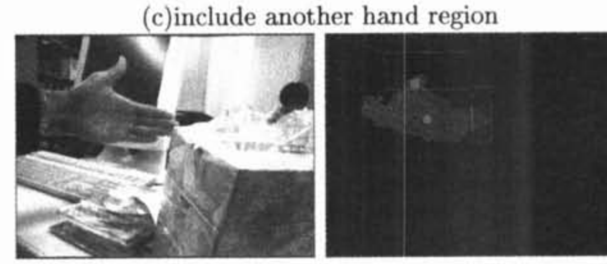
(a)include only hand



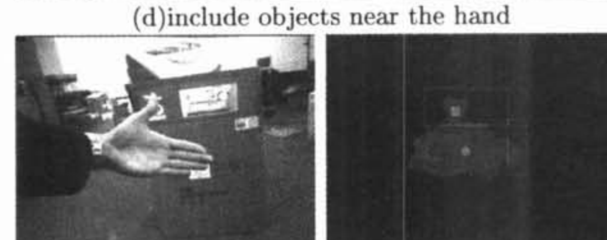
(b)against the light



(c)include another hand region



(d)include objects near the hand



(e)include the region which is same hue back the hand

Figure 8: the results of recognitioning hand under various environment

5 Experimental Results

We equipped the camera, the monitor and IBM ThinkPad T23 (CPU : Pentium III 1.13GHz, Memory : 512MB). Then we performed experiments inside our room under various environment. In Figure 8, examples of captured images by the system are shown ; left image is input color image and right image is recognition image. This system works in 5 frames per second approximately.

In this system, we use color information. Therefore lighting condition is very important to extract hand region. Figure 7 is the result of the hand region extraction. The upper shows the case with no white balance adjustment, and the lower shows the case with white balance adjustment. This demonstrates that adjusting white balance is effective to remove lighting condition.

Figure 8(b) is the result against the light. Because of the white balance adjustment, we can extract the hand even under the condition like that. Figure 8(c),(d), and (e) are the results under various environment. If we use only disparity image or only color image, we can't extract the hand region as well as these results. These results show that this system can work under various environments.

6 Conclusions

In this paper, we propose a 3D desktop environment for wearable computing system, in which a stereo camera system is mounted on the user's chest for detecting the user's hand for 3D hand motion control. In our system, disparity image and color image are used for robustly extraction the user's hand of which the 3D position and orientation enable 3D manipulation in the 3D desktop environment without contact and large scale devices. By performing experiments under various conditions, we have demonstrated that this system can be used as an efficient interface for wearable PC environment.

References

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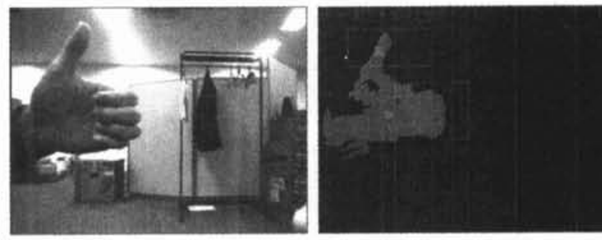
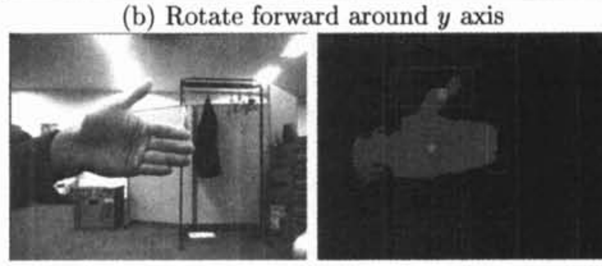
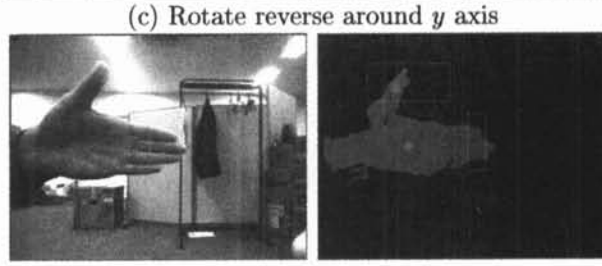


(a) Click

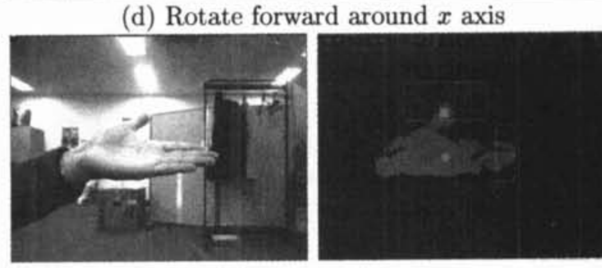
(b) Rotate forward around y axis



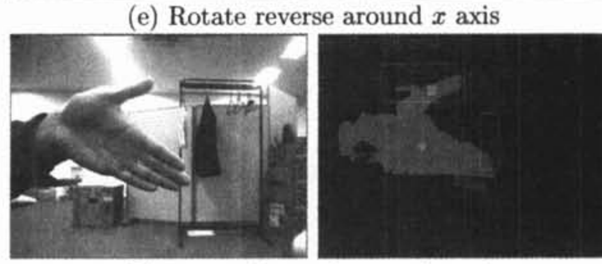
(c) Rotate reverse around y axis



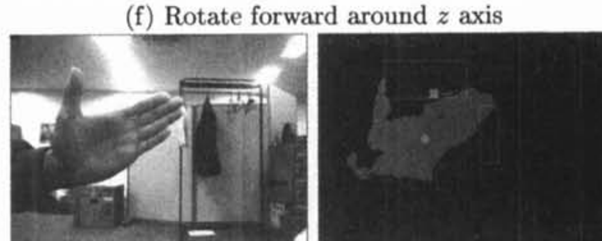
(d) Rotate forward around x axis



(e) Rotate reverse around x axis



(f) Rotate forward around z axis



(g)rotate reverse around z axis

Figure 9: Commands