Advances in Computer Science and its Applications (ACSA)
Vol. 2, No. 1, 2012, ISSN 2166-2924

www.worldsciencepublisher.org

3DWI: A Wearable Three-dimensional Interface

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Abstract: In this paper, we introduce 3DWI, a Wearable Three-dimensional Interface which make people deal with augmented reality information anywhere. Users, with a mini projector and a low cost camera mounted on a hat, can interact naturally with 2D or 3D GUI projected onto surfaces, walls, and physical objects around us. We present virtual mouse to offer precise interaction. We also introduce a projection screen marker which can generate virtual objects above the screen. And users can interact with virtual objects by gesture anywhere.

Keywords: Gestural Interaction; Augmented Reality; 3D GUI

1 Introduction

The input devices of traditional Graphical User Interface (GUI) are the mouse and keyboard. With the demand for natural and flexible interaction, people want human-computer interaction (HCI) not to use the mouse but their own hands [1]. Multi-Touch enhances the efficiency of our interaction with computers.

In 1982, Nimish Mehta has designed the first Multi-Touch display based on the pressure of fingers [2]. Until now, the multi-touch technology can be classified as sensor-based systems and computer vision-based [3]. And now Augmented Reality (AR) applications on mobile and small mobile devices have become popular [4]. As purely-vision-based multi-touch system is simple, cheap, portable, natural and flexible, projector-camera systems becomes a research focus. Everywhere Display [5] and PlayAnywhere [6] are created by projector-camera systems. The former system turn a common touch screen into an interactive display screen through image processing technology. And the latter one is a well mobile desktop front-projected computer vision-based interactive system with a front camera. Most of these systems depend on the physical touch-based interaction between the user's fingers and physical screen. Pranav presents WUW, a computer-vision based wearable and gestural information interface [7]. WUW proposes natural hand gestures as the mechanism to interact with that information and provide the intuitive experience. WUW uses three types of gestures substitute for traditional mouse, which are gestures supported by multi-touch systems, freehand gestures and iconic gestures. WUW can augment the physical world around us with digital information. And the cost of the WUW prototype runs about $350. This makes it possible to apply to mobile devices. At the same time 3D become more and more popular in commerce. 3D GUI, like Real Desktop (http://www.real-desktop.de/) and BumpTop (http://bumptop.com/), not only changes the display but also expands the display space. As the accuracy of monocular purely-vision-based multi-touch system is low [8], the GUI display may be much bigger in order to locate more easily. 3D GUI can make display space big and accommodate more icons.

In this paper, we present 3DWI, a purely-vision-based wearable and gestural interaction system. 3DWI supports 3D desktop and applications. For the problem of low accuracy, we present a virtual mouse to improve the interaction.

2 3DWI Design

3DWI, Wearable Three-dimensional Interface, is a wearable gestural 3D GUI. It only consists of an ordinary camera and a mini projector. In order to make the camera see what the user sees and not obstruct the mini projector to display the interface, the camera and mini projector should mounted on a hat.

2.1 Mini Projector

Previously portable displays of AR systems use head mounted displays (HMD). Virtual data and real world is shown overlaid on a HMD. But many HMDs are too heavy to continuously natural interact. Fortunately, the mini projector is created. The mini projector can project

information which the user can interact with. In this approach, the desired virtual information is projected directly on the surfaces or the physical objects to be augmented, and let the user interact the virtual data naturally and comfortably which is seen by your own eyes. The mini projector of 3DWI is connected to a laptop or even mobile device. Fortunately, with the development of mini projectors, mini projectors will become the standard setup on mobile devices in the near future. Therefore, 3DWI will have great commercial value.

2.2 Ordinary Camera

Unlike the previous computer vision-and optical-based system, like Frustrated Total Internal Reflection (FTIR) and Diffused Illumination (DI) [3], the camera of 3DWI is cheap and ordinary. Even a camera on the phone is entirely possible. The camera may capture hand gestures using simple computer-vision based techniques. The hand gestures data is used to interact with the virtual data. In this way, the user can easily and naturally interact with computer without a mouse.

2.3 3D Interface

There are two types of interfaces in the 3DWI:
(1) 2D General Interface
(2) 3D Virtual World Interface

2D general interface is familiar with the user and can be obtained easily. With the development of 3D graphics, 3D GUI, like BumpTop, has been attracted attention. First, 3D graphics is more in line with the world seen by eyes. Second, 3D interface allows the limited space to show more things. Since the depth of field, the user can see not only the close-range images but also the images of distant range. Through HCI, the user can get the distant things. Since mini projectors give relatively large screen and the accuracy of interaction is less, it is especially necessary for a purely-vision-based wearable and gestural interaction system like WUW or 3DWI. Third, the growing acceptance of Virtual Reality (VR) techniques, VR applications must be popular in the mobile devices in the near future.

2.4 Support Technology

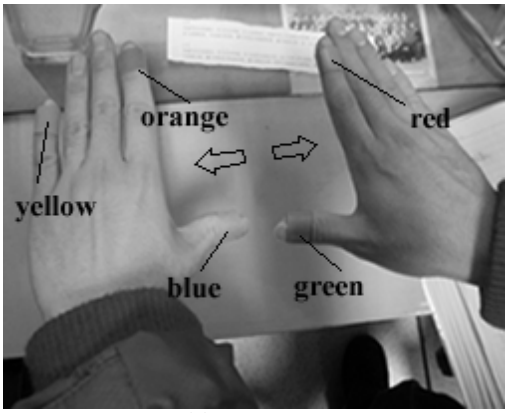
The support technologies of 3DWI are computer-vision based techniques [9], gesture recognition techniques [10], wearable computing research [11], 3D input device techniques [12] and augmented reality techniques [4]. And most of them are not complicated. It is hard for monocular purely-vision-based multi-touch system to have precision using cheap and common equipment [3, 6, 11]. Although the accuracy of WUW [7] is not high, it has good results. It means that not every application requires high-precision. It is not necessary for wearable gestural interface to be accurate like a CAD system. The applications on 3DWI are as same as the ones on mobile phones. The user of 3DWI can make a phone call, take photos, draw a 2D or 3D picture and do other almost everything which you can do with a computer. It is worth waiting for the next generation of mobile phones with a camera and a mini projector, which will make it possible for 3DWI to go into people's daily life.

3 Interaction of 3DWI

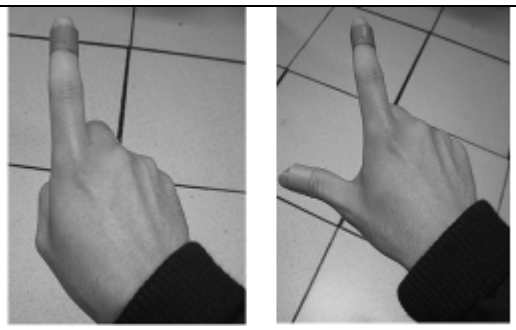
The 3DWI primarily recognizes four types of gestures:

(1) Gestures supported by multi-touch systems
(2) Freehand gestures
(3) Combination gestures
(4)Virtual mouse

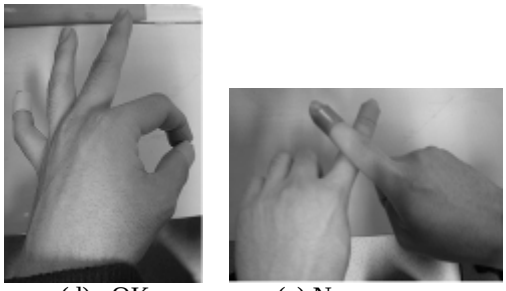
Fig. 1 shows a few examples of these gesture types. For the habit of human beings, people use their index fingers and thumb fingers more always than others fingers. 3DWI uses color markers on two index fingers and thumb fingers to register. 3DWI can recognize gestures supported by multi-touch systems, which is like use Microsoft Surface or Apple iPhone [7]. Such gestures include zoom in and zoom out the image using two palms (Fig.1 a), drag the target through the index finger (Fig.1 b). Of course, in order to be compatible with current computer system. 3DWI gestures can use fingers to achieve the function of mouse (Fig.1 c).



(a) Zoom Out



(b) Pan (Thumb hidden) (c) Select



(d) OK (e) No

Fig .1 Example Gestures

3DWI can also recognize the freehand gestures (postures). The user can put a framing gesture and then 3DWI can capture the image that the user sees. The user can put an 'OK' gesture to determine the operation (Fig.1 d). Or put two index fingers cross to cancel the operation (Fig.1 e). These freehand gestures are as same as Shortcuts and make the interaction much faster and more natural.

In addition to such gestures, 3DWI also supports combination gestures. Combination gestures mean that the user cannot use his only one hand but two hands to interact with virtual data. Due to existence of 3D Interface, it is hard for one hand to interact with computer. The user should use his both hands to control the 3D world. For example, the user can move the target using the gesture like Fig.1 (c) by his right hand. Meanwhile, he can rotate the object or interface by his left hand. In this method, the left hand is like Globefish [12]. Then you can do everything in the virtual 3D world.

The interaction of economical wearable monocular camera-projector multi-touch systems is different from other kinds of multi-touch systems. It let the user interact with computer 'too' freely and naturally. And users are accustomed to using the mouse. The user would like to interact by touching something physical. So we present a novel gesture, virtual mouse. If the user wants to use virtual mouse, the posture of his left hand should be like Fig.2.

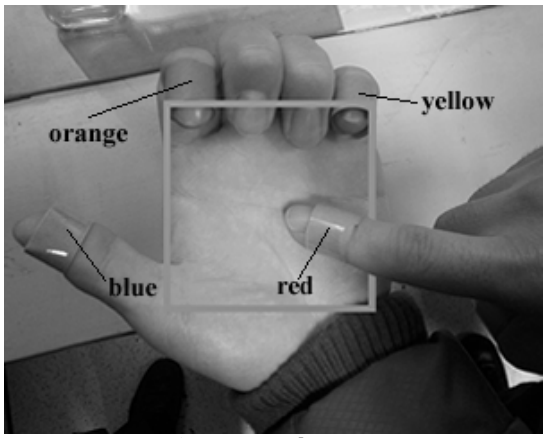


Fig .2 Virtual Mouse

The user can bend the index finger and little finger. At this point, the color maskers of index finger and little finger are the same height. These two color maskers are the two feature points of virtual mouse. We can calculate the distance between two points. According to this distance and two points, a square can be made as Fig.2, which almost coincides with the palm. Then we can use simple computer-vision based techniques to link palm coordinate with screen

coordinate. Then when the right index finger moves on the left palm, the pointer on the screen will move along with it. In this way, the user can simply and accurately select virtual objects. For example, the user can enter text, which is difficult for WUW, with virtual keyboard. And the virtual mouse can make the user to do more things which need accuracy.

4 3D Virtual World Interface

As mentioned above, 3DWI's interfaces include 2D General Interface and 3D Virtual World Interface. Recent the GUI is almost 2D. The advantages of it are known well, and commercial products have a large quantity. But 3D GUI is few. One of commercial 3D GUI, BumpTop, can provide a wonderful and different new experience. The user can set icons on the four walls and the floor and can see four surfaces at the same time. It means that the user can see much more icons. 3DWI can support the 3D interface, and it will be different from previous systems such as WUW.

Of course, 3DWI' 3D virtual world interface is not only desktop but also 3D applications. This paper presents a way to register 3D virtual objects using Projection Screen Marker (Fig.3). When the content is projected on a surface, the screen may be geometrically distorted. Geometric calibration techniques are always used to calibration the screen. However, the markers, like ARTag (http://www.artag.net./), are used it to compute the orientation. Why not take the advantage of it? 3DWI can project a special image with four markers in the four corners (Fig.3). The screen projected on the wall may be distorted when the user is not in front of the wall. The camera can capture four markers and compute the orientation of the screen using simple computer-vision techniques. According to this orientation, virtual objects can be generated. With the movement of the projector which is equipped by the user, screen distortion will be different, and the location of virtual objects will be changed. If the accuracy of camera is enough and the user equips a special marker, virtual-reality interaction will come true.

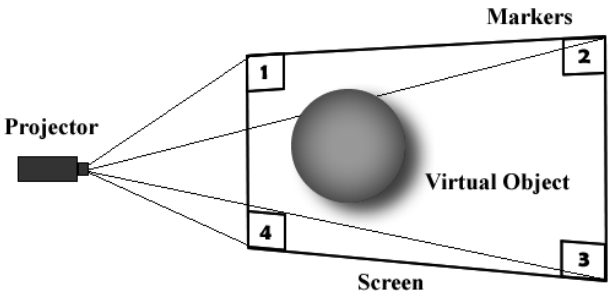


Fig .3 Projection Screen Marker

5 3DWI prototype

The 3DWI prototype (Fig.4) is comprised of three main hardware components: a mini projector (SNMSUNG SP-H03), an ordinary camera (Logitech HD Pro Webcam C910) and a laptop computer. The camera captures the color markers at the tip of the user's fingers. Through the simple computer-vision techniques, the prototype can recognize the user's gestures. The prototype system can implement a few applications. For instance, the user can draw and input text by virtual mouse or other gestures, and interact with the 3D interface.

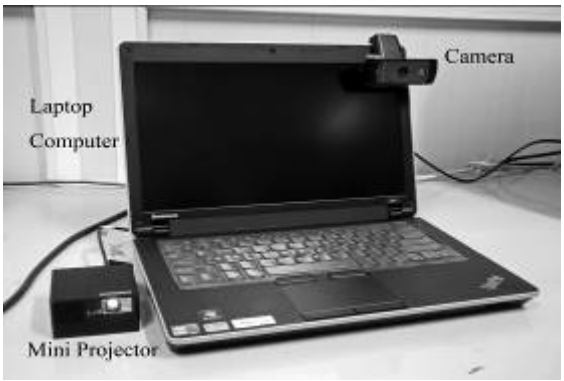


Fig.4 3DWI prototype system

6 Future work

In this paper, we presented 3DWI, a Wearable Three-dimensional Interface that let people interact with digital information anywhere. The user can project the 3D or 2D interface on the walls, physical objects and any surfaces, and use his hands to operate freely in space to deal with the virtual data. And we presented some gestures. One of them

is virtual mouse. The user can comparatively precisely interact, input text and draw. We also presented a projection screen marker which can generate virtual objects above the screen.

In the near future, mobile terminal will be equipped a camera and a mini projector. Then 3DWI will be only a mobile phone. We foresee several improvements to 3DWI. First, we plan to find a computer-vision technique not to use color marker. Second, we plan to improve virtual mouse accuracy. Third, we also plan to make the projection screen marker not require projecting markers and let virtual-reality interaction natural and easy. Fourth, we plan to develop more 3DWI applications.

Acknowledgment

This work is partially supported by science and technology project of Suqian College (No. 0712、0706 and 811314010422).

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