ARKB: 3D vision-based Augmented Reality Keyboard*

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Abstract

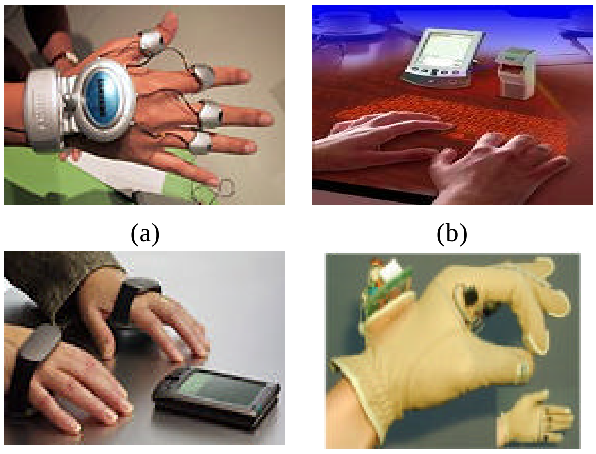
In this paper, we propose a wearable 3D Augmented Reality Keyboard (ARKB) which enables a user to type text or control CG objects without using conventional interfaces, such as keyboard or mouse. The proposed ARKB exploits 3D depth information obtained through a stereo camera attached to an HMD. The ARKB consists of three modules: (i) 3D vision-based tracking, (ii) natural interaction with fingers, and (iii) audiovisual feedback on the 3D video see-through HMD. The proposed ARKB can be applied as an interface for typing in AR environment. The remaining challenges are study on tracking method to improve accuracy and newly designed virtual keyboard which is proper in representing the advantage of the interaction in 3D space.

Key words: Augmented Reality, Virtual keyboard, 3D vision-based, Natural interaction

1. Introduction

As computing environment changes, new interfaces have been introduced to provide natural interaction between human and computers [1]. A portable keyboard is the first system to improve the disadvantage of general keyboard that is cumbersome to carry [2]. However, it is hard to use these devices with wearable computers. To resolve this problem, the concept of virtual keyboard is introduced. Virtual keyboard is defined as a touch-typing device which does not have physical state of the sensing area [3]. That is, sensing area is not real. So, a virtual button works as a button. Thus, the sensing areas are recognized by high efficiency finger tracking methods such as photoelectric sensor, high efficiency finger tracking method, or touch pads, etc.

Figure 1(a) shows SCURRY [4]. It detects movements of fingers and wrist by employing gyro sensors attached on user's fingers. It recognizes key inputs by detecting and analyzing the movements. Figure 1(b) shows VKB (Virtual Keyboard) [5]. It projects a virtual keyboard on any flat surface by using a laser diode. Then, it recognizes the interaction between user's finger and projected images by using an IR camera. Senseboard, shown in Figure1(c), includes two sensors made of combination of rubber and plastic [6]. It recognizes typing by analyzing the data from the sensors attached to user's palm. Figure 1(d) shows Key-glove[7]. It recognizes signal of data glove which changes according to the movements of user's fingers.



(a) (b) (c) (d)

Figure 1. Virtual Keyboard systems (a) SCURRY (SAIT, Samsung Electronics) (b) VKB (VKB Ltd.) (c) Senseboard (Senseboard Technologies AB's) (d) Key-glove (KITECH)

As explained, the recently introduced wearable virtual keyboards needs to have some kinds of special sensors to detect movements of users' hand [4][5][6]. This limits user's free movement. In addition, sensors attached on the body may distract users from concentrating their original tasks [7]. Furthermore, these are not suitable for a wearable computer with a video-see through HMD. An input device which works similar to the virtual keyboards can be constructed by using a camera, which attached to the video-see through HMD.

In this paper, we propose Augmented Reality Keyboard (ARKB), a novel and convenient wearable keyboard, for the next generation wearable computers with a video

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see-through HMD. It provides a natural interface. The proposed ARKB recognizes fiducial markers captured using a stereo camera on a video see-through HMD and calculates 3D position and orientation of the markers by exploiting ARToolKit. Then, the system augments and tracks a virtual keyboard on 3D space in front of a user. At the same time, ARKB also detects and tracks the user's fingertips by using the color markers attached on each fingertip. We assume that a collision occurs when a number of cloud points are contained in a volume space of virtual key. As a result, ARKB tosses corresponding character as an input of audiovisual feedback module. Through audiovisual feedback, ARKB can provide more realistic experience to a user.

The proposed system monitors the collision between fingers and augmented keyboard without using any physical sensors. A virtual keyboard is displayed regardless of table color and does not need additional space because it is displayed on HMD worn by the user. ARKB provides natural interaction by exploiting 3D information of a fiducial marker and user's hand. The proposed system provides natural feeling by feeding back through virtual monitor and speakers.

This paper is organized as follows: In Section 2, we describe the proposed ARK in more detail. Some preliminary experimental results and discussions are followed in Section 3 and 4, respectively.

2. ARKB

The proposed ARKB is a wearable input device which obtains vision-based information using a stereo camera on a video see-through HMD.

The proposed ARKB, as shown in Figure 2, consists of three modules: (i) vision-based tracking, (ii) interaction, and (iii) audiovisual feedback.

2.1 Vision-based tracking

In the vision-based tracking module, ARKB recognizes and tracks a fiducial marker to augment virtual keyboard, and color markers, attached to user's finger tips to measure movement of fingers, by using ARToolKit [8].

The stereo camera on HMD consists of two lenses. Based on the camera's geometry and the correspondences between pixels in two images, it is possible to determine the depth image. 3D position of a fiducial marker, to augment virtual keyboard, and user's fingertips, for interaction, can be determined from depth image. The more accurate camera calibration is be determined from disparity map.

The proposed system uses marker detection algorithm of ARToolKit to align augmented 3D virtual objects. After detecting rectangular area from a binary image, the system will recognize as a result of pattern matching [9][10]. Then, we can obtain 3D position of the detected area of a rectangular marker by using disparity map.

2.2. Interaction

In the interaction module, the ARKB augments a virtual keyboard on each video image. Also ARKB detects the collisions between fingertips and virtual keys by using 3D position information obtained from vision-based tracking module. When the given number of cloud points are contained in a virtual key volume, we assume that collision has occurred. The proposed ARKB recognizes user's hand by using the color of user's skin. This is necessary to provide interaction between virtual object and user's hand. Then, ARKB segments and detects user's fingertips by using color marker. It detects user's fingertips by setting the upper and lower threshold values of Red, Green, and Blue. The ARKB can obtain 3D position information by using disparity map of detected area.

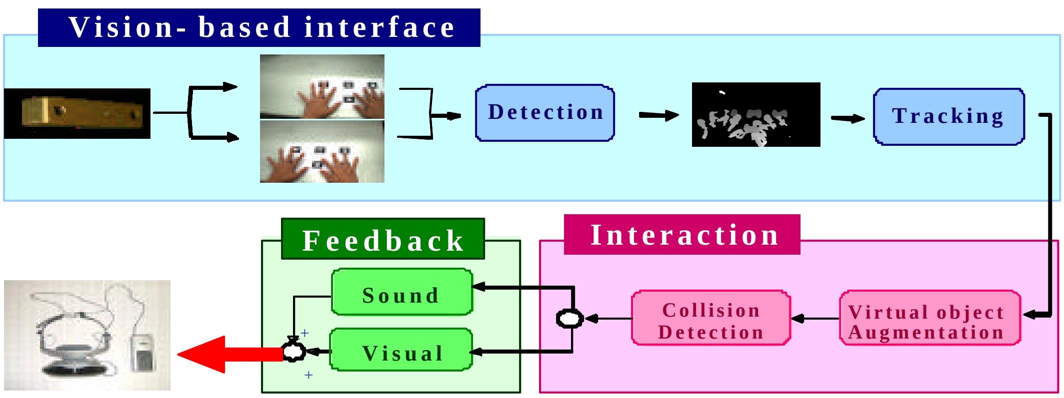


Figure 2. System Configuration

After separating the detected area, ARKB visualizes it by using cloud points.

The virtual keyboard is augmented on a fiducial marker by using 3D position information obtained from vision-based tracking module. Thus, we can assume that a virtual key of virtual keyboard is a cell consisting of eight 3D position information $P_{keyn\_p}(x_{np}, y_{np}, z_{np})$. Volume space formed by the virtual key and cloud points of user's fingertip are used to detect interaction. That is, we assume that a collision happens when the cloud points of user's finger tip exists within the volume space generated by a virtual key.

If the collision occurs between a virtual key and user's fingertip, ARKB tosses corresponding characters as an input of audiovisual feedback module.

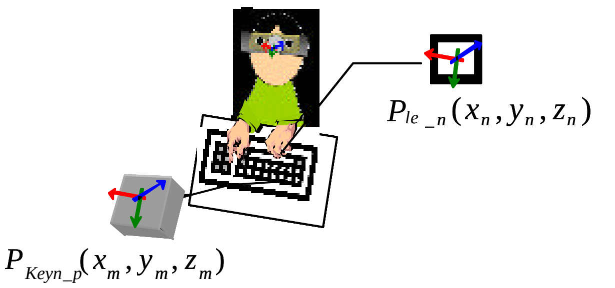


Figure 3. Collision Detection

2.3. Audiovisual feedback

To provide a more natural feeling of typing, ARKB provides audiovisual feedback when it detects the collision between a finger and a key.

For example, the pressed key is highlighted and the corresponding character is displayed on a virtual monitor. This lets user identify the pressed key. A sound is also beeped while displaying the character on monitor.

For example, a user can recognize which key is pressed by watching around the pressed key. Also, a user can encounter effects similar to using a computer. Without any additional display device, this is achieved by displaying corresponding character on the virtual monitor. In addition, ARKB gives an audio feedback to the user when a key is pressed. Above all, a user can have more realism through 3D display on HMD.

3. Experimental Results

In this section, we show preliminary experimental results of the proposed system. As the input or output device of the proposed system, we used i-Visor of Daeyang E&C with a stereo camera. The camera is connected to Workstation with 2.8GHz Xeon dual CPUs, and the video out of the workstation connected to the HMD. The workstation is used to process video signals from camera, and to render a virtual keyboard on HMD. To provide natural interaction to a user, we attached nail-sized color markers on user's fingertip. Thus, it does not obstacle the movements of user's fingers.

Figure 5 shows the results of segmentation of user's hand by using user's skin color. Figure 5(a) shows the user's hands before segmentation, and Figure 5(b) shows the mask to segment user's hand without the color markers. Figure 5(c) shows the result of color marker segmentation. And Figure 5(d) shows merged image of Figure 5(b) and Figure 5(c).

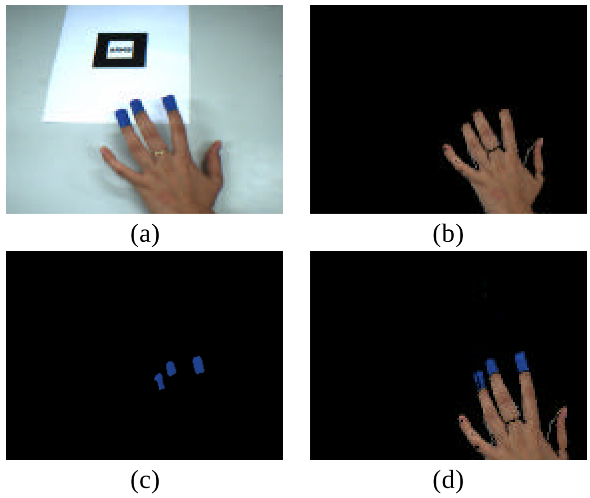
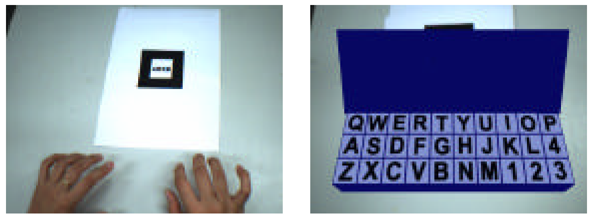
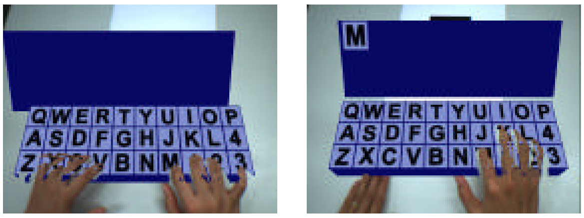


Figure 5. Finger segmentation (a) Original image (b) Segmented user's hand without color markers (c) Segmented color markers (d) Result image of segmentation

Figure 6 shows augmented ARKB. Figure 6(a) shows a real world setting, and Figure 6(b) shows augmented virtual keyboard and virtual monitor on a fiducial marker. Figure 6(c) shows a user's hand placed on the virtual keyboard, and Figure 6(d) shows the result of collision between a virtual key and a finger tip. As mentioned earlier, corresponding key to collision is displayed on virtual monitor.



(a) (b)



(c) (d)

Figure 6. Augmented Reality Keyboard system, (a) real environment setup, (b)detected fingers augmented virtual keyboard after recognizing markers, (c) a finger on virtual keyboard before collision, (d) a collision between a finger and a virtual key

Figure 7 shows the comparison between the 2D vision-based ARKB [10]

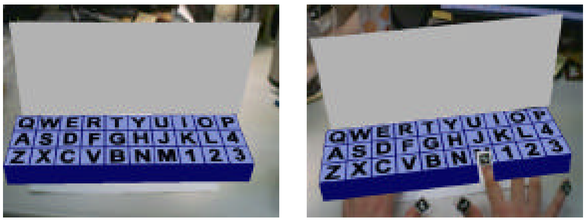


Figure 7. 2D vision-based ARKB

As a result, 3D vision-based ARKB overcomes the shortcoming of 2D vision-based one, shown in Figure 7, problem that the virtual objects occlude a user's hand. Thus, it provides natural interaction with a virtual object.

4. Conclusion

In this paper, we proposed ARK which provides a convenient mobile interface with a video see-through HMD. The proposed system uses a fiducial marker to augment the virtual keyboard, and ARToolKit to recognize and track the marker. The ARKB provides a natural interface for wearable computers with a HMD by replacing any physical input devices on hands or fingers with color markers. The remaining challenges are to improve accuracy which is worsens due to image delay, and usability test of the proposed system.

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