STEREOSCOPIC EYE-TRACKING SYSTEM BASED ON A MOVING PARALLAX BARRIER

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ABSTRACT

We present a novel head tracking system for stereoscopic displays that ensures the viewer has a high degree of movement. The tracker is capable of segmenting the viewer from background objects using their relative distance. A depth camera is used to generate a key signal for head tracking application. A method of the moving parallax barrier is also introduced to supplement a disadvantage of the fixed parallax barrier that provides observation at the specific locations.

Keywords: stereoscopic display, depth camera, parallax barrier, head tracker

1. INTRODUCTION

It is bothersome to put special glasses on to see 3D image. To make 3D display without using the special glasses was engineers' dream who are studying 3D image. In general, the method that an optical plate such as parallax barrier and lenticular screen is installed at the front or the rear of the display screen is used for viewing it with two eyes by separating the right and left images[1]-[3]. However, this method, in general, provided the narrow effective viewing area and only one available user, recently, the multi-view image display that a number of viewers are able to see is introduced and remarkably attracts a public attention as the next generation display[4][5].
As parallax barrier takes advantage of using 2D and 3D in two ways, its application to small display such as mobile phone and notebook that the individuals often use is actively carried out[6][7]. However, it has a chronicle disadvantage of the fixed location that the users should adjust eyesight to the right and left image to observe 3D image, namely, in the event that the users move horizontally, the right and left image are reversed. Thus, it requires technical solutions like an increase of a point of viewing and eye-tracking system [8]. In the paper, the moving parallax barrier panel that is likely to be practically used to eye-tracking system is introduced and the result of its experiment is described for the purpose of suggesting countermeasure of this issue.

2. MOVING PARALLAX BARRIER

2.1 Parallax Barrier

In general, the method of parallax barrier is the fixed type that barrier's location and shape are not changed. However, the method of liquid crystal parallax barrier that is capable of dynamically changing barrier's shape and location is newly introduced. In this paper in order to supplement the disadvantage of the conventional parallax barrier that the users observe it at the only specific locations, the method of the moving parallax barrier is newly suggested.

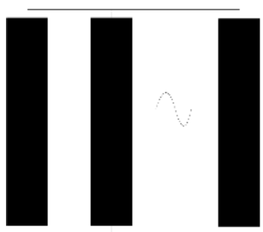


Fig. 1. Conventional PBP

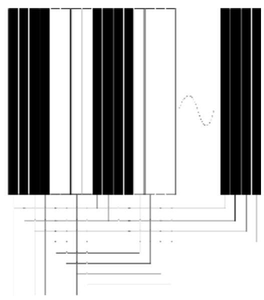


Fig. 2. Moving PBP

Figure 1 show a structure of the conventional fixed parallax barrier, in contrast, the Figure 2 shows the panel structure of the moving parallax barrier that enables that the barrier's locations are changed. In Figure 2 the general one barrier constitutes four small lines and one aperture constitutes four small lines also. The electrical connection of the moving parallax barrier is constituted with one group that is composed of eight lines; barrier no. 1 and no. 9 are electrically connected. In a same method, no. 2 and no. 10 barrier are electrically connected. In the event of that the users move to right and left, the line of the moving parallax barrier moves to right and left, it brings an effect as if the parallax barrier moves to right and left.
For activating the moving parallax barrier, activation ITO line should be constituted like Figure 3. In this event, the panel to constitute the parallax barrier uses inexpensive TN panel in price, however, in the event of implementation of Figure 2, the precise TFT technology and expertise should be used. Moreover, when manufactur- ing the panel every time, the new implementation line should be constituted, after all, it becomes a factor in price rise and such a constitution results in a structure of extremely ineffective production.

2.2 Cross Connector

In order to solve above described issue, the part of implementation line is separated and the cross connection is designed in this paper. Figure 4 shows an image of the cross connector that is connected between 640 line FPC and 20 line FPC. As complicatedly cross activation line like Figure 3 uses the cross connector, it can be made as a simple module type and effectively used.

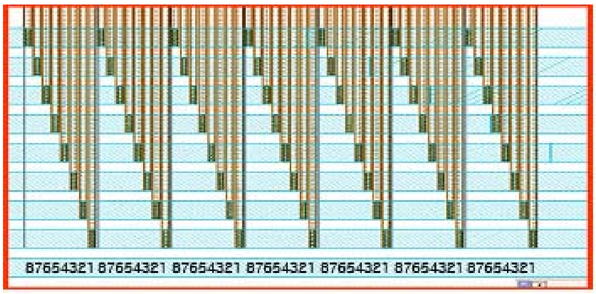


Fig. 3. Line connection of moving parallax barrier pane

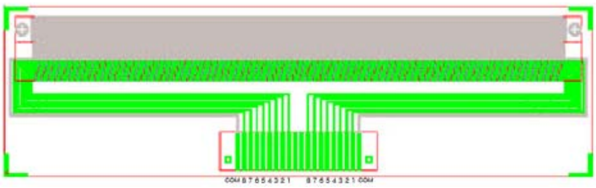


Fig. 4. Detail drawing of cross connector

Figure 4 shows the manufactured cross connector, the implementation with every eight lines is designed for driving panel. In this experiment, the cross connector is designed with 640 lines. This cross connector takes advantage of being used properly according to display resolution.

3. IMPLEMENTATION OF MPB

15.4" Notebook TFT-LCD that is currently sold in a market is used for the experiment. The number of vertical line pixel is defined 5120 pixel and the eight cross connectors that is constituted with 640 lines are in need. The control board shown in Figure 5 is manufactured to control eight cross connectors. As the panel control simultaneously the numerous cross connectors, the control board that fits its panel should be specially manufactured.

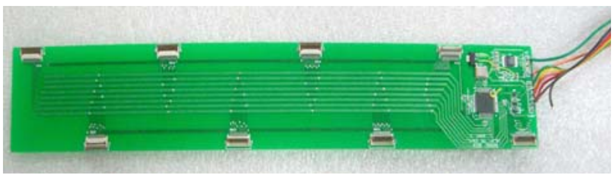
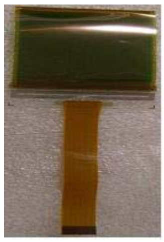


Fig. 5. Control board of cross connector

Figure 6 shows highly precise cross connector that is made of a bundle of 640 lines. Four cross connectors are respectively connected on the top and bottom of panel in Figure 7. The implementation signal of the cross connector on the top and bottom should be mutually reversed so that it is normally operated. The wide area on the top of cross connector made of FPC with 640 lines is connected to the panel in Figure 8 and the narrow area on the bottom is connected to the control board so that the control signal of 20 lines is transferred. Figure 9 shows the connection between the panel and the control board.



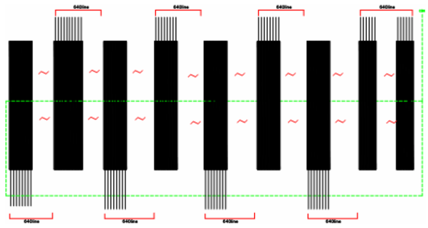


Fig 6. Cross connector Fig. 7. MPBP

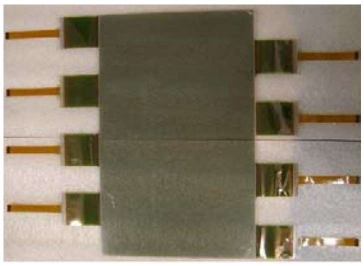


Fig. 8. Connection of the cross connector and panel

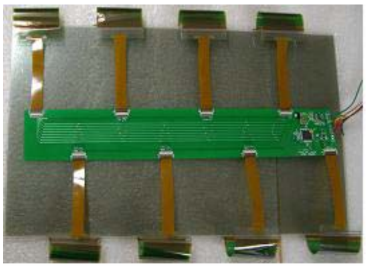


Fig. 9. Connection of the panel and control board

4. EYE-TRACKING SYSTEM

4.1 Depth Measure Principle

The range measurement principle is based on the TOF techniques that processes the photo charges in a purely CMOS process. In this approach, high range resolution could only be achieved if the photo charge generated is quickly and efficiently transferred to a storage node. Storage capacitors are used to store photo charges generated in relations to the TOF, which in turn would be used to determine range information from the scene. The sensor depends on a light pulse source with a known frequency. These light pulses are transmitted to illuminate a scene, which will then reflect it back to the sensor. Thus, the pulses have strong correlation with the switching time of switches φ1 and φ2. Figure 10 shows the related control signals that drive the 3DV sensor. The reflected or received pulse will arrive to the sensor with a delay of T_D. When pulse φ1 is switched on, the accumulated charge is transferred to storage node C1. This is known as the front cut of the reflected signal. When pulse φ2 is switched on, the accumulated charge is transferred to storage node C2. This is known as the back cut of the reflected signal. By knowing the front cut, back cut and background signals the range per pixel can be calculated.

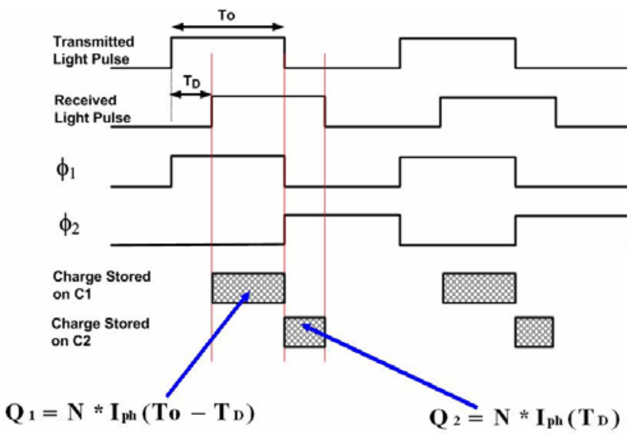


Fig. 10. Control signals for the 3D sensor

4.2 Eye-Tracking with A Depth Camera

The parallax barrier display has a disadvantage that it tends to cause eye fatigue and users cannot feel a 3D effect due to reversed left and right images when the viewers move. In order to solve this problem, eye-tracking system is generally utilized. In a method of eye tracking system the problem is solved with a technique of swapping right and left display image by extracting the observer's x-y-z direction. In this paper, depth sensor camera that is capable of measuring the distance away from the camera in real time is utilized to implement eye-tracking system. With the depth sensor, background and face are extracted in real time and precise location is informed to PC. It enables that right and left images of the parallax barrier display are swapped to be aligned with eye's location so that the 3D effect is smoothly observed. The method of general eye tracking is using template-matching system by extracting face region using color information. In the event of using ordinary camera for the image acquisition, the real time process is slightly delayed due to a plenty of calculation amounts in pre-processing. The pre-processing is to convert intensity of illumination on the distorted face to histogram equalization by light condition and to extract the face region through color domain conversion (RGB->HSI or RGB->YCrCv). In the event of using general web camera, over 15 frame image capture per second with the user program is difficult and as there are so much calculation amounts in pre-processing, eye tracking is, in fact, 10 frames per second. Main processing is the template matching method that is a process of separating eye's region and make coordinates. In this paper, relatively, depth sensor algorithm is utilized in plenty of pre-processing calculations. In the event of using the depth camera, the calculation corresponding with face region extraction is processed in the sensor firmware in real time. Next, the eye recognition is the template matching method that extracts the coordinate's value on the separated face region so that the real time tracking is possible. In the experiment, the eyes coordinates' value is calculated by tracking the observer's face by the depth sensor camera that is fixed on the top of the center of the monitor in indoor environment. The images transferring from the depth sensor camera to PC are the face region extracted from the firmware, from these regions, the right and left eyes coordinates are calculated on the basis of the template matching method. In the event of that the coordinates lies in the substitute eyes region, the disposition of the right and left images that will be displayed is determined by the location of the observers and monitor coordinates. The PC that controls the display converts re-deposited images to serial communication (RS-232) in alignment with 3D image output and controls 3D monitor. Accordingly, the reverse of right and left image that is the problem of auto stereoscopic display method is compensated to enable that the observers comfortably observe the 3D effect. The flowchart of the eye tracking system is depicted in Figure 11. The experimental eye tracking system is depicted in Figure 12.

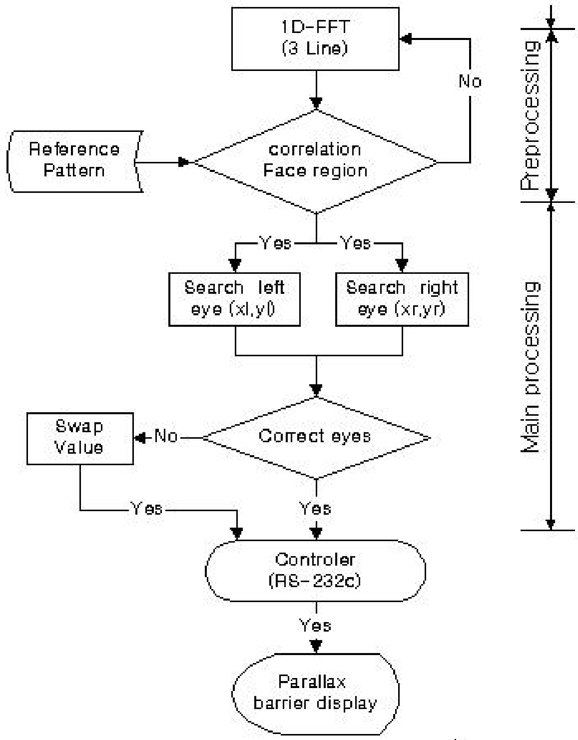


Fig. 11. Eye-tracking flowchart

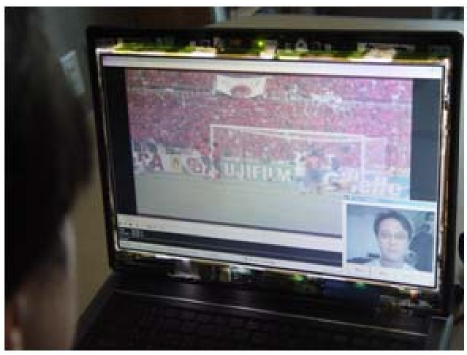


Fig. 12. Stereoscopic eye-tracking system

5. CONCLUSION

In this paper, we presented an eye-tracking system that enables the observation of 3D images at all times regardless of a movement of a viewing point. The depth sensor camera that is capable of measuring the distance away from the camera in real time is utilized to implement eye-tracking system. With the depth sensor, background and face are extracted in real time and precise location is informed to the computer. Also the moving parallax barrier panel supplements the disadvantage of the method of the fixed parallax barrier and saving the costs of 3D displays.

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