Realization of Interactive Aerial Buttons Using a Combination of Arc 3D Display and 3D Sensors

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Keywords: glass etching, 3D display, 3D sensor, aerial interface

ABSTRACT

We propose and develop an aerial button with continuous motion parallax. Aerial button is realized by combining Arc 3D display composed of many arc-shaped grooves and 3D sensor of hand motion. The aerial button has been successfully operated over a wide viewing zone because of continuous motion parallax and 3D sensor.

1 Introduction

In recent years, the spread of the new coronavirus has raised awareness of hygiene issues, such as the routine use of masks and hand disinfection. As we strive to live with the virus, we need mechanisms for preventing infection. One of the problems in our daily lives is the operation of machines, such as ATMs, elevators, and vending machines, which require the pressing or touching of buttons. In order to operate a machine without physically touching the buttons, it is important to have a technology that virtually forms the buttons in the air and senses the gesture of pressing the buttons. Although there are many types of aerial displays [1] of buttons, a low-cost and highly flexible design are required. Arc 3D display [2, 3] with a simple structure and flexible design is suitable for designing aerial buttons. This is because Arc 3D display needs only a transparent substrate and a single light and has smooth motion parallax and wide viewing angle [4].

Conventional Arc 3D display is fabricated by handmade using tools such as compass cutters, which is time-consuming. In addition, the substrate needs to be disinfected due to hygiene issues, resulting in high chemical resistance. To solve this problems, we used the pattern etching method to realize Arc 3D display on a glass substrate.

As color of Arc 3D image simply changed by the illumination color because this 3D image uses only refracted or reflected light of illumination light, it is possible to change the Arc 3D image color according to the operation of the buttons.

In this study, we propose and develop an aerial button with continuous motion parallax and without touching by using Arc 3D display and 3D sensor.

2 Principle of aerial button

2.1 Principle of Arc 3D display

Figure 1 shows the principle of Arc 3D display. Arc-shaped grooves are fabricated on a transparent substrate. Since Arc-shaped groove has conically scattered light by a single light illumination, the bright points on an arc-shaped groove are different for both eyes. This difference leads to binocular parallax. Moreover, the bright points move accordingly when the eye position changes. These result in depth perception by binocular disparity and motion parallax. Perceived depth is proportional to the radius of the arc. As one bright point corresponds to one arc, dotted line drawing is constructed by connecting these bright points with many arc-shaped grooves.

As shown in Fig. 2(a), conventional Arc 3D display is generated by scratching arc-shaped grooves one by one using a compass cutter. Figure 2(b) shows the Arc 3D display generated by the compass cutter. Each dotted line drawing is generated with the same radius and pitch of dotted line is the same as pitch of arc-shaped grooves.

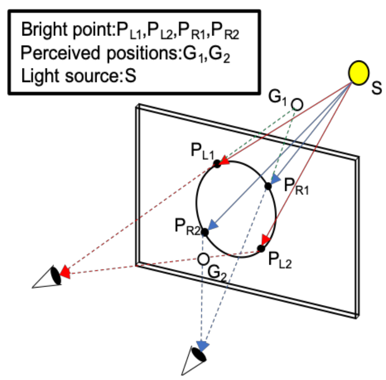


Fig. 1. Schematic diagrams on viewing a transparent plate.

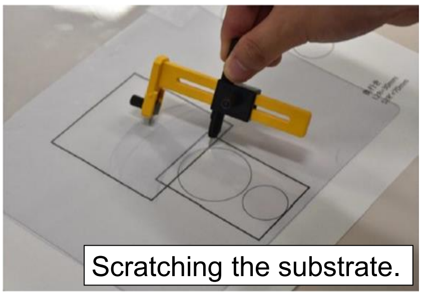
2.2 Arc 3D display by glass etching method

The Arc 3D images created by the conventional method are shown in Fig. 3. The Arc 3D images created by the glass etching method are shown in Fig. 4 [5]. Both images are taken by the viewpoint of (a) left, (b) middle and (c) right positions, which show that the almost same motion parallax is obtained.

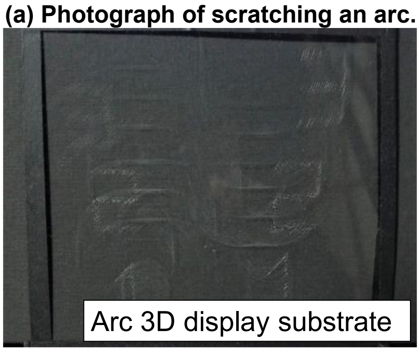
As the conventional method by handmade in Fig. 3 leads to fluctuation in the depth or width of the grooves, unnecessary scattering light occur, and the unnecessary grooves are visible. On the other hand, as shown in Fig. 4, the glass etching method can achieve no unnecessary scattering because of uniform grooves.

For the resolution, the conventional method by handmade in Fig. 3 causes fluctuations in the bright spots or dotted pattern, which degrade overall resolution. On the other hands, as shown in Fig. 4, the glass etching method leads to no fluctuation in the bright spots and smooth image, resulting in improvement of resolution because of uniform grooves.

Thus, it is appropriate to use the Arc 3D display generated by the glass etching method for the aerial buttons in this experiment.



(a) Photograph of scratching an arc.



(b) Arc 3D display Substrate.

Fig. 2. Arc 3D display substrate fabrication.
(a) Photograph of scratching an arc.
(b) Arc 3D display Substrate.

2.3 Colorization of Arc 3D display

As human interface of an aerial button, it is important to express coloring and color change to the button in order to distinguish the pressed button from other buttons because of no tactile sensation.

As the Arc 3D image is constructed only by refracted or reflected lights, the color of bright spots is the almost same as the color of the illuminated light. Figure 5 shows an image in which four different colors of light are irradiated to Arc 3D substrate using a projector. The color of the aerial line drawings can be successfully changed according to the irradiated light color. In addition, as region in projector image black to make the bright spots less noticeable, turning a button on and off can be achieved.

3 Interactive aerial button

3.1 Setting up of experiments

An interactive aerial button was created by combining an Arc 3D display with a 3D sensor that can acquire the position of the hand or finger, as shown in Fig. 6. The Arc 3D display was illuminated by a projector, and a 3D sensor (Leap Motion: LM-010) is placed in front of the Arc 3D display to acquire the position of the finger. The Arc 3D display was the same as the one shown in Fig. 4. Only one part of the display was illuminated so that the part protruding from the substrate can be used as a button. To set the position of the aerial button as the position of the finger, a program was created to recognize the position of the aerial button based on that position.

3.2 Interactive operation of our aerial button

Figure 7 shows the operation of our interactive aerial button. In Fig. 7(a), the button color is white when the fingertip is released from the aerial button. In Fig. 7(b), the button color changes from white to green when the fingertip reaches aerial button position. The color changes at the distance of about 1 cm from Arc 3D substrate as if the finger touched to aerial button.

Our interactive aerial button successfully achieve the sensation of pressing the aerial button without tactile sensation.

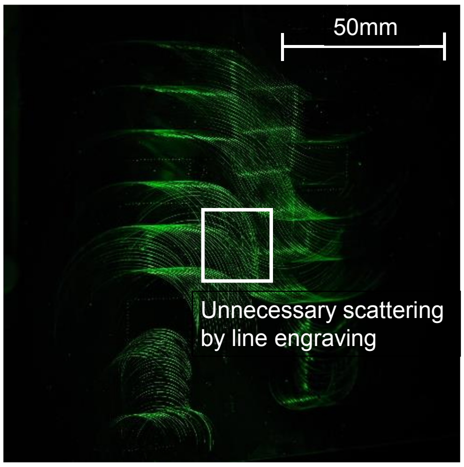
4 Discussion

By using Arc 3D display with color change, we were able to add a visual change to the aerial buttons by giving them a color change when touched. Since the 3D sensor can scan from the fingertips to the arm movements, it can respond to a wide range of motions, not just touching the buttons with the fingertips.

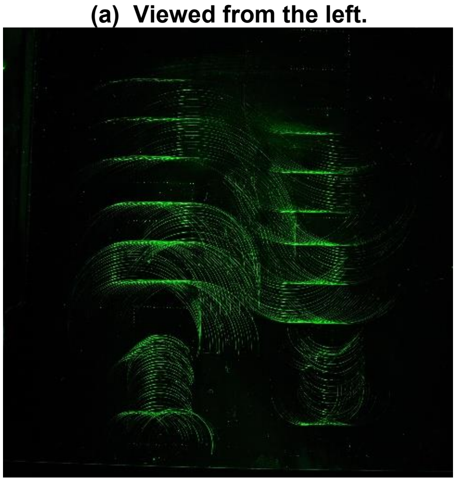
In the program we generated this time, the position of the sensor and projector changes depending on the location where it is installed each time, so we set the position of the button based on the position of the finger at the beginning. If the environment is completely fixed, it is accurate enough to be used as a button at the exact position.

In this case, the color changes to green when the finger touches the button and to white when it is released. It is also possible to display the aerial button as if it were turned off by using a light gray image from the projector.

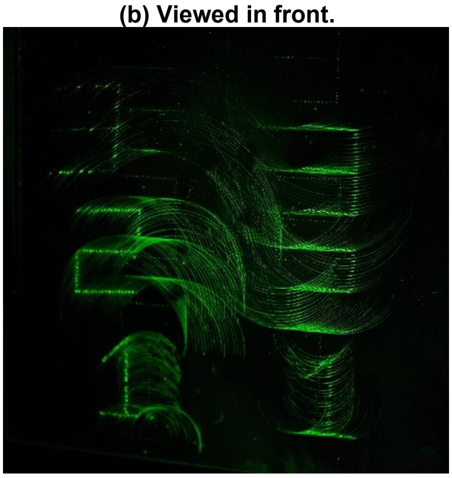
In Fig. 7, the button is shown as an arc with a radius of 2 cm, but since Arc 3D display can change the protrusion distance depending on the radius, it is possible to combine arcs with multiple radii to create a more 3D button that can be easily used as an aerial button.



(a) Viewed from the left.

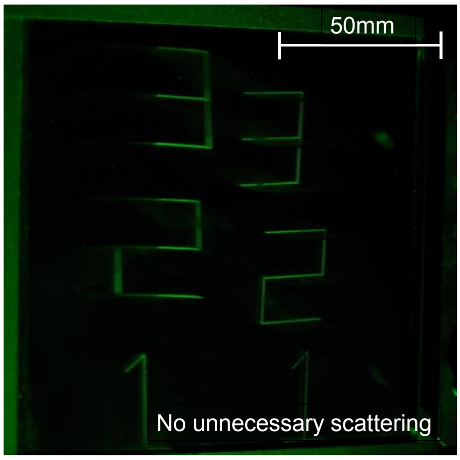


(b) Viewed in front.

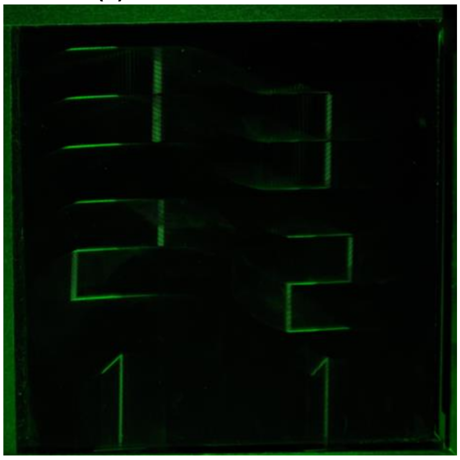


(c) Viewed from the right.

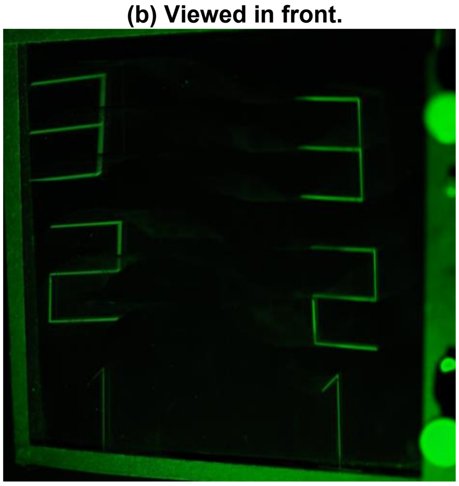
Fig. 3. Arc 3D display with conventional method. The radii of the arc-shaped scratches are, in order from the top number, 3, 2, and 1 (cm). The pitch between scratches is 1(mm).Viewed (a) from the left, (b) in front, (c) from the right.



(a) Viewed from the left.

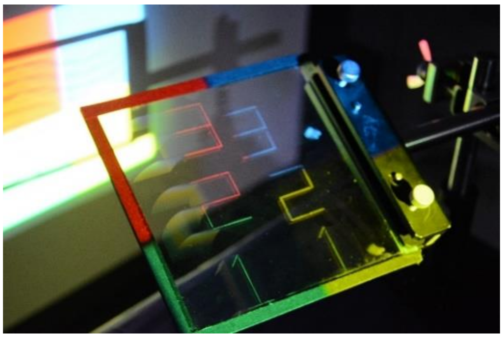


(b) Viewed in front.

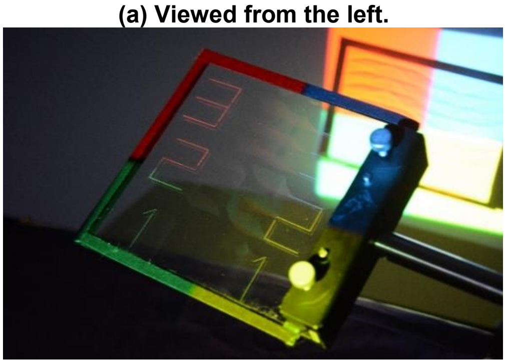


(c) Viewed from the right.

Fig. 4. Arc 3D display by patterned glass etching method. The radii of the arc-shaped scratches are, in order from the top number, 3, 2, and 1 (cm). The pitch between scratches is 1(mm). Viewed (a) from the left, (b) in front, (c) from the right.



(a) Viewed from the left.



(b) Viewed from the right.

Fig. 5. Colorization of Arc 3D display by use of a lighting projector. Viewed images (a) from the left and (b) from the right.

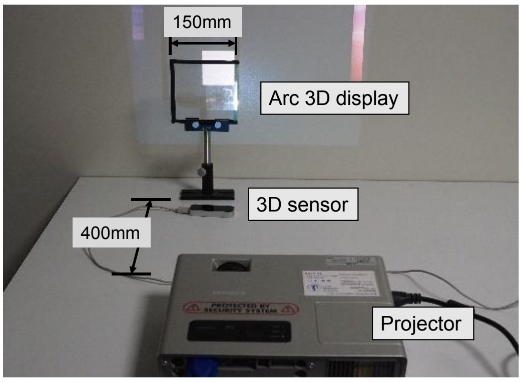


Fig. 6. Setting up an aerial button using Arc 3D display combined with a 3D sensor.

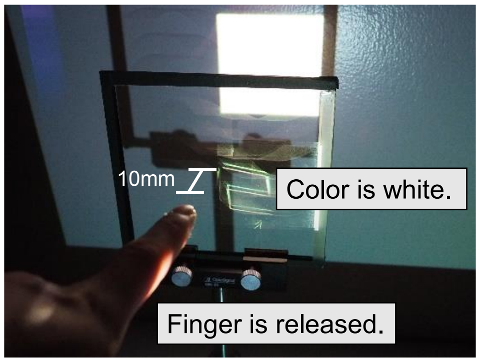
5 Conclusions

We have proposed and developed interactive aerial button by using Arc 3D display of a transparent substrate and simple lighting and 3D sensor that can acquire hand gestures.

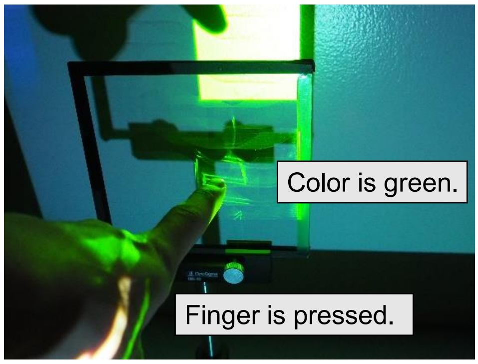
Arc 3D display formed by glass etching method can display smooth and clear aerial images as compared to the conventional Arc 3D display by handmade.

Our interactive aerial button successfully achieve the sensation of pressing the aerial button without tactile sensation.

Thus, Arc 3D display formed by glass etching method is effective for displaying button marks and our aerial button with a simple configuration can be used in a wide range of applications.



(a) When the finger is released, button color is white.



(b) When the finger is pressed, button color is green.

Fig. 7. Using aerial buttons with Arc 3D display and 3D sensors (a) when the finger is released and (b) when the finger is pressed.

References

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