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Autostereoscopic Dynamic Simulation System Using Integral Photography on a Tablet PC

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Abstract - In this paper, we propose a novel autostereoscopic dynamic simulation system in which a tablet PC and a fly's eye lens are used. Dynamic simulation, which helps inexperienced physics students to understand the motion of objects intuitively, is one of the applications suitable for smartphones and tablet PCs. The reason is that an object displayed on the LCD can be moved toward a lower position by simply tilting the tablet as if real gravity were applied. We introduced integral photography (IP) to enhance the sense of reality. Unlike many other autostereoscopic systems, IP can produce not only horizontal but also vertical parallax. Therefore, a stereoscopic view is possible from any direction when users look down on an almost flat LCD from above. Although the high development costs of tailor-made fly's eye lens were reduced with the emergence of the extended fractional view (EFV) method, using the EFV method involves certain problems. Because the relative position of the object and the fly's eye lens changes depending on the position of the object, the IP image of the object cannot remain the same over an entire screen. We solved this problem by choosing the optimal IP image among numerous IP images created in advance. Experimental results showed that the ball looked as though it were moving smoothly.

***Keywords*:** Integral photography, Tablet PC, Interaction, Extended fractional view.

1. Introduction

In recent years, the use of smartphones and tablet PCs has spread rapidly. These devices are particularly suitable for various applications in which interactions play important roles. Among these applications, dynamic simulation helps inexperienced physics students to understand the motion of objects intuitively. The use of smartphones or tablet PCs is particularly advantageous in that users can operate these devices by hand. Smartphones are typically equipped with acceleration sensors that can be used, and the simulation results can be displayed on the screen in real time. We introduced integral photography (IP) so that the results would appear three-dimensional regardless of viewing direction because parallax exists in all directions. In this study, we developed a simple system in which a user can move an autostereoscopic ball displayed on the LCD of an Android tablet PC covered by a fly's eye lens by using the extended fractional view (EFV) method (Yanaka 2008), which is a type of IP.

2. Our Approach

In the proposed system, users look down on an almost flat LCD from above, so a stereoscopic view should be possible from any direction. IP is a promising solution that can be constructed simply by placing a fly's eye lens on top of the LCD, as shown in Fig. 1.

In conventional IP methods, the pitch of a fly's eye lens strictly has to be an integer multiple of the pixel pitch of the LCD, as shown in Fig. 2 (a). Thus, fly's eye lenses had to be made specifically in accordance with the pixel pitch of the LCD. However, this restriction was removed from the EFV method illustrated in Fig. 2 (b). As a result, obtaining high-quality stereoscopic images has become possible by using a relatively inexpensive off-the-shelf fly's eye lens in combination with the EFV method.

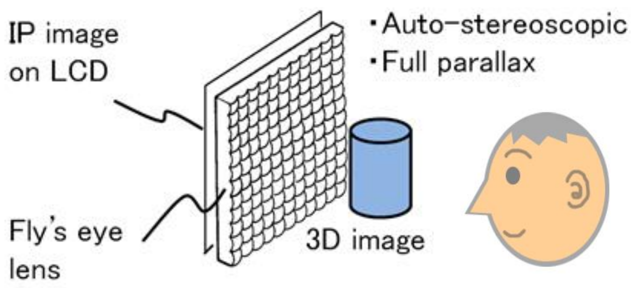

Fig. 1. Simple integral photography system.

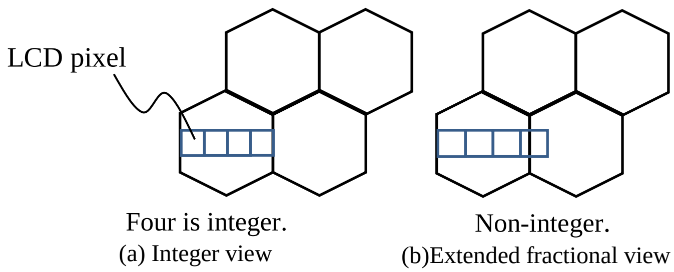

Fig. 2. Comparison between integer view and EFV.

However, using the EFV method involves certain problems. Because the relative position of the object and fly's eye lens changes depending on the position of the object, the IP image of the object cannot remain the same over an entire screen. Therefore, different IP images should be used when the location of the object changes. Although generating an IP image that matches the object's position each time is possible, an enormous amount of processing would be necessary to do so in real time. One solution is to use GPU (Graphics Processing Unit) (Yanaka and Kimura 2013), but we chose another approach, in which $m \times m$ IP images of the same object are created in advance. The typical value of m in these images is eight, and the IP image most appropriate for the object's current position is displayed.

In Fig. 3, X and Y denote the coordinate system of the fly's eye lens and x and y denote the coordinate system of the object. The displacement between the two systems is shown as the vector $\boldsymbol{d} = (d_x, d_y)$. A fly's eye lens can be considered a periodic figure, of which the horizontal period is a pixel and the vertical period is b pixel, as shown by the rectangle in Fig. 3. Evidently, $0 \leq d_x \leq a$ and $0 \leq d_y \leq b$, where $b = \sqrt{3}a$. When considering the displacement, we can consider only the interior of the rectangle.

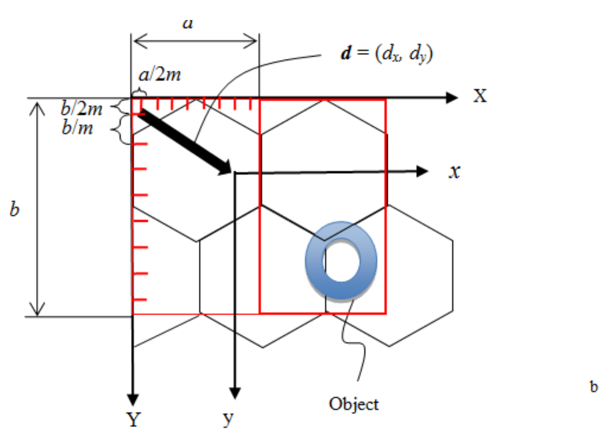

Fig. 3. Displacement of coordinate system of fly's eye lens (XY) and coordinate system of object (xy).

However, even in this case, an infinite number of points exist in the rectangle. Therefore, we quantized d_x and d_y into m levels, where the typical value of m is eight. The $m \times m$ IP images of the object are created in advance, as illustrated in Fig. 4. When the object is to be displayed at the position (*x*, *y*) during the simulation, the index (I_x, I_y) of the IP image is calculated as follows:

$$I_x = floor(fmod(x, a)/(a/m) + 0.5) \quad (1)$$

$$I_y = floor(fmod(y, b)/(b/m) + 0.5) \quad (2)$$

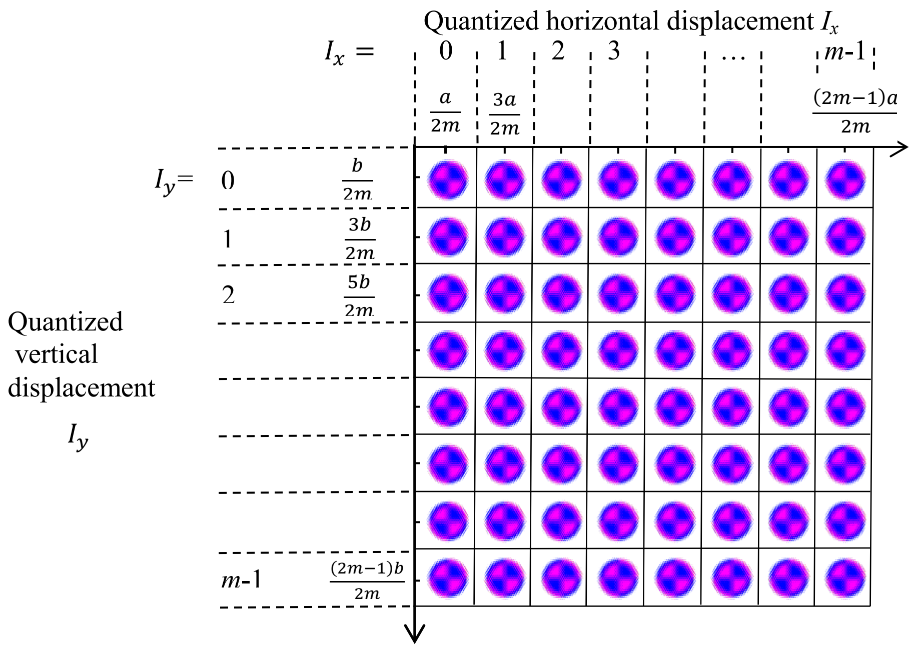

Fig. 4. $m \times m$ IP images of the object.

3. Experimental Results

A tablet PC is an ideal platform for IP application because it is portable and has a high-definition LCD (Kawano and Yanaka 2013). Our system consists of an Android tablet PC (Sony SGPT111JP/S) and a fly's eye lens (Fresnel Technologies 360). The aforementioned algorithm was programmed in Java. As shown in Fig. 3, an autostereoscopic ball is displayed as if it were popping out of the LCD, and the ball can be moved by tilting the tablet. The motion looked extremely smooth although only 8 × 8 IP images were used.

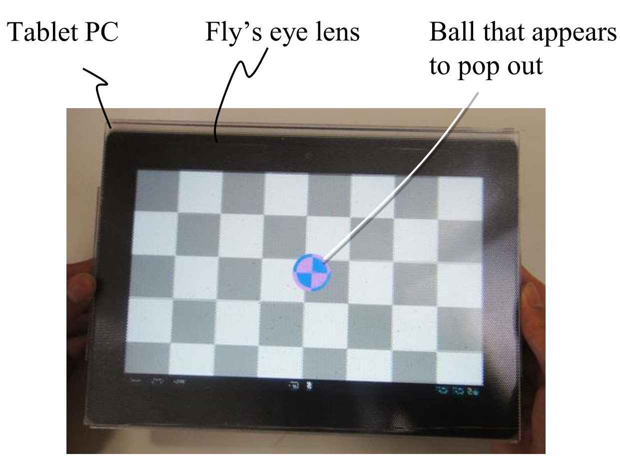

Fig. 5. Experimental system.

4. Conclusion

We developed a dynamic simulation system using IP on a tablet PC in which an autostereoscopic virtual ball displayed on an LCD can be moved by tilting the tablet. Experimental results showed that the ball looked as though it were moving smoothly, as if it were a real ball rolling down a slope. This technology is not only useful for physics students but is also applicable to games, such as pinball.

Acknowledgment

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