

# 3D CG Integral Photography Artwork Using Glittering Effects in the Post-processing of Multi-viewpoint Rendered Images

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**Abstract.** Among various 3D display technologies, integral photography (IP) is one of the ideal 3D display systems because not only horizontal but also vertical parallax can be achieved through it without requiring users to wear special 3D glasses. Another advantage of IP is its applicability in material expression. In usual CG, in which rendering is carried out from one camera position, the glittering caused by the surface material is difficult to reproduce. As for users, they can perceive glittering when they move because each tiny convex lens on a fly's eye lens emits direction-dependent light. However, glittering is usually weak because the viewing zone of the IP display is not wide enough. Therefore, we propose a new method for implementing a glittering effect in the post-processing of images rendered for IP. A user can paint a large number of rendered images simultaneously and revise them with ease. We conduct experiments using a system that comprises a tablet PC with retina display and a fly's eye lens. When this method is applied to a motif of ice floating in air, which is part of an artwork entitled "Frozen Time," a strong glittering effect is obtained, especially when the tablet PC is held and tilted in various directions.

## 1 Introduction

Integral photography (IP) is an outstanding 3D display system through which not only horizontal but also vertical parallax can be achieved without requiring users to wear special 3D glasses. Thus, IP has an advantage that is similar to that of holography. However, IP is superior to holography in terms of the ease of electronic rewriting and color reproducibility. A simple IP system consisting of a liquid crystal display (LCD) and a fly's eye lens is shown in Figure 1. The light that changes directions is emitted from each minute convex lens, which forms a fly's eye lens (Figure 2). When the displayed image is seen from a fixed position with both eyes, a sense of depth is acquired as a result of binocular disparity. A sense of depth is also acquired through motion parallax when the position of the eye is moving even if the display is seen with only one eye.

Another advantage of IP is the glittering effect obtained if light goes into only one eye. This phenomenon could be attributed to binocular rivalry. Therefore, IP can also identify differences in materials. As a scene is rendered from a single camera position

in non-stereoscopic CG, only a small part of the scene data is used. However, IP requires additional information from scene data because of its use of images rendered using a large number of camera positions. Therefore, various materials such as glittering material can be expressed by changing the angle from which a user views the image.

This advantage becomes remarkable especially when IP is carried out using a mobile device. A tablet device uses high-resolution LCD and can thus display high-quality 3D images. As such devices are small and lightweight, they can be carried anywhere at any time, thus allowing users to view 3D images without place and time restrictions. Furthermore, tablets are handheld devices and can thus be viewed from any direction. The binocular and motion parallax of an IP system facilitates an auto-stereoscopic view and allows the identification of materials. An advantage of the system is the transmission of 3D images through the Internet. Therefore, this system is a suitable device for producing media artwork.

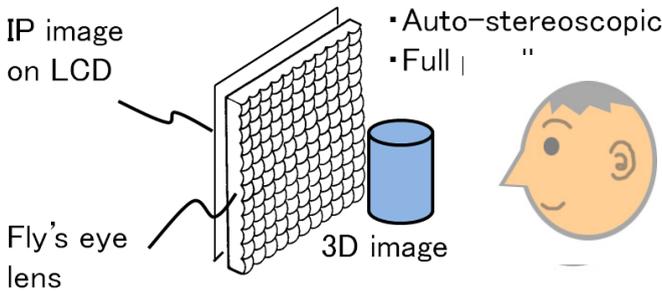


Fig. 1. Simple IP system

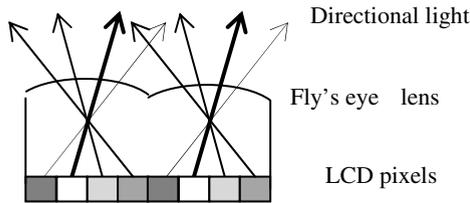


Fig. 2. Directional light

## 2 Method for Creating IP Images

The proposed method for creating IP images is an extension of an existing method [1–3]. We first describe the existing method as shown in Figure 3. When IP images are made using CG techniques, multi-viewpoint rendering shown in Figure 3 (a) is performed first. In this technique, the position and the angle of a virtual camera are

changed regularly, and rendering is carried out from the camera position. Our original script controls the procedure. An MEL script can be utilized when Maya is used in rendering.

As shown in Figure 3 (b), the use of this method produces a rendered still image for every camera position. As the camera position moves on  $n \times n$  grid points,  $n^2$  rendered still images are obtained. With the typical value of  $n$  being 32,  $n^2 = 1,024$  still images are obtained. Then, a single image called an “IP image,” which is shown in Figure 3 (d), is synthesized from these images using an algorithm shown in Figure 3 (c). Subsequently, the IP image is displayed on a flat panel display such as an LCD. The displayed IP image is observed through a fly's eye lens, which is a two-dimensional array of small convex lenses. The fly's eye lens is called as such because of its similarity to the compound eye of insects. Then, an auto-stereoscopic image with both horizontal and vertical parallax can be observed.

### 3 Adding a Glittering Effect through Post-production

As an IP system can emit light that is direction dependent (Figure 2), obtaining a certain amount of glittering is possible. However, achieving strong glittering is difficult.

A simple and straightforward way to add artificial glittering to a scene is to modify one of the rendered images in Figure 3 (b) by using paint software programs such as Adobe Photoshop. However, the effect is too small to be visible if only one of the 1,024 rendered images is modified. A sufficient number of rendered images must thus be modified simultaneously to obtain a visible result.

However, correcting the same portion of many rendered images simultaneously is very time consuming for an operator. Thus, we introduce an intermediate image, which is a single image created by rearranging the original pixels of  $n' \times n'$  adjacent rendered images.

A multi-viewpoint rendered image, as shown in Figure 4 (a), is created by connecting  $n \times n$  discrete rendered images, as shown in Figure 3 (b), where  $n = 32$ . Then,  $n' \times n'$  adjacent rendered images are put together in one group, as shown in Figure 4 (a). The pixels are rearranged to obtain the intermediate image shown in Figure 4 (b), where  $n' = 4$ . For an operator, the image in Figure 4 (b) is easier to handle than that in Figure 4 (a). This difference is attributable to the fact that if only one place is modified in the image in Figure 4 (b), the effect is the same as that when 16 places are modified in the picture shown in Figure 4 (a). The modified intermediate image in Figure 4(c) is then inverse-transformed to obtain the multi-viewpoint rendered image in Figure 4(d).

### 4 Experiment 1 (Coloring)

First, the effect in which the object appears colored only when seen from a certain direction was added using the aforementioned method.

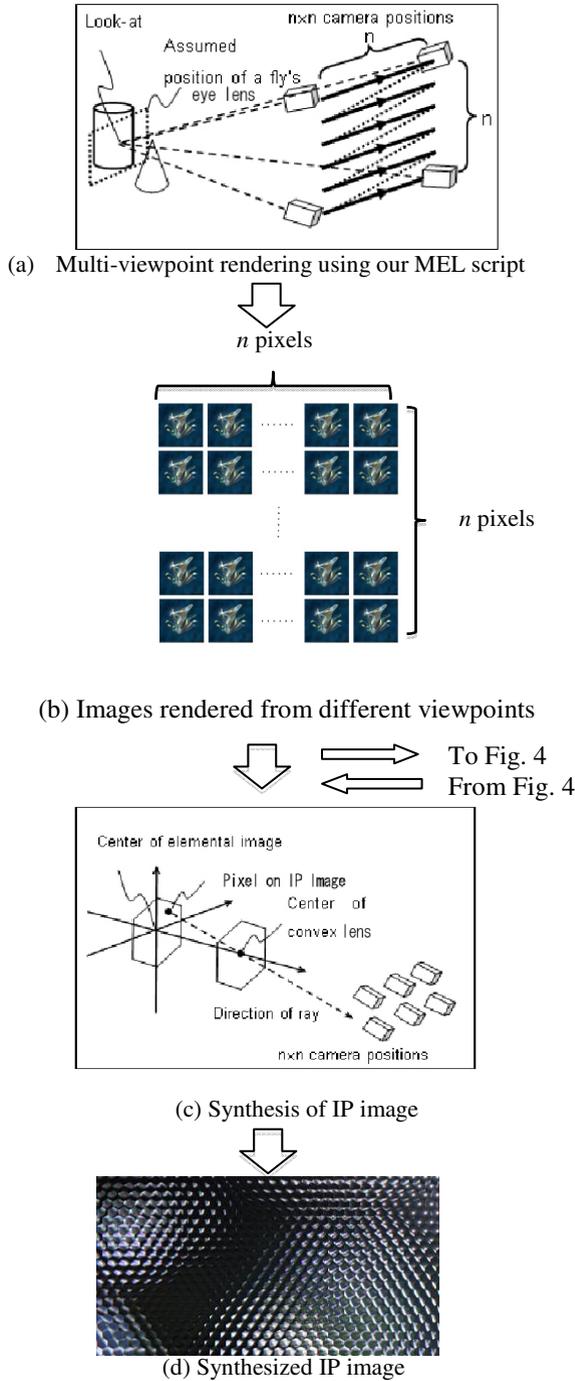


Fig. 3. Procedure of synthesizing an IP image

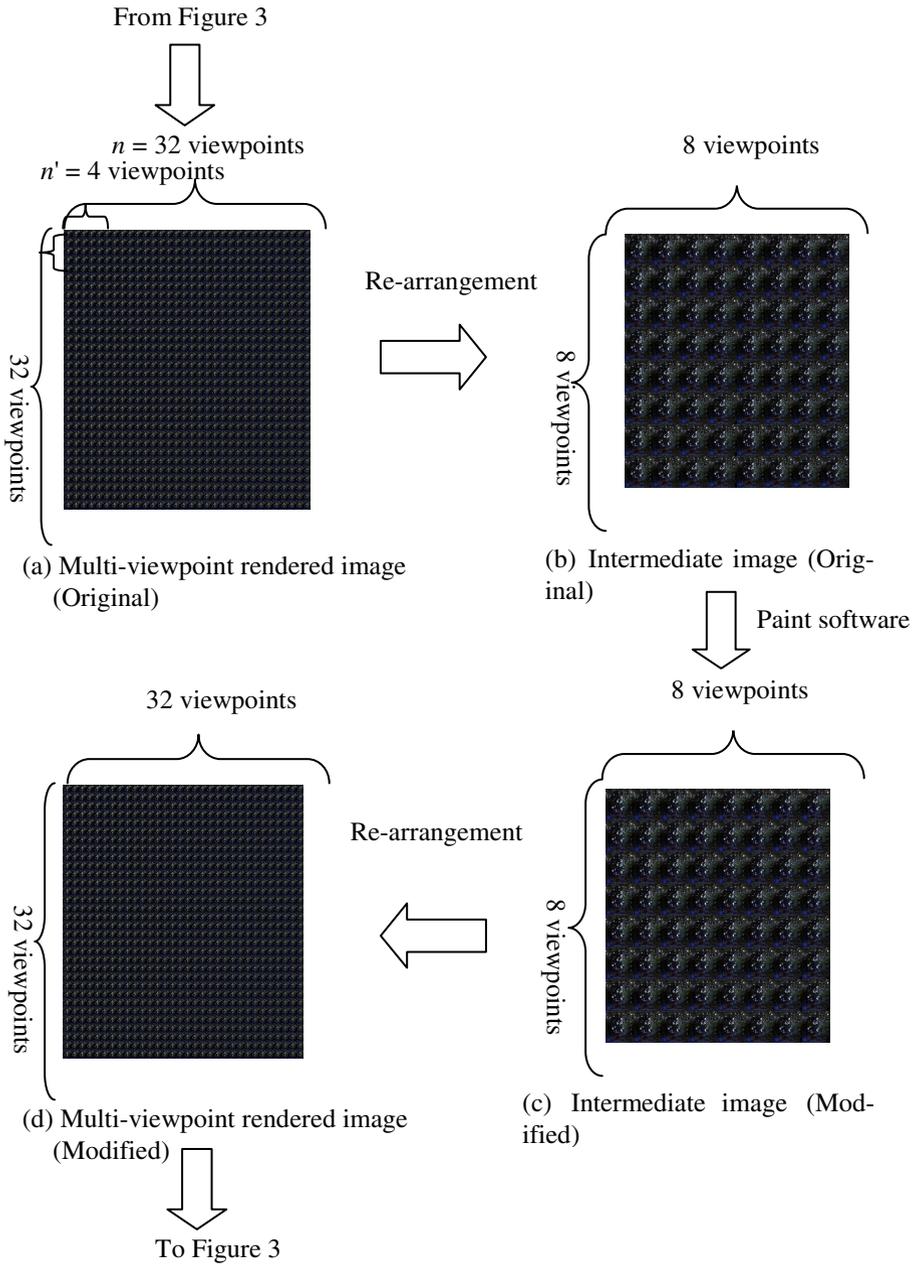


Fig. 4. Transformation into an intermediate image, modification, and inverse transformation

#### 4.1 In the Case of an Intermediate Image Consisting of $2 \times 2$ Regions

To examine this effect, we conducted an experiment where  $n = 32$  and  $n' = 16$ . In this case, the multi-viewpoint image is transformed into an intermediate image consisting of  $2 \times 2$  regions, as shown in Figure 5 (a). The contrast in the lower left region of Figure 5 (a) increased. The contrast of the displayed image increases only when the displayed image is seen from the lower left.



(a) Intermediate image consisting of  $2 \times 2$  regions

(b) Synthesized and displayed IP image

**Fig. 5.** Case of  $n = 32$  and  $n' = 16$

#### 4.2 In the Case of an Intermediate Image Consisting of $4 \times 4$ Regions

Figure 6 shows a case where  $n = 32$  and  $n' = 8$ . In this case, the multi-viewpoint image is transformed into an intermediate image consisting of  $4 \times 4$  regions, as shown in Figure 6 (a). The yellow component is enhanced in the four lower left regions, and the blue component is enhanced in three diagonal regions. Thus, the colors vary depending on the direction from which the image is viewed, as shown in Figure 5 (b).



(a) Intermediate image consisting of  $4 \times 4$  regions.

(b) Synthesized and displayed IP image.

**Fig. 6.** Case of  $n = 32$  and  $n' = 8$

## 5 Experiment 2 (Glittering)

The aforementioned method was applied to a picture of ice to produce a glittering effect.

Three columns from the right of the  $4 \times 4$  domain image in Figure 7 were identified. The rightmost sequence was colored in white using paint software to represent the rightmost area of the ice. The same was done for the middle sequence, which represents the middle area of the ice that could glitter, and for the left sequence, which represents the leftmost area of the ice that could glitter.

As shown in the  $4 \times 4$  image in Figure 7, the rightmost surface of the ice in the third image, the middle surface of the ice in the second image, and the left surface of the ice in the first image were all painted white to achieve a glittering effect. As a result, the different surfaces of the ice appear to glitter when the screen is tilted slightly.

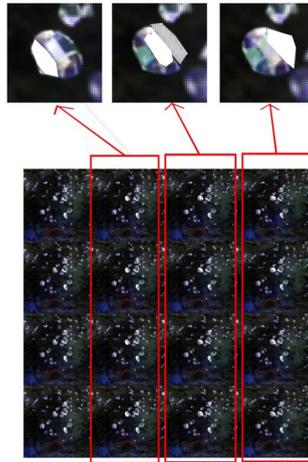


Fig. 7. Application of the glittering effect

## 6 Application to Artwork

We applied this technique to an artwork entitled “Frozen Time,” which was derived from a short film called “Fossil Tears [4–5].” A star somewhere in the universe is expressed in the artwork. On this star, everything, even time, is frozen. The motifs are a crystallized fossil, a clock made out of opal, ice floating in the air, and others. We applied the aforementioned technique to achieve a glittering effect for each motif.

The obtained IP image was displayed on the 9.7-inch retina display ( $2048 \times 1536$  pixels) of a commercially available tablet computer and was observed through a commercially available minute fly’s eye lens, which had a lens pitch of 1 mm. A ready-made fly’s eye lens was used because the extended fractional view method was applied to synthesize the IP images. As a result, strong glittering was obtained. The glittering effect caused the ice to appear more crystallized than that when this technique was not applied. This result suggests the effectiveness of the technique.



**Fig. 8.** Artwork using the LCD of a tablet PC and a fly's eye lens: "Ice floating in the air" and part of "Frozen Time"

## 7 Discussion

We propose a technique for glittering a part of an object in the post-processing of rendered images.

A method that follows physical laws for making objects glitter is available. In this method, glittering is produced through the reflection and refraction on the surface of an object. The well-known ray tracing technique is suitable in creating the glittering effect through the proper placement of many light sources. However, this method has a drawback. As the viewing zone of IP systems is generally narrow, targets should have many surfaces whose normal vectors are slightly different from one another to make targets glitter within the narrow zone. However, setting the orientations of the surfaces in such a way that the reflected rays go within the narrow viewing zone is difficult, especially when many objects are present. In addition, the fact that the path of reflected light depends on not only the normal vector of the surface but also the z-coordinates of the surface increases the complexity of the problem. Another problem is the increase in rendering time in proportion to the number of surfaces. This method will become feasible if these problems are solved.

## 8 Summary and Conclusion

We proposed a novel technique for IP, in which visual effects such as glittering are applied artificially by modifying multi-viewpoint rendered images. We verified the effectiveness of the proposed method by applying it to an artwork entitled "Frozen Time."

The strong glittering we obtained caused the image of the ice to appear more crystallized than that when the technique was not applied. The effect was especially

visible when the tablet PC was held and tilted in various directions. These results indicate the effectiveness of the proposed technique. Physically impossible and ever-changing visual effects, as well as previously impossible expressions, can be achieved using the proposed technology. The technique described in this paper is expected to be useful in extending the range of artistic expression using IP.

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