New Image Mapping Algorithm for 3D Integral Imaging Display System used in Virtual Reality

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Abstract

A new algorithm of the image mapping which is a technique of the elemental image generation is proposed. The proposed method is based on the characteristics of the lens array such as the number, the size and the focal length of the elemental lens. The 3D image generated by 3D graphic API such as OpenGL can be directly adopted without the complex adaptation. Since the image mapping using the proposed method can enhance the speed of the elemental image generation, the computer- generated integral imaging system can be applied to virtual reality system.

1. Objectives and Background

Integral imaging is one of the most promising three-dimensional (3D) display methods among the autostereoscopic because it can provide the full color image and both vertical and horizontal parallaxes without any special aids on observer [1]. Figure 1 shows the concept of the integral imaging system. As shown in Fig. 1, the integral imaging system consists of two parts, i.e., the pickup part and the display part.

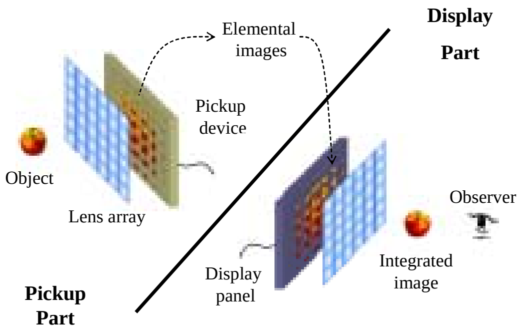

Fig. 1. Concept of integral imaging

The lens array composed of the elemental lenses produces the elemental images about the object in the pickup part. In the display part, the elemental images presented on the 2D display panel pass through the lens array to be reconstructed into the 3D integrated image. Instead of the pickup part, however, the elemental images can be generated by the computer process, named image mapping [2].

Virtual reality (VR) system is an interactive multimedia system which provides the realistic information to the observer and receives the reaction of the observer, which is used to change the provided information with the real time processing [3]. Therefore, the 3D display system, which is the ultimate visual media and can transfer the visual information with most reality to the observer, is indispensable to the VR system. If the elemental image generation can be performed in real time, the integral imaging display system can be adopted in the VR system.

In this paper a new algorithm of the image mapping, which is used for the computer-generated (CG) integral imaging system, is proposed. The proposed method is based on the characteristics of the lens array such as the number, the size and the focal length of the elemental lens, and can directly use the VR image generated by 3D graphic application programming interface (API) such as OpenGL (Open Graphics Library) without a complex adaptation.

2. The Proposed Algorithm using OpenGL API

We propose a new image mapping algorithm using OpenGL API. OpenGL is the layer between the programmer and the graphics hardware, which has several advantages such as high quality, high performance and high usability. Therefore we can easily implement the real-time 3D graphics if we use the libraries packaged with OpenGL.

Figure 2 shows the flow chart of the proposed algorithm. The proposed method is similar to the conventional pickup process, which is based on the characteristics of the lens array, not the integrated image. In the proposed method, each elemental image

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is obtained from the object image at the corresponding viewpoint according to the centers of the elemental lenses, which is a kind of 3D VR image and can be generated by the OpenGL API. After the elemental image generation, all of the elemental images are tiled. Therefore, the processing time is determined by the number of the elemental lens, not the size of the integrated image. Since, in most cases, the number of the elemental lens is smaller than the number of the integrated image pixel, the processing time can be improved by the proposed method. Moreover, the high-quality VR image can be directly adopted in the proposed method. The advanced image compression method of the digital image processing can also be applied to the improvement of the elemental image quality.

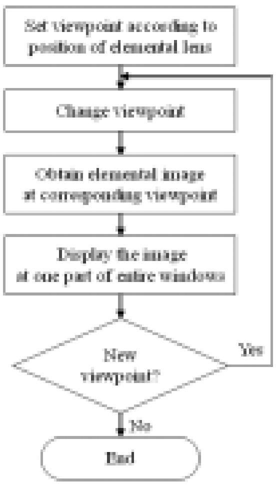

Fig. 2. Flow chart of proposed algorithm

Figure 3 shows the relationship between the 3D object and the elemental image. In the first process, the modeling transformation is performed to make and place the 3D object model in the world coordinates which is the application coordinate system that we define in our programs. After this process, the 3D robot object is created and positioned to the origin.

In the second process, the viewing transformation is performed to position the camera in camera coordinate. For example, the camera which looks at the 3D robot object is placed to the corresponding position to the center of an elemental lens. In the third process, the projection transformation adjusts the lens of camera, and projects the 3D object in the window or screen coordinates that use the units measured in pixels. In the last process, the viewport transformation chooses the size of the final image on the screen. In our algorithm, the 3D robot object is drawn on the sub-window, called viewport. This viewport which is the same size as an elemental lens among the lens array is placed in the same position of the corresponding elemental lens. And the process above is performed to the whole lens repeatedly. After all processes, we can obtain the elemental images on the windows.

The real pickup integral imaging system has a pseudoscopic problem, which means the longitudinal inversion of the integrated image depth. This is due to the fact that the viewers observe the image from the opposite direction of the pickup. To correct the pseudoscopic problem, each elemental image must be rotated by 180 degree centrosymmetrically. But the elemental image obtained by the proposed method can be directly used without the pseudoscopic problem because the elemental image is uprightly projected from 3D object. Therefore the display mode in this integral imaging system is the virtual mode [4].

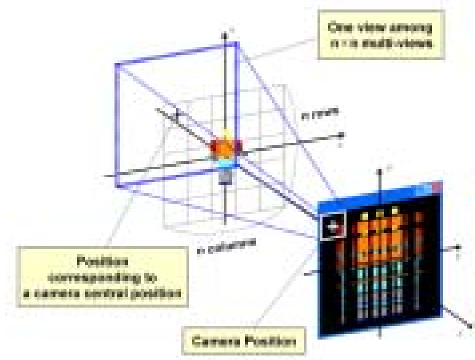

Fig. 3. Relationship between the 3D object and elemental images

3. Experimental Setup

The CG integral imaging system is composed of only the display part of the conventional integral imaging system, in which the image mapping is substituted for the pickup part. In the previous image mapping method, an imaginary 3D object point is mapped to a set of 2D points in accordance with the characteristics of the lens array. Therefore, all of the points to be displayed must pass through the mapping process and the processing time is dependent on the size of the integrated image [5].

The display device of the setup consists of the high-resolution beam projector and the screen. The lens array is placed in front of the screen. And the base line of the elemental images on the screen should be set to the base line of the lens array.

The specifications of the image generation setup are shown in Table 1. The lens array is composed of 13×13 Fresnel lenses. The elemental lens pitch is 10 mm. The focal length of each lens is 22 mm. Each elemental image contains 38×38 pixels of the display device. The screen displays an elemental image which is 10 mm2. Therefore the pixel size of display is about 0.26 mm per a pixel in the width.

Figure 4 shows the experimental system setup of integral imaging system. And the 3D object used in the experiment is shown in Fig. 5. We can calculate some of viewing characteristics about the integral image from this experiment with these equipment specifications.

Table 1. Equipment specifications

Display device	Number of pixels	494(H) × 494(V)
	Display area size	130 × 130 mm^2
	Display pixel pitch	0.26 mm
Lens array	Number of elemental lenses	13(H) × 13(V)
	Pitch	10 mm
	Focal length	22 mm

Fig. 4. Experimental system setup of the integral imaging system

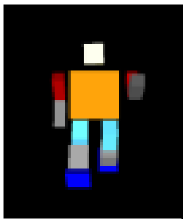

Fig. 5. 3D object used in the experiment

4. Experimental Results and Discussion

Figure 6 shows the image mapping results, the elemental images, which have two types: the real mode and the virtual mode. Among them, we choose the virtual mode, and we get the 3D integral image from this virtual mode. Figure 7 shows the integrated image of the experimental results made by the proposed method. The distance between the left viewpoint and the right viewpoint is about 400 mm.

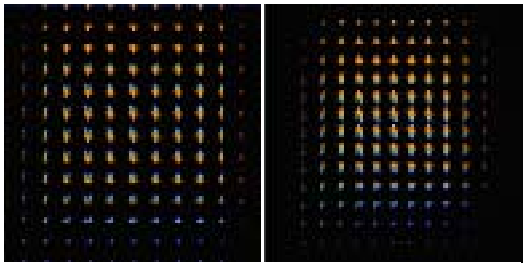

Fig. 6. Elemental images: the real mode (left), the virtual mode (right)

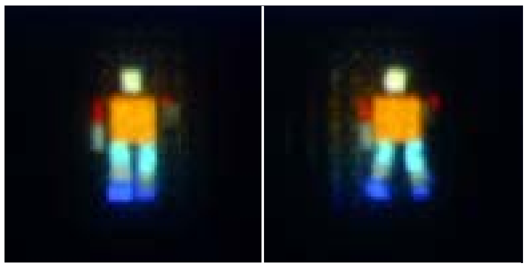

Fig. 7. Integral image of the experimental results: from the left viewpoint (left) and from the right viewpoint (right)

Above all, we assume that 4 points in the world coordinates equals to 10mm in real world. The distance between the 3D object and the camera viewpoint during pickup process of our experiments is 50 points.

The gap between the lens array and the screen can be obtained by Eq.(1), which is induced by the lens equitation.

$$g = \frac{fl}{f-l}, \quad (1)$$

where g is the gap between the lens arrays and the screen, l is the position of the central depth plane and f is the focal length of the elemental lens.

In integral imaging system, there are viewing characteristics such as the image resolution, the viewing angle and the marginal image depth [6]. The resolution of the reconstructed image is expressed as eq. (2).

$$R_I = 1/P_I = \frac{g}{lP_X} = \frac{g}{l} R_X, \quad (2)$$

where R_I is the image resolution, P_I is the pixel size of the image, P_x is the pixel pitch of the screen, R_x is the resolution of the screen. According to eq. (2), the resolution of the reconstructed image is almost dependent on the resolution of the beam projector.

The viewing angle is given by

$$\tan\left(\frac{\Omega}{2}\right) = \frac{P_L}{2g}, \quad (3)$$

where Ω is the viewing angle and P_L is the lens pitch.

Lastly the marginal image depth can be considered by

$$\Delta z_m = 2\frac{l}{P_L} P_I, \quad (4)$$

where Δz_m is the marginal image depth.

In our experiments, we choose that l is 125 mm. Then the gap, g, is set on 26.7 mm. According to eqs. (2), (3) and (4), the image resolution is 0.812 mm^{-1}, the viewing angle is 21.2 deg and the marginal image depth is 30.8 mm.

The calculated distance from lens array to integral image is 125 mm. The distance measured by our experiments is similar to the calculated distance. We change temporarily from the virtual mode to the real mode for measuring the distance. That is because it is difficult to check the distance in the virtual mode. The calculated results are shown in Table 2.

Table 2. Calculation results

The distance from lens array to integrated image (mm)	125
The gap (mm)	26.7
The image resolution (mm^{-1})	0.812
The viewing angle (deg)	21.2
The marginal image depth (mm)	30.8

With the floating lens, our proposed system in virtual mode can transfer the 3D image to the position near by the observer. The technique emphasizes the feel of depth [7].

The interaction between human and a virtual environment is necessary to adapt the 3D integral imaging display system to the VR system with the real time processing. Thus we choose a keyboard, which is one of the input devices, in our system. The 3D object can react to the keystrokes with the real time processing. For instance, the arrow keys make the robot run in the aimed direction.

More analysis and experimental results will be provided at the presentation.

5. Summary

In this paper, new algorithm of the image mapping was proposed, which can improve the processing speed and can use the VR image generated by 3D graphic API such as OpenGL. Using the proposed method, CG integral imaging system can be successfully applied to the VR system.

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7. References

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