Image Compression for Integral Photography

*Kazuhisa Yanaka, Hideo Kasuga and Yasushi Hoshino**
Kanagawa Institute of Technology, Shimo-ogino, Atsugi, Kanagawa, Japan
**Nippon Institute of Technology, Miyashiro, Saitama, Japan*

Abstract

Integral photography is one of excellent 3D display systems in which viewers can see 3D objects from arbitrary viewpoints without wearing special glasses. This system can be realized by sandwiching a transparent board between two transparent sheets, which are OHP sheets on which special still images were printed by an ink jet printer. The upper transparent sheet is a pinhole array, therefore even when its data compression is needed, it is very orderly and can easily be compressed. On the other hand, the image printed on the lower transparent sheet is complex and the resolution of the image is very high. For example, the number of picture elements is 5760 × 5760 and the depth is 3(RGB)×8 bit. Therefore, compression is strongly required. This paper describes lossless compression algorithms suitable for the image to be printed on the lower transparent sheet. Through experiments it has been shown that PNG is considerably better than GIF and JPEG2000.

Introduction

3D images which give the true sense of depth are so impressive and attractive that various 3D display systems[1] have been proposed until now. Among them the holography is in a sense an ideal system because viewers can see 3D images from any directions within certain limits without wearing special viewing glasses. However, delicate technologies such as laser optics are required. The integral photography (IP) is also able to reproduce 3D images identical to the original objects without special glasses, and yet it is technically more feasible. The only difficulty might be to manufacture a high-precision fly-eye lens array at low cost, but it is known that the lens array can be replaced with a pinhole array.

It is not necessary to drill a board in order to manufacture the pinhole array. As Sasaki et al.[2] pointed out, printing a pinhole array image with light blocking ink on a transparent sheet brings about an equivalent result. They proposed an integral photography system, shown in Fig.1, in which a transparent board is sandwiched by two transparent sheets. A pinhole array is printed on one of the transparent sheets, and a special pattern which is synthesized by our computer program, is printed on the other transparent board. From here on we call the pattern "IP image", where IP stands for Integral Photography.

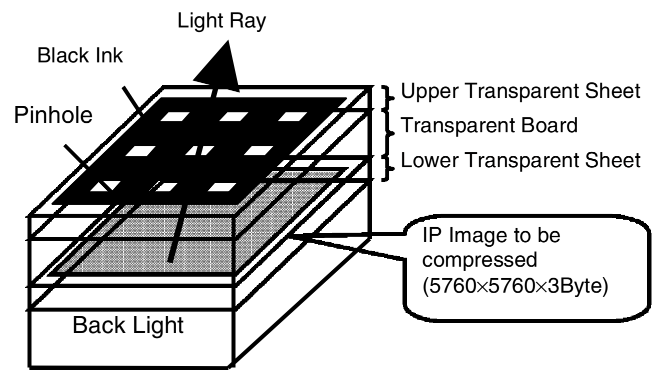

Figure 1. An Integral Photography System

A typical number of pinholes printed on a 203.2 × 203.2mm transparent sheet is 180 × 180. And each pinhole corresponds to an element image of 32×32 pixels so that viewers can see 1,024 different images by moving their eyes horizontally and vertically. Therefore, the total number of picture elements of an IP image is 5760 x 5760. Each pixel has 3(RGB)×8 bit depth so that full color 3D images can be displayed. In this case the total amount of data is as much as 94Mbytes. Therefore data compression is strongly desired.

Lossless Coding

Because an IP image is a kind of continuous-tone still image, it can be compressed by various methods. Generally speaking, image coding can be classified into two categories: lossless coding and lossy coding. In lossles coding, the decoded image data is completely the same as the original image data. On the other hand, in lossy coding the decoded image data is usually very similar to the original. But both are not completely the same, even if the difference cannot be perceived by human visual system.

From here we are going to focus attention on lossless coding. Up to now various kinds of lossless coding schemes have been proposed. Among them, typical coding systems, namely GIF[3], PNG[3], and JPEG2000[4] are examined in this paper.

GIF (Graphics Interchange Format) allows only 256 colors. GIF uses a patented compression technique known as LZW.

PNG (Portable Network Graphics) format was designed to replace GIF format which has a legal issue. The PNG format contains true color. The PNG specification was issued as a W3C Recommendation.

JPEG2000 is a new version of JPEG image coding system. Wavelet technology has been adopted for more efficient compression. Though both lossless and lossy compression are possible, only lossless mode was examined in this paper.

IP Image Generation by CG

IP images, to be used in after-mentioned experiments, have to be prepared in advance. Sasaki et al.[2] proposed a method to generate IP images by their own ray tracing algorithm which is relatively simple and can display undistorted 3D objects. However, their program supported only simple 3D objects such as spheres and checkerboards. Yanaka et al.[5] proposed a system in which a series of CG images made by POV-Ray[6] are composed by their original algorithm to get an IP image. Since POV-Ray is very powerful CG freeware with a variety of functions, sophisticated scenes including transparent glass and complex 3D objects can be generated easily. However, the algorithm proposed in Yanaka et al.'s previous paper was too simple to get undistorted 3D objects. In this paper we propose a new algorithm so that geometrically undistorted 3D objects can be displayed.

First, a scene file which specifies the arrangement of 3D objects is prepared, and it is rendered by POV-Ray system. Figure 2 shows the motion of a virtual camera in POV-Ray coordinate system. 32×32=1024 still images are rendered successively. Regardless of the camera motion, the camera always looks at the origin. The camera must be a parallel projection camera.

Then an IP image is synthesized by our algorithm based on the still images. As shown in Figure 3, a virtual pinhole array is placed at the XY-plane in the 3D space generated by POV-Ray. The equation of a light ray which go through a pinhole (x_0,y_0,z_0) and the orientation of which is (a,b,c) is shown as

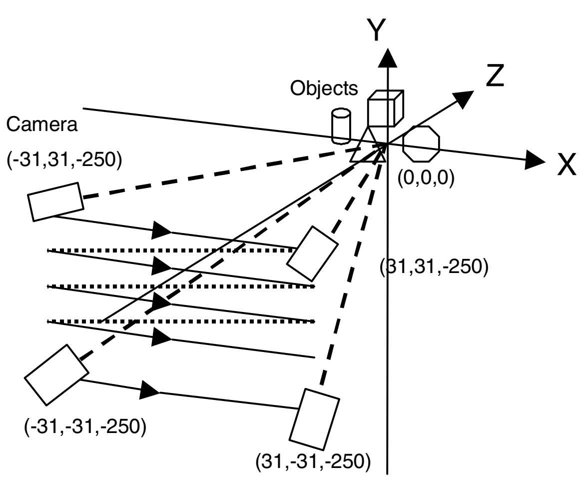

Figure 2. Motion of the virtual camera

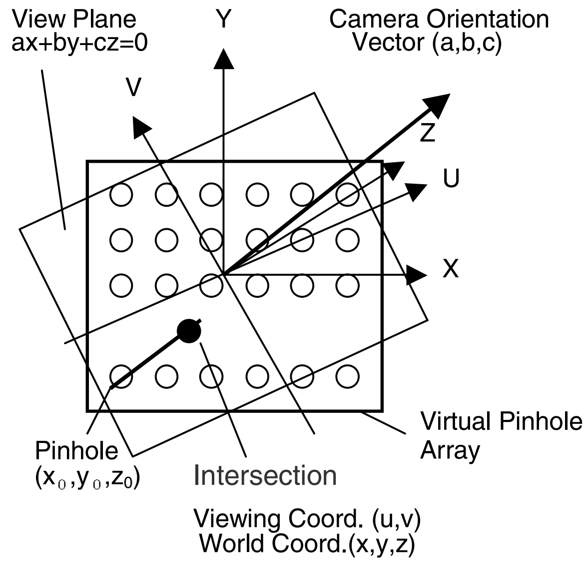

Figure 3. Synthesis of an IP image

$$
\begin{aligned}
x &= x_0 + at \\
y &= y_0 + bt \\
z &= z_0 + ct
\end{aligned}
\qquad (1)
$$

where t is a parameter. Please note that only the direction of the vector (a,b,c) has meaning because parallel projection is used. The equation of the view plane is

$$ax + by + cz = 0 \qquad (2)$$

Therefore, the value of t of the intersection of the right ray and the view plane is as follows.

$$t = -\frac{ax_0 + by_0 + cz_0}{a^2 + b^2 + c^2} \qquad (3)$$

By substituting the parameter t of (1) for (3), the coordinates of the intersection (x,y,z) are obtained. Then they are transformed to the viewing coordinates (u,v) as follows.

$$
u = \frac{cx - az}{\sqrt{a^2 + c^2}}
$$
$$
v = \sqrt{\frac{a^2 + b^2 + c^2}{a^2 + c^2}}\, y \qquad (4)
$$

From the POV-Ray image whose camera orientation is (a,b,c), the value of a pixel which corresponds to the viewing coordinates (u,v) is sampled, and the value is set to the corresponding pixel of the IP image.

IP Image Generation by Real Camera

Another way to make IP images is to use dedicated input system using real camera. Kasuga et al.[7] proposed an input system using a CCD camera which is attached to an XY plotter instead of a pen.

Experiments

Six IP images were used in our experiments. Four of them, namely "objects180", "cubes180", "objects360" and "cubes360" are generated by POV-Ray. Others, "flower180" and "fruits180", are captured by real camera. Here the final number, 180 or 360, stands for the number of pinholes on a side. In the case of 180, the size of an element image is 32×32. In the case of 360, the size of an element image is 16×16. Therefore, the total number of pixels of an IP image is 5760×5760 in both cases. Examples of the IP images are shown in Figures 4 and 5.

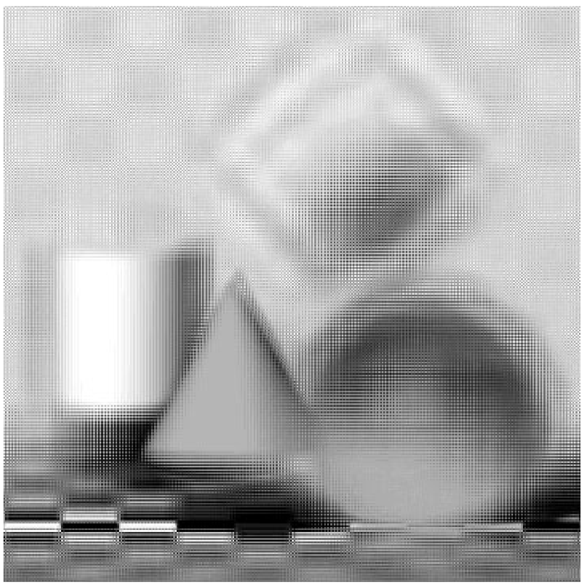

Figure 4. "objects180"(An example of IP images created by CG)

Figure 5. "fruits180"(An example of IP images captured by CCD camera)

Each IP image is then encoded by three methods: GIF, PNG, and JPEG2000 lossless mode. In the case of GIF, the IP image is separated into three color components in advance because images including more than 256 colors are not accepted. The compression ratio is shown in Figure 6, in which "1" means that the size of the compressed data is the same as that of the original data. If the ratio is smaller, the performance of the coding algorithm is better.

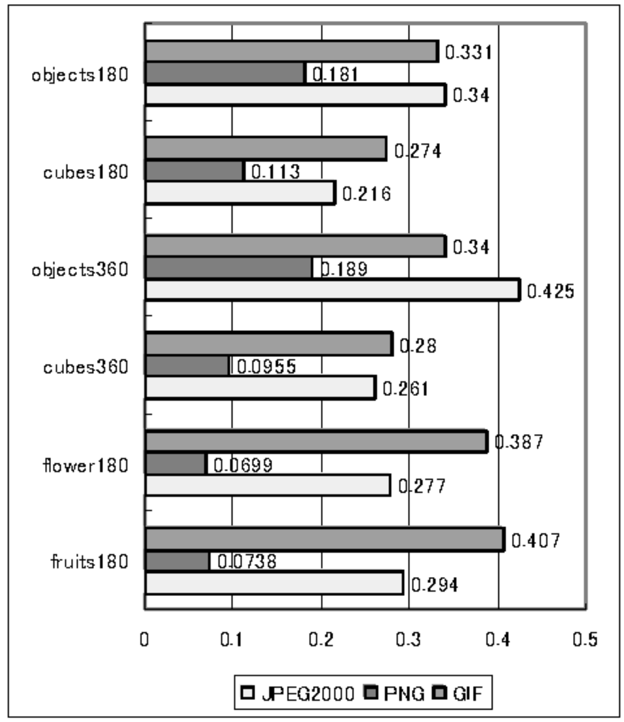

Figure 6. Compression ratio of IP images

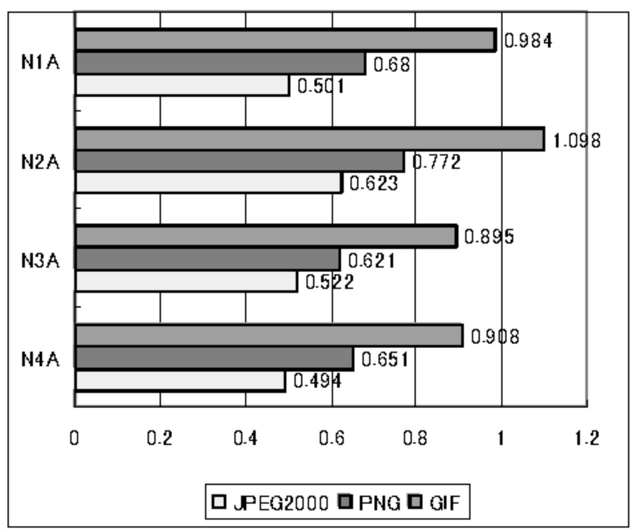

Figure 7. Compression ratio of SCID images

For the sake of comparison, Figure 7 shows the results of non-IP images which are included in ISO SCID (Standard Color Image Data).
N1A: portrait
N2A: cafeteria
N3A: fruits basket
N4A: wine and silver

Clearly situation differs. In Figure 7 JPEG2000 lossless mode is the best and the second is PNG. To the contrary PNG outperforms others in Figure 6. The cause seems to be attributed to the inherent microstructure of IP images shown in Figure 8. As stated above, an IP image consists of many element images, the typical size of which is 32 × 32. This kind of periodicity would be advantageous to PNG.

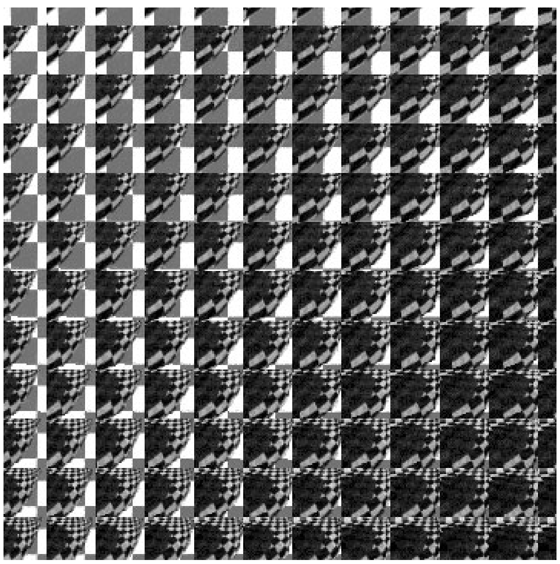

Figure 8. Microstructure of an IP image (A portion of Figure 4 was magnified)

Conclusion

In order to compress the huge data of images for integral photography, three lossless coding methods, namely GIF, PNG, and JPEG2000 lossless mode were examined. The test images were made by computer graphics or real CCD camera. Experimental results show that PNG is suitable for compressing IP images. JPEG2000 lossless mode is not as good as PNG. This is probably because an IP image has periodicity, since it consists of many element images, each of which corresponds to a pinhole.

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References

1. Graham Saxby, "The Science of Imaging: An Introduction," Institute of Physics Publishing, Bristol, UK, 2002.
2. Susumu Sasaki, Hideo Kasuga, Kazuhisa Yanaka and Yasushi Hoshino, "3D Display System Using High Resolution Transparent Printer Output", IS&T's NIP18, 2002 International Conference on Diigital Printing Technologies, San Diego, CA.
3. James D. Murray and William vanRyper, "Graphics File Formats, Second Edition", O'Reilly & Associates, Inc., Sebastopol, CA. (1996)
4. David S. Taubman and Michael W. Marcellin, "JPEG 2000 Image Compression Fundamentals, Standards and Practice," Kluwer Academic Publishers, Norwell, MA.(2002).
5. Kazuhisa Yanaka, Susumu Sasaki, Hideo Kasuga and Yasushi Hoshino,"3D Image Display Using Ink-jet Printer (in Japanese)," Technical Report of IECIE, EID2002-124 (2003-02).
6. Hideki Komuro," Computer Graphics Practice by POV-Ray (in Japanese)," ASCII Publisher, Tokyo, Japan (2000).
7. Hideo Kasuga, Kazuhisa Yanaka, Susumu Sasaki and Yasushi Hoshino,"3D Image Input System for Integral Photography", IS&T's NIP19, 2003 International Conference on Diigital Printing Technologies, Mew Orleans, LA.

Biographies

Kazuhisa Yanaka is a professor of Kanagawa Institute of Technology, Japan. He gained BE, ME and Dr.Eng. degrees from the University of Tokyo, in 1977, 1979, and 1982 respectively. He joined Electrical Communication Laboratories of NTT in 1982 and developed videotex terminals, teleconferencing systems, and image coding algorithms. He moved to Kanagawa Institute of Technology in 1997.

Hideo Kasuga is a research associate of Kanagawa Institute of Technology, Japan. He gained BE, ME and Dr.Eng. degrees from Shinshu University in 1995, 1997, and 2000 respectively. He worked at the university as a research associate for months, and he moved to Kanagawa Institute of Technology in 2000. His main research field is image processing.

Yasushi Hoshino is a professor of Nippon Institute of Technology, Japan. He gained BE, ME and Dr.Eng. degrees from the University of Tokyo, in 1970, 1972, and 1984 respectively. After he gained ME degree, he joined Electrical Communication Laboratories of NTT and developed LED printers, laser printers, and ion flow printers. He moved to Nippon Institute of Technology in 1994. He published more than 20 papers, including several papers in IS&T's journal. He attended almost all NIP conferences.