Proceedings of *ICO Topical Meeting on Optoinfomatics/Information Photonics* 2006, pp.99–100,
September 4-7, 2006, St. Petersburg Russia

# PERFORMANCE OF THE POLYGON-SOURCE METHOD FOR CREATING COMPUTER-GENERATED HOLOGRAMS OF SURFACE OBJECTS

K. Matsushima, Department of Electrical Engineering and Computer Science, Kansai University,
Yamate-cho 3-3-35, Suita, Osaka 564-8680, Japan. E-mail: matsu@kansai-u.ac.jp
Session "In Memoriam of Emmett Leith: Enlightening the World of Holography", Poster

The polygon-source method was implemented and its performance was measured. The method was proposed by the author for fast computation of object fields from virtual surface objects and creation of computer-generated holograms (CGHs).

## 1. Introduction

A method based on point sources of light has been successfully used for numerical calculation of object fields from virtual objects in CGHs for display purposes. However, the point source method is too slow to create CGHs of surface objects especially for full-parallax holograms, because the surface density of 100 points/mm$^2$ or more is required for forming point sources into a surface. The author has proposed using surface sources of light for surface objects instead of point sources[1, 2]. In the method, an object is composed of small planar surfaces, polygons. A polygon, illuminated by virtual source of light, reflects the light and behaves itself as a surface source of light, i.e. the polygon source. The light from the polygon source is calculated by rotational transformation of wave fields using FFT[3]. The rotational transformation also plays an important role in a case occlusion occurs[4], i.e. in hidden-surfaces removal[5].

## 2. Computational complexity

The rotational transformation is the core of the proposed method and most likely consumes almost all computation time. Fig. 1 shows a diagram of computational process of the transformation. The complex amplitudes $s(x, y)$, given in local coordinates defined for each polygon, is called surface property function, which keeps property of the polygon such as the shape, texture or diffusiveness. $\hat{h}(\hat{x},\hat{y})$ is also complex amplitudes given in global coordinates parallel to the hologram. FFT operation (**F**) must be executed twice for the rotational transformation of a polygon. Furthermore, it is required for each polygon that coordinates rotation (**R**) including interpolation and multiplication by a phase factor $P(d)$ for translational propagation in Fourier space.

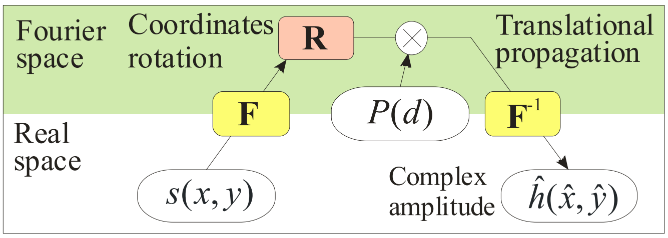


Fig.1 The diagram for calculating the object field from a polygon source of light

## 3. Performance

Optical reconstruction of the hologram of a cube is shown in Fig.2 as an example of the proposed method. The hologram has 3.2 M (≈8192×4096) sampling points. Fig.2 (a)–(b) show amplitude patterns of the polygons 1 to 3, calculated around the polygons, respectively. The light emitted from three polygons, of which dimensions are 6 mm square, are separately calculated and totaled on the hologram plane.

Measured total computation time was 92 sec in executing by single CPU of Xeon 3.0 GHz. Fig.3 shows the ratios of the CPU time consumed for each numerical process. In the case of the object shown in Fig. 2, FFT operations are executed 8 times and were supposed to be the most time-consuming process. However, measured longest numerical process is the coordinate rotation accompanied with interpolation, which accounts for 44 percent of all.

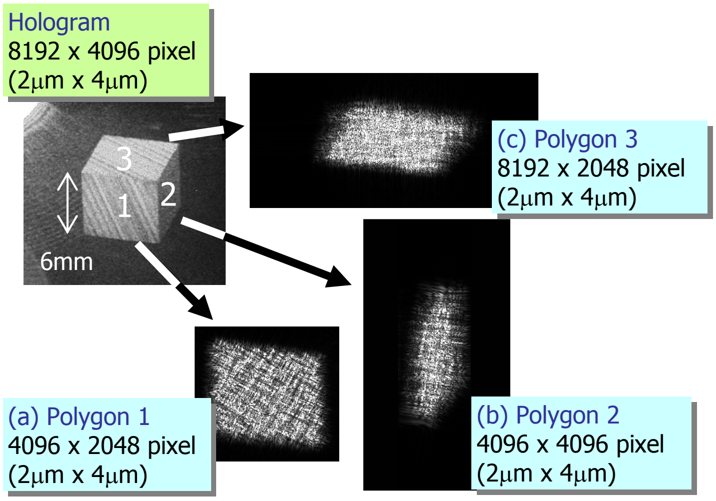


Fig.2 An example of optical reconstruction of a surface object; a cube, and calculated amplitudes of fields (a)–(b), emitted from each polygon.

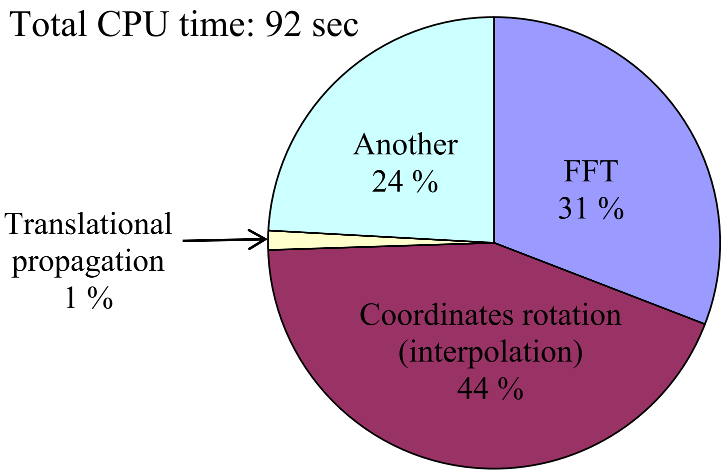


Fig.3 The ratios of CPU time consumed for each numerical process.

4. Conclusion

Performance of algorithm for calculating object fields emitted from polygon sources of light was measured for fast creation of full-parallax computer-generated holograms of surface object. In the algorithm FFT operations are required twice for calculating the field from a polygon. However, the measured ratio of CPU time suggests that the bottle neck of the algorithm is not in FFT but in interpolation. Algorithm of FFT is sufficiently studied and tuned up, while interpolation is not. Therefore, it is every possibility of further reducing the CPU time.

1. K. Matsushima: "Computer-Generated Holograms for Three-Dimensional Surface Objects with Shade and Texture", Appl. Opt., **44**, 4607-4614(2005).
2. K. Matsushima: "Development of the Surface Diffraction Method for Computer-Generated Display Holograms", 7$^{th}$ Intern. Symposium on Display Holography, North Wales, (2006) in press.
3. K. Matsushima, H. Schimmel, F. Wyrowski: "Fast Calculation Method for Optical Diffraction on Tilted Planes Using the Angular Spectrum of Plane Waves", J. Opt. Soc. Am., **A20**, 1755-1762(2003).
4. K. Matsushima: "Fast Creation of Digitally Synthetic Holograms of Surface Objects by Use of a Wave-Optical Method", ICO Conf. on *Optics & Photonics in Technology Frontier*, Tokyo, 467-468(2004).
5. K. Matsushima: "Exact Hidden-Surface Removal in Digitally Synthetic Full-Parallax Holograms", *Practical Holography XIX and Holographic Materials XI*, SPIE Proc. #**5742**, San Jose, 25-32(2005).