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Fast Calculation of Amplitude-modulated Computer Generated Hologram with Multiple Ampere-GPU Cluster System

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ABSTRACT

We propose a fast computer-generated hologram (CGH) calculation algorithm to reduce the number of the trigonometric function calculations. The proposed algorithm is implemented on 2-node multiple GPU cluster system with 6 GPUs used for CGH calculations. Finally, we realized a real-time electroholography of a 3D model comprising approximately 260,000 points.

1 INTRODUCTION

Real-time electroholography is expected to realize the ultimate 3D television. However, enormous computer-generated hologram (CGH) calculation prevents the practical use of real-time electroholography.

A graphics processing unit (GPU) provides high-performance floating-point operations at low cost. GPU accelerates CGH calculation and directly displays the calculated CGH on a spatial light modulator (SLM). In our previous works, the acceleration of CGH calculation using a GPU has been reported [1]. We adopted our acceleration technique [1] to real-time electroholography with a multi-GPU cluster system [2–5].

In the CGH calculation, the trigonometric functions become the bottleneck. A GPU has many Special Function Units (SFUs) to accelerate the computations of sine and cosine functions. In each stream multiprocessor of the latest GPU based on Ampere GA102 architecture [6], the number of SFUs is reduced relative to the number of CUDA cores, compared with GPUs based on Turing [7] and Pascal GP104 architectures [8]. In order to achieve faster CGH calculation using an Ampere GPU, the CGH calculation algorithm that reduces the number of trigonometric function calculations is desirable.

We propose the simple and fast CGH calculation algorithm to reduce the number of the trigonometric function calculations. Furthermore, the proposed algorithm is implemented on 2-node multi-GPU cluster system comprising a CGH display node with a single GPU and a CGH calculation node with 6 GPUs . Finally, we realized a real-time electroholography of point-cloud 3D model comprising approximately 260,000 points.

2 PROPOSED CGH CALCULATION

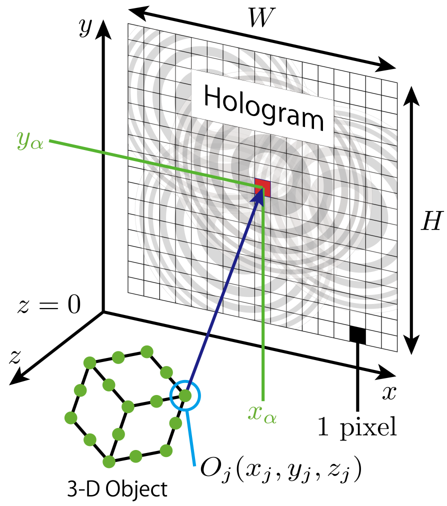

Fig. 2.1: Coordinate system in CGH calculation

Fig. 2.1 shows a coordinate system in CGH calculation. We used the algorithm to calculate an in-line hologram from the 3D object expressed by the point cloud. For a 3D object comprised of N_p points, the light intensity of each point on CGH is calculated by the following equation [1]:

$$I(x_\alpha, y_\alpha, 0) = \sum_{j=1}^{N_p} A_j \cos\left[\frac{\pi}{\lambda z_j}\left\{(x_\alpha - x_j)^2 + (y_\alpha - y_j)^2\right\}\right], \tag{1}$$

where $I(x_\alpha, y_\alpha, 0)$ is the light intensity of the point (x_α, y_α) on the hologram, (x_j, y_j, z_j) and A_j show respectively the coordinate and intensity of the j-th point on a 3D object.

In equation (1), Z, X, Y are defined as follows:

$$Z = \frac{\pi}{\lambda z_j}, X = Z(x_\alpha - x_j)^2, Y = Z(y_\alpha - y_j)^2.$$

By trigonometric addition theorem, equation (1) can be expressed as:

$$\begin{aligned} I(x_\alpha, y_\alpha) &= \sum_{j=1}^{N_p} A_j \cos(X+Y) \\ &= \sum_{j=1}^{N_p} A_j(\cos X \cos Y + \sin X \sin Y). \quad (2) \end{aligned}$$

From equation (2), cosine part can be calculated individually x-axis and y-axis.

3 IMPLEMENTATION

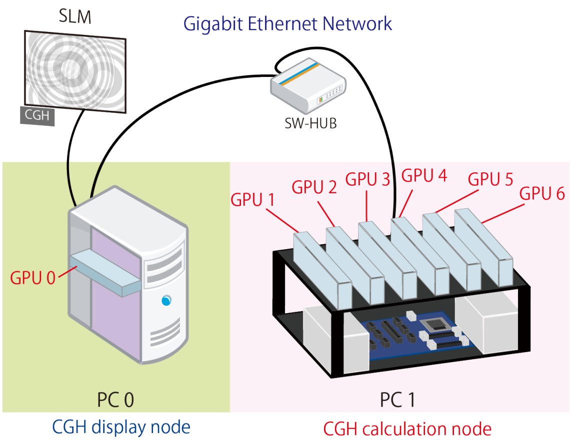

Fig. 3.1: 2-node multi-GPU cluster system

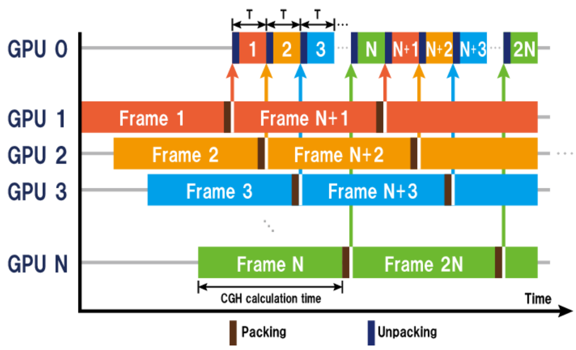

Fig. 3.2: Time-chart of CGH calculation using 2-node multi-GPU cluster system

Fig. 3.1 shows 2-node multi-GPU cluster system comprising a CGH display node (PC0) with a single GPU and a CGH calculation node (PC1) with 6 GPUs. Fig. 3.2 shows CGH calculation time-chart of real-time electroholography using the multi-GPU cluster system. As shown in Fig. 3.2, a CGH calculation node (PC1) calculates CGHs using 6 GPUs. A CGH display node (PC0) displays the calculated CGH on a SLM.

4 RESULTS AND DISCUSSION

We used NVIDIA GeForce RTX 3080, Intel Core i7-9700K, CUDA 11.2 SDK, MPICH 3.4.2, and Linux (CentOS 7.9.2009). In the multi-GPU cluster, a gigabit ethernet network is used [3]. Table 4.1 and Fig. 4.1 show display-time interval of each CGH frame when the resolution of CGH is 1,920×1,024. "1 GPU" shows the CGH computation time, which includes the CGH calculation and display time, using a PC with a GPU. "6 GPU" shows the display-time interval when the number of GPUs on a CGH calculation node is six. It includes the CGH calculation and display time and the CGH data transfer time from a CGH calculation node to a CGH display node.

In using 6 GPUs on a CGH calculation node for CGH calculations, we realized a real-time electroholography of a 3D model comprising approximately 260,000 points. The speedup by the proposed method is more than 90 % of the theoretical performance of 6 times.

Table 4.1: Display-time interval of CGH

Object points	Display-time interval [ms] 1 GPU	6 GPUs	Speed-up 1GPU/6GPUs
51,200	35.80	6.38	5.61
102,400	71.99	12.86	5.60
153,600	107.59	19.22	5.60
204,800	144.63	25.76	5.61
256,000	180.97	32.22	5.62
307,200	217.22	38.66	5.62

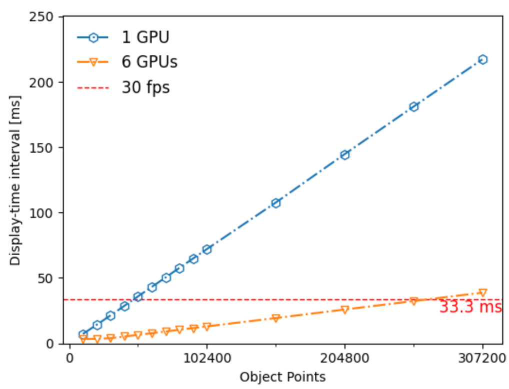

Fig. 4.1: CGH display-time intervals of "1 GPU" and "6 GPUs."

5 CONCLUSION

We proposed a fast CGH calculation algorithm to reduce the number of the trigonometric function calculations. The proposed algorithm is suitable for an Ampere-GPU (NVIDIA GeForce RTX 3080). We implement the proposed algorithm on 2-node multi-GPU cluster system with 6 GPUs used in CGH calculations. Consequently, we realized a real-time electroholography of a 3D model comprising approximately 260,000 points.

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