Large scale calculation for holography using SSD

Atsushi Sugiyama[*1,2], Hayato Akiyama[2], Shingo Hashikawa[2], Tomoyoshi Shimobaba[1], Takashi Kakue[1] , and Tomoyoshi Ito[1]

[1]*Graduate School of Engineering, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan,*
[2]*ELSA Japan Inc., 3-42-10 Shiba, Minato-ku, Tokyo 105-0014, Japan*

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Abstract—Computer based holography such as electro-holography and digital holography advances because the resolution of an imaging display and a sensing device such as a liquid crystal display (LCD) and a charge coupled device (CCD) becomes higher. The higher resolution of an imaging device requires a more powerful computing system. On the other hand, a solid state drive (SSD) develops as a storage device of computers. We studied the effectiveness of an SSD for a large-scale digital holography calculation. When the calculation data scale exceeds the main memory capacity, the SSD system showed better performance compared with a hard disk drive (HDD) system at computational speed and stability.

In electro-holography to reflect a three-dimensional (3-D) picture, we use spatial light modulators (SLMs) such as a high-definition LCD [1-3]. Recently, the number of pixels constructing an LCD increases. A 32 M pixel-LCD (8 000×4 000) is going to be marketed. A large-scale electro-holography system using three panels of a 32 M pixel-LCD has been developed [3]. In digital holography to 3-D measurement, a large-scale microscope using a scanner has been developed [4, 5].

Such a high number of pixels makes image quality high. On the other hand, it causes the problem that the number of data required for calculation increases. In large-scale calculation, the transfer speed of an auxiliary storage such as an HDD and an SSD is important. The capacity of main memory increases. However, when the quantity of data in calculation exceeds the capacity of the main memory, the computer performs a swap of data to auxiliary storage. Therefore, the computing speed extremely decreases. In addition, even when the quantity of data required for calculation is smaller than the capacity of the main memory, the computer often performs swapping frequently. It depends on how to write the program, the algorithm of computing, the condition of the computer, and so on.

Today, an SSD has rapidly developed. The transmission rate shows around one-tenth speed of the main memory. This is around 10 times faster than an HDD. As for the data capacity, more than a 1 T Byte SSD becomes available in the market, which is almost the same as compared with an HDD.

* E-mail: asugiyama@elsa-jp.co.jp

Therefore, we performed a large-scale digital holographic calculation using an SSD and evaluated the effectiveness of an SSD. In this study, we targeted a digital holographic microscope (DHM). By Ref. [4], we can record an extensive observation area at once by using a scanner. We show the DHM system using a scanner in Fig. 1. As shown in Fig. 2, we obtain observation slices with a different focus length from the recorded hologram data. In this way, we can change the object which we want to observe using different calculations once we have recorded it in a hologram.

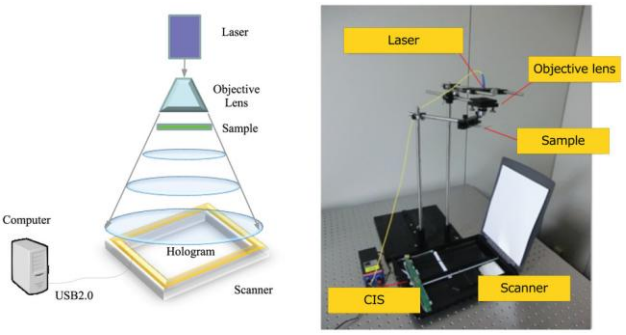

Fig. 1. Large-scale DHM system using a scanner.

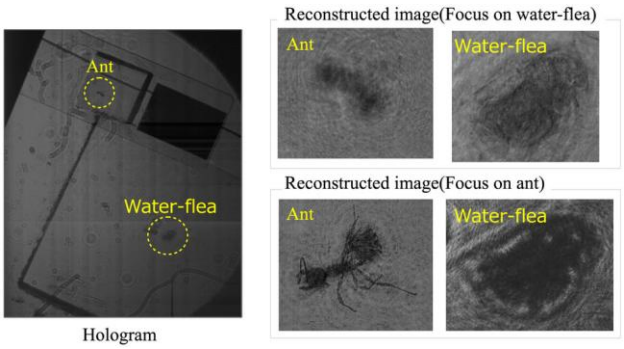

Fig. 2. Recorded hologram and reconstructed images by computer.

However, for a large-scale DHM system, a large-scale calculation processing is necessary. At present, the pixel-pitch of a commercially available high-definition

imaging element is around 5 microns. As for an imaging size (hologram size), it is technically possible to take the domain of 1m×1m. In such a case, the number of pixels becomes 40 billion (200 000×200 000). The calculation complexity is proportional to the number of pixels. Therefore, we have to provide enough memory areas, including virtual memory area, inside auxiliary storage. Otherwise, the calculation fails. Therefore, the role of auxiliary memory (an HDD or an SSD) becomes important.

In this study, we attached an HDD and an SSD to the same personal computer (PC) and calculated a reconstructed image while changing the number of input data (pixels of hologram). Then, we compared both systems. We show the specifications of the PC in Table 1, those of the HDD in Table 2, and those of SSD in Table 3.

Table 1. Specifications of PC as the platform.

CPU		Intel Corei7-4770K
Main memory	DDR3-1333	4GB(2GBx2)
	Transmission speed (peak)	21GB/s
OS		Windows 7 Pro SP1

Table 2. Specifications of HDD.

SEAGATE ST1000NM0033	
Capacity	1TB
Transmission speed (peak)	170MB/s

Table 3. Specifications of SSD.

Huawei Tecal ES3000	
Capacity	1.2TB
Transmission speed (peak)	3.2GB/s

In digital holography, several diffractions are used for calculating light propagation. In this study, we used the angular spectrum method. The program was made by CWO++ library [6]. We show the calculation area and the required corresponding memory capacity in Table 4.

Table 4. Required memory against calculation area (pixels of hologram).

Resolution (pixels)	Required memory（G Byte）
1M (1k×1k)	0.03125
2M (2k×1k)	0.0625
4M (2k×2k)	0.125
8M (4k×2k)	0.25
16M (4k×4k)	0.5
32M (8k×4k)	1
64M (8k×8k)	2
128M (16k×8k)	4
256M (16k×16k)	8
512M (32k×16k)	16
1G (32k×32k)	32

We show the result in Table 5. Each value means the calculation time required to make one sheet of a reconstructed image from the corresponding hologram.

Table 5. Calculation time.

Resolution (pixels)	HDD (sec)	SSD (sec)
1M (1k×1k)	0.522	0.493
2M (2k×1k)	0.738	1.014
4M (2k×2k)	2.408	2.703
8M (4k×2k)	4.991	4.949
16M (4k×4k)	10.628	10.443
32M (8k×4k)	21.116	21.242
64M (8k×8k)	42.805	42.389
128M (16k×8k)	1 750.617	178.740
256M (16k×16k)	8 698.198	539.114
512M (32k×16k)	41 936.208	1 093.841

When the quantity of data is delivered to the main memory, the difference is not seen in both systems, HDD and SSD. In addition, the calculation time is proportional to the quantity of data. When the quantity of data exceeds the capacity of the main memory, the calculation time increases remarkably.

At 128M resolution, the quantity of data is equal to the size of the main memory (4GByte). In Fig. 3, we show the results as the graphs in around 128M resolution. The calculation time is evaluated approximately 350 seconds at 512M resolution if we extrapolate the calculation only in the main memory. The HDD system is 120 times slower then and it takes 12 hours to generate one sheet of a reconstructed image. In contrast, the SSD system takes only 1 094 seconds (18 min). Although the SSD system is 3 times slower than the main memory system, the difference is not large enough to cause the user's stress. In addition, the calculation time using an SSD is also proportional to the quantity of data, which is a desirable feature as a computational resource. On the other hand, the result shows that the required time for the swapping process of an HDD is unstable.

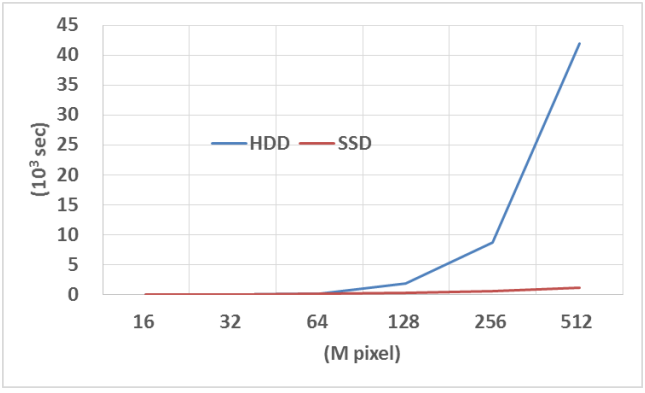

Fig. 3. Calculation time compered between HDD and SSD.

The capacity of the main memory has increased year by year. However, the PC of an end user has a limited main memory, due to the number of slots and so on. On the other hand, the calculation scale that the researchers want to perform in computer holography increases since the high definition of imaging element advances year by year. Therefore, the performance of auxiliary storage becomes important. However, the speed difference between the main memory and the conventional HDD is very large. It is difficult for an HDD to perform large-scale computation in computer holography. On the other hand, an SSD shows good performance and is capable of facilitating large-scale calculation.

In this study, we showed the usefulness of SSD in computer holography. For example, we want to deal with 40 billion pixels in DHM using a scanner. By the conventional HDD system, it takes a year for us to obtain the result, which is not practical. In contrast, by the system of SSD, we can obtain the result only a day. It is considered that a study of computer holography is activated by utilizing SSD.

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