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GPU-Based Acceleration for 3D OCT Imaging

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ABSTRACT

We designed a graphics processing unit (GPU)-based acceleration to reconstruct the optical coherence tomography (OCT) images as sub-micrometer resolution with the spectral domain OCT (SD-OCT) system. GPU-based acceleration is the use of general purpose GPU (GP-GPU) together with a CPU to accelerate the specific operation. As a result, by applying GPU acceleration to the tomographic inspection of biological samples, SD-OCT imaging can be obtained in excess of 40 frames per second (FPS) for the K6000 GPU-accelerated SD-OCT with frame size 4096 (axial) × 512 (lateral), and more than 512x512x500 volumes can be reconstructed with a speed increase of 7x or more (compared to a non-GPU).

KEYWORDS: Graphic Processing Unit, Optical Coherence Tomography, Tomographic Inspection

1. INTRODUCTION

OCT has been employed in industrial applications for wafer thickness and topography metrology [1]. Since the performance of a real-time imaging for OCT is very important for inspection applications that need immediate diagnosis, the high-speed parallel processing has been studied to reconstruct the OCT images and the GPU is an attractive hardware for functional OCT features as well [2]-[5]. Generally, SD-OCT method increases the imaging speeds 50 times faster than time-domain OCT (TD-OCT) [6]. However, the interpolation data on SD-OCT is obtained by convoluting the acquired data and the coefficients in the spectral domain. Thus, a lot of interpolations and convolutions can be performed concurrently and is suitable for GPU-based parallel processing. In this work, we propose a parallel processing technique that uses shared memory based on NVIDIA's GPUs. Finally, we evaluate GPU-based acceleration using 3D spectral data that has 4096×512 frame size showing the performance to be faster than 40 FPS.

2. SD-OCT PROCESSING

The SD-OCT reconstruction steps consist of the following five procedures: removal of DC component, spectrum shaping, spectrum re-sampling and its interpolation, and Fourier transformation. To improve the speed of this reconstruction, the processing can be realized by using GP-GPU with computer unified device architecture (CUDA). Since the shared memory of the GPU is much faster than local and global memory, we utilized the shared memories which are allocated per thread block, so all threads in the block have access to the same shared memory.

3. EXPERIMENTAL RESULTS

To speed up the reconstruction of the spectrum, we utilized the NVIDIA GP-GPUs after acquiring the spectrum data from SD-OCT system. The spectrum size for 1-frame is 4096 (axial)×512 (lateral). The spectrum data are transferred from the CPU memory to the GPU memory to use the GPU acceleration, and GPU kernel code is executed in an NVIDIA K6000, M6000 GPUs ship with 2880, 3072 CUDA cores. The CUDA driver and runtime version is 7.5. The remainder of the execution code runs on the CPU system which consists of an Intel i7-5930K processor. Table 1 shows the reconstruction performances to generate 1-frame slice without and with GPU acceleration.

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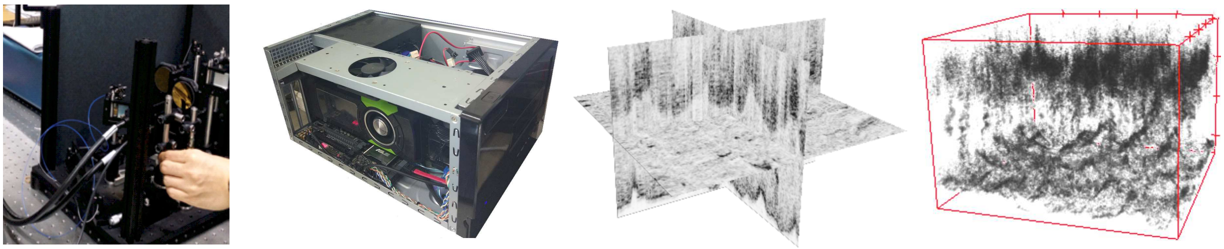
Table 1: Reconstruction performances with and without GPU acceleration

Operation	Without acceleration	With acceleration	
		K6000	M6000
DC removal & spectrum shaping	99.66	22.93 (not optimized)	25.47(not optimized)
Interpolation	11.62	0.17	0.13
FFT	60.84	1.87	1.70

Finally, we reconstructed the 3D volume from 500 slice series. The spectral data of finger tips are acquired as shown in Figure 1(a) and reconstructed in Figure 1(b). Figure 1(c) and 1(d) show the 3D tomographic data which are reconstructed by GPU-based acceleration hardware.



(a) (b) (c) (d)

Figure 1: (a) SD-OCT module, (b) GPU-based acceleration hardware, (c) orthoslice and (d) volume images reconstructed by using the reconstruction system.

3. CONCLUSIONS

We employ the GPU-based approach to further accelerate the running times for volume reconstruction of SD-OCT imaging. Moreover, by using this technique, 3D images obtained from SD-OCT can be reconstructed to be faster than than 40 FPS while processing biological spectrum of 4096×512 frame size. In the near future, we will can efficiently utilize the GPU resources and memory bandwidth to achieve significant speedups.

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