GPU Accelerated Ultrasonic Tomography Using Propagation and Backpropagation Method

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Introduction

Graphic Processing Units (GPUs) are computation-dedicated hardware that can significantly accelerate execution of algorithms for different applications. In 2007, NVIDIA released their Computational Unified Device Architecture (CUDA) programming model, which allows C/C++ users to use the GPU resources in a simpler and friendly manner. This new programming model is being used, nowadays, for a wide range of applications such as medical imaging, online gaming, etc. due to its flexibility and high performance.

Problem Description

Ultrasonic Tomography is widely used for medical imaging applications due to its great features. However, typical tomographic imaging algorithms are very slow due to the amount of computations that are required. Software efficient techniques have been proposed in order to improve the performance. In this poster, we propose a hardware technique that utilizes GPU resources to speed up the reconstruction process.

Reconstruction Model

The process of reconstructing images from ultrasonic information starts with the acoustical wave equation:

$$\frac{\partial^2}{\partial t^2}u(x, t) = c^2(x)\Delta u(x, t) + \sum_{i=1}^{m} s(x, s_i, t)$$

where $u(x, t) \in \Omega \times [0, T]$. And $J_m$ is the number of simultaneous excitation sources. $c(x) = c_0\sqrt{1 + f(x)}$ is the propagation speed of the acoustic wave in the medium, and $\Delta u(x)$ is the acoustic potential function that needs to be reconstructed.

The imaging problem described by (1) can be formulated as an inverse problem:

$$R_j(f) = g_j$$

where $g_j$ is the measurement data collected at the acoustic sensors, and the $R_j$ is the non-linear operator governed by (1). The solution of (2) can be solved using the PBP method which takes the form of

$$f^{k+1}(x) = f^k(x) + R^j(f^k(x))^\dagger[g_j - R_j(f^k(x))]$$

where $k = 0, 1, 2,...$ is the iteration time-step.

GPU Acceleration

For CUDA implementation of the tomographic imaging algorithm, image values at each grid point (i.e., pixels) are calculated in parallel (Fig. 2). Each grid point is processed by a thread. Threads are then organized into blocks by CUDA. Although, it is believed that different kernel configurations impact the acceleration performance, to the best of our knowledge, there is very limited research regarding how block dimensionality affects the performance of CUDA applications, particularly for imaging algorithms. In this work, we conduct experimental tests on GPU of the PBP imaging algorithm and identify its optimal kernel configuration.

Experimental Setup

Our tests consist of finding which kernel configuration works better for our application by testing all the possible options. We modify the kernels of our program (Fig. 3), making sure that the quality of the reconstructed image remains comparable. We measure the execution time of each test. Finally, we examine all the configuration results and analyze how timings change based on these configurations (Table 1).

Results

We benchmark our results using three different platforms. The original PBP algorithm was implemented in MATLAB. Since the CUDA programming model is based on C/C++, we propose to use both C/C++ and CUDA to test the performance improvement. Using these three programming models we test different imaging scenarios that lead to different processing times with comparable image quality. Execution times and performance improvement can be seen in Table 2 and 3, respectively. Final imaging results can be seen in Fig. 4.

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<thead>
<tr>
<th>Platform</th>
<th>Architecture</th>
<th>C/C++</th>
<th>CUDA/C++</th>
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<td>C/C++</td>
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Table 2. Processing times

Table 3. Performance tabulation

Conclusion

We developed a faster hardware implementation algorithm that utilizes GPU resources to accelerate the imaging problem by propagation and backpropagation ultrasonic tomography. The initial algorithm took 6 hours to finish, and we managed to reduce the processing time to 43 seconds, thus achieving improvements of 115x faster than the initial MATLAB implementation, and 80x faster than the C/C++ implementation. Furthermore, we proposed a kernel configuration that maximizes the throughput of the PBP imaging algorithms using CUDA.

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