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GPGPU Based High-speed Visualization Techniques for Sound Wave Propagation
音波伝搬解析のための GPGPU 高速可視化

Naoki Kawada[1†], Kan Okubo[1], Norio Tagawa[1], and Takao Tsuchiya[2] ([1]Grad. School System-Design., Tokyo Metropolitan Univ; [2]Sci and Eng., Doshisha Univ;)
河田 直樹 [1†], 大久保 寛 [1], 田川 憲男 [1], 土屋 隆生 [2]([1] 首都大院 システムデザイン, [2] 同志社大 理工)

1. Introduction

To date, numerical analysis for sound wave propagation in time domain has been investigated widely as a result of computer development. Acoustic simulation in time domain is an effective technique for the estimation of time-series sound pressure data (e.g., nonlinear acoustic propagation phenomenon, acoustical measurements and instrumentation, acoustical imaging). For time domain acoustic simulation, the development of the visualization method is an important technical issue.

Recently, GPU (Graphic Processing Unit) is used as an acceleration tool for the calculation in various study fields. This movement is called GPGPU (General Purpose computing on GPUs) [1, 2]. In the last few years the performance of GPU keeps on improving rapidly. That is, a PC (personal computer) with GPUs might be a personal supercomputer. GPU computing gives us the high-performance computing environment at a lower cost than before. Therefore, the use of GPUs contributes to a significant reduction of the calculation time in large-scale sound wave propagation. Moreover, use of GPU has an advantage of visualization of calculated fields, since GPU is originally architecture for graphics processing.

The purpose of this study is the development of sound field analysis method using the interactive simulation. We examined an interactive simulation using GPU parallel calculation and PMCC (Permeable Multi Cross-section Contours) as a visualization technique.

2. Time-Domain Acoustic Simulation Using GPU

2.1. FDTD method

The purpose of this study is interactive simulation based on high-speed visualization. Therefore, we employ the Finite-Difference Time-Domain (FDTD) method[2] with less computational cost. FDTD method directly solves the governing equation using the finite deference with the staggered grid. Update of the values on each grid has no dependence. That is, the value of the field can be calculated independently each other: FDTD method is suitable for parallelization on the GPU.

2.2. GPU Programming with CUDA and GPGPU-Visualization with OpenGL

Recently, NVIDIA developed CUDA (Compute Unified Device Architecture). CUDA is a programming language for GPGPU, which is an extension of the C language. Thus, programming for GPU became relatively easier than before by means of just the knowledge of the C language.

We describe a method of conventional visualization using the CPU. First, the calculation result is converted to the drawing information. Then, it is transferred to video memory (VRAM) for drawing on the video card. In this process by CPU computation, calculation result is once stored and needs to be transferred to the VRAM from main memory (RAM). The transfer by the PCI bus is required; therefore, this process might be a bottleneck for visualization of calculated results.

On the other hand, in implementation on a GPU computing by CUDA, the data of OpenGL can be associated. In addition, the calculated data is stored in the VRAM. Therefore, it is possible to write drawing information to the VRAM on the video card without the transfer of the PCI bus. This is a large advantage for high-speed visualization.

3. 3D Acoustic Simulation and Visualization method

Recently, as a visualization technique so-called volume rendering using opacity has been proposed. The feature of this method is that it uses all information of three-dimensional sound field. Therefore, it can displayed three-dimensional space at one time. However, this method has to handle all

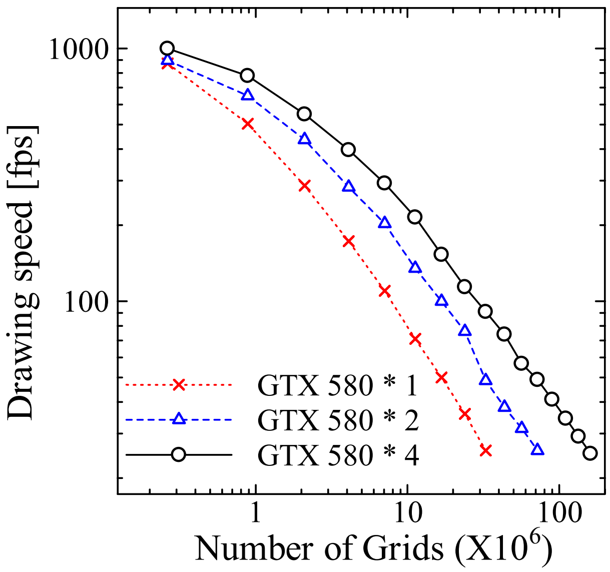

Fig. 1 Rendering speed against the number of grid

information in each voxel of a three-dimensional sound field. This gives a disadvantage for the drawing speed by use of a lot of computational load process. Consequently, drawing speed is reduced compared to other conventional methods.

We have proposed PMCC (Permeable Multi Cross-section Contours) [4] as a visualization method for three-dimensional sound field. PMCC is a method that can set the opacity in the multi cross-section contours. Number and angle of the cross-section can be set arbitrarily; there is flexibility in the computational visualization.

4. High-speed Visualization and Interactive Simulation

We examine high-speed visualization and interactive simulation that combines OpenGL and CUDA. In this study, we use the GeForce GTX 580.

Figure 1 shows the results of drawing speed against number of grids. By using GTX 580 quad GPU, we can visualize at 25fps in 512^3 grids.

The high-speed visualization using the GPU makes the following possible:

1. To change the analysis parameters in computation and visualization.
2. To dynamically change the analysis point
3. To change the input signal

In this way, the interactive simulation is possible using the GPU calculation and visualization.

Figs. 2 and 3 show examples of the interactive simulation. A plot window has a main frame that displays three-dimensional space using

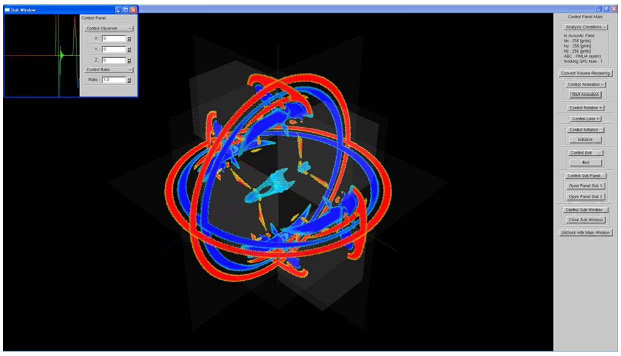

Fig. 2 Example of visualization for acoustic simulation (case 1)

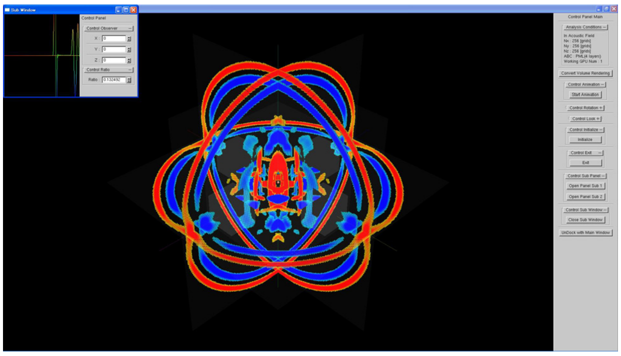

Fig. 3 Example of visualization for acoustic simulation (case 2)

the PMCC. And, there are sub-frames to display the sound field intensity in a time series for a certain analysis point. The main window can be freely selected calculated the sound pressure or particle velocity of the sound field. In the sub-frame, dynamic analysis is possible because it can move the analysis point in calculating.

5. Conclusions

In this study, we examine the feasibility for interactive simulation of three-dimensional sound field numerical analysis. As a visualization method of three-dimensional sound field, the PMCC were evaluated. By use of sub-frames, analysis points are treated interactively; GPGPU interactive simulation can be a new important technique of sound field simulation.

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