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Short note

GPU accelerated non-illuminated graphical electromagnetic computing method with high accuracy☆

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ABSTRACT

In this paper, a novel non-illuminated Graphical Electromagnetic Computing Method (NI-GRECO) based on GPU acceleration has been proposed. It has the advantages of high accuracy and efficiency compared to the traditional GRECO method, and does not suffer from the limitation in the illumination model anymore. In this NI-GRECO we also proposed a pixel subdivision technique, which can improve the display accuracy of the target model and then increase computing accuracy. In case of the data output, the method of data extraction by using the Frame Buffer Object (FBO) can also improve computing accuracy. In this way, the data output is no longer subject to color restriction. The extraction accuracy of the normal vector increased from 1/256 to 1/1000000. Additionally, the novel method has a significant speedup, which is up to 36 times than the original GRECO method for a sphere RCS simulation thanks to the parallel GPU processing.

1. Introduction

Traditional GRECO method is an electromagnetic scattering calculation method based on physical optics (PO) and computer graphics [1]. Compared to full wave algorithms such as MOM and FDTD, this method has many advantages, such as low memory consumption during simulation, fast calculation speed due to hardware shielding process, free of additional discretization of the target model, and so on. However, this method suffers some limitations which in all respects cut down the simulation accuracy. First of all, target model is discretized by pixels in a simulation and should be fully displayed on computer screen accordingly. So the screen resolution is a limitation. Proper scale of an electrically large target to be fully displayed on computer screen often leads to too large pixel width compare to the wavelength, which indicates that the minutiae part of the target will not be resolved properly. Secondly, normal vector extraction from the illumination model is cumbersome and in low accuracy due to the limited number of bits for color buffers. The required depth information in the simulation extracted from the depth buffer suffers the same limitation as well.

Nowadays, advanced GPU unit is adopted in many computer systems. Due to its inherent parallel property, GPU is widely used to boost scientific simulations. Acceleware, a tech company, has made an electromagnetic field simulation of a cell phone antenna. In this simulation, calculations using a dual-core 3.2 GHz CPU may require 15 h compare to 15 min when using a GPU [2]. Jian Guan et al. proposed that the OpenMP-CUDA- MLFMA method can achieve more than 20 total speedup ratios

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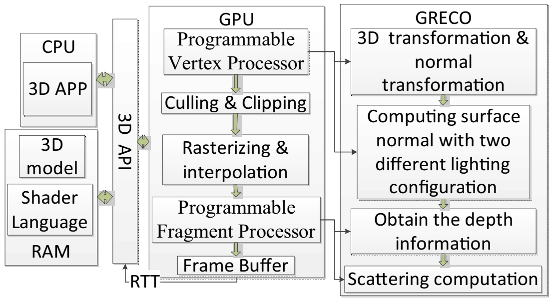

Fig. 1. GPU-CPU cooperative computing architecture associated with GRECO.

compared to the 8-threaded CPU-based MLFMA in another paper. Yong Zhang et al. proposed a OpenMP-CUDA Accelerated Moment Method (MoM) for the electromagnetic scattering by 3-D arbitrarily shaped homogeneous dielectric objects [3–5].

Although a large number of GPU acceleration in the field of full wave algorithms could be found in literatures, there are few literatures on high frequency method with GPU acceleration. For full wave algorithms and even for high frequency method reported in limited literatures, GPU was used to achieve parallel computing for a speedup [6,7]. However, when we accelerate GRECO with GPU, some other attractive improvements for accuracy is revealed besides parallel speedup.

In this work several optimization for the traditional GRECO has been done with GPU acceleration. We use parallel matrix transformation in GPU instead of the illumination model in the traditional GRECO to get normal vector at the integration point on the surface of the model under simulation, thus an innovative non-illuminated GRECO is achieved. The new non-illuminated GRECO further simplifies the algorithm and also greatly enhances the computing accuracy and speed. Compare to the traditional GRECO, the extraction accuracy of the normal vector increased from 1/256 to 1/1000000. Combining off-screen rendering function provided in GPU, we develop a novel Pixel Subdivision Technique for the non-illuminated GRECO method, which relaxes the screen resolution limitation and further improves the accuracy through fine discretization of the model. RCS of a sphere is calculated with the modified GRECO with GPU acceleration, a 36.4 times speedup is achieved and the accuracy improvement is demonstrated.

2. Methodology

Conventional GRECO requires rendering a three-dimensional model of the target at first, in which fast hardware shielding is performed to ensure efficient simulation. Information, including depth and RGB color of each pixel, is then read from the frame buffer. After properly designed lighting procedure, the extracted color information of each pixel can be used to calculate its normal vector. The scattering field of each pixel can be calculated at last by using physical optics.

In this paper we will modify each crucial step of the traditional GRECO methods. Firstly, when rendering the target model with GPU functions, it is possible for us to obtain the necessary information of each pixel for electromagnetic scattering computing, including the coordinate information, the depth information, as well as the normal vector. As a result, we do not need to re-calculate the pixel normal vector with the redundant twice lighting procedures, which we have to do in the traditional GRECO due to the fact that the calculated normal vector of each pixel for illuminating is discarded immediately after the lighting procedure finish in the OpenGL implementation. It is inevitable to introduce error to the extracted normal vector with the illuminating RGB colors. Fortunately, in GPU implementation, the exact normal vector of each pixel is calculated and saved, thus can be read efficiently for further use. Considering the GPU's programmable features and powerful parallel computing capabilities, the computing of scattered field for each pixel will also be placed on GPU shaders, so we don't need any longer to transfer the depth information and the normal vector from GPU memory to CPU memory, thus reducing the overhead of data exchange. Finally, we only need to collect the scattering field of each pixel that is already calculated from the GPU shaders to form the total scattering field.

2.1. Non-illuminated GRECO parallel computing model

Fig. 1 shows a modern GPU-CPU cooperative computing architecture, in which the handing of vertices and fragment can be programmed, as shown in the programmable vertex processor and programmable fragment processor module below.

Combining GRECO methods and programming language in GLSL of OpenGL, we use parallel matrix transformation in vertex shader processor instead of the illumination model in the traditional GRECO to get normal vector at the integration point on the surface of the model under simulation. Then the normal vector and position information are rasterized and discretized to the fragment shaders. Now, using the graphical electromagnetic scattering formula directly in the fragment shader with GLSL language, we can get the scattering component of each discrete unit, thus an innovative non-illuminated GRECO is achieved.