A GPU Accelerated Microwave Tomography System for Breast Cancer Screening

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Abstract

This paper presents a novel parallelization strategy to accelerate microwave tomography for reconstruction of the dielectric properties of the human breast. The gain in computational throughput is found to be in the range of 26 to 58, on different imaging grid sizes.

1. Introduction

Microwave Tomography (MT) has demonstrated excellent ability to reconstruct dielectric profiles of breast tissues; however, it comes with a much higher computational cost. This paper presents a novel parallelization strategy to accelerate a Time-Domain Inverse Scattering (TDIS) algorithm for reconstruction of the dielectric properties of human breast. The inversion algorithm is based on the nonlinear conjugate gradient method [1] and is targeted for execution on a massively parallel GPU architecture.

2. Reconstruction Method and Parallel Execution Model

In the TDIS algorithm, an iterative optimization technique is used to minimize the following least square problem:

$$F(\epsilon_r,\sigma) = \int_0^T \sum_{m=1}^{M} \sum_{r=1}^{R} W(t) |E_{m,r}^{meas}(t) - E_{m,r}^{calc}(\epsilon_r,\sigma,t)|^2 dt$$

where $E_{m,r}^{meas}(t)$ is the measured electromagnetic (EM) signal at receiving position *r* corresponding to a transmitted signal from antenna m. The signal $E_{m,r}^{calc}(\epsilon_r,\sigma,t)$ is the forward EM scattering solution computed on a numerical model of the breast with estimated relative permittivity (ϵ_r) and conductivity (σ) values.

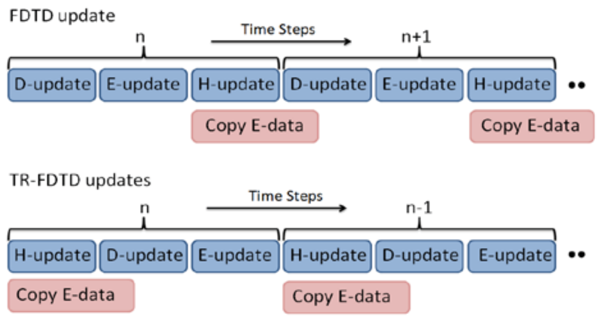

Figure 1. FDTD and (Time Reversed)TR-FDTD updates with overlapped data transfer.

The TDIS algorithm requires the computation of forward and adjoint EM scattering solution (proposed update scheme for finite difference time domain solver is shown in Fig. 1), Fréchet derivative of the cost functional (proposed computation scheme shown in Fig. 2), conjugate directions, and the PR constant at each iteration. The details on the TDIS method can be found in [1].

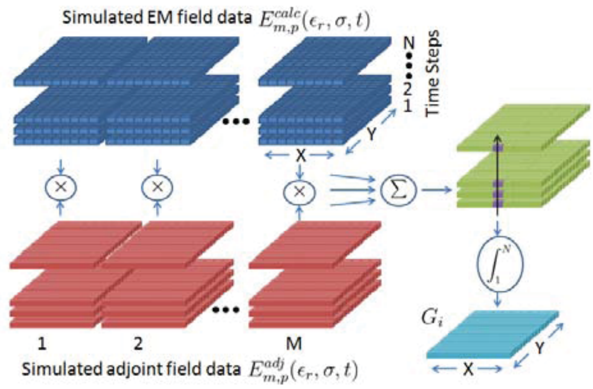

Figure 2.Computation of the gradients of dielectric parameters; M is number of transmitting antennas and N is number of time steps in the FDTD simulation.

3. Results

The algorithm was implemented and verified on an NVIDIA graphics card and compared with an optimized sequential implementation on a desktop CPU. Table 1 presents a comparison of the computational time for both the standard and the proposed parallel execution model against different grid sizes. The gain in computational throughput is found to be in the range of 26 to 58, on different imaging grid sizes.

TABLE I
EXECUTION TIME IN SECONDS FOR STANDARD METHOD AND PROPOSED PARALLEL METHOD

Grid Size	Standard Method (Sec)	Parallel Method (Sec)	Gain
50×50	113.5	30.80	3.68
100×100	426	32.07	13.28
150×150	970	36.27	26.74
200×200	1811	44.84	40.39
250×250	3140	53.53	58.66

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References

[1] T. Takenaka, T. Moriyama, K. A. H. Ping and T. Yamasaki, "Microwave breast imaging by the filtered forward-backward time-stepping method," in *URSI International Symposium on Electromagnetic Theory (EMTS)*, Berlin, 2010.