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3D Microwave Time Domain Inversion Technique for Breast Cancer Detection

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Electrical Engineering – Electrophysics

Introduction

Detection of breast tumors at their early stage, when they are smaller than 5mm in diameters, will help the early treatment of the tumor and significantly increase the survival rate of the patients. Using microwave imaging modality for breast cancer detection has been proved feasible and has several advantages:

- Sufficient permittivity contrast between benign breast tissue and tumors
- Non-ionizing frequency range, safer imaging process
- Sufficient resolution to distinguish benign tissue and tumor
- Relatively lower cost compared to MRI

Breast Cancer Imaging Modalities Comparison

Modality	Microwave	MRI	X-ray	Ultrasound
Comparison	•Sufficient resolution •Low cost •Low radiation	•Good resolution •High cost •High false-positive rate	•Good resolution •High radiation •High false-positive rate	•Insufficient resolution •Low cost •Artifacts & ambiguities

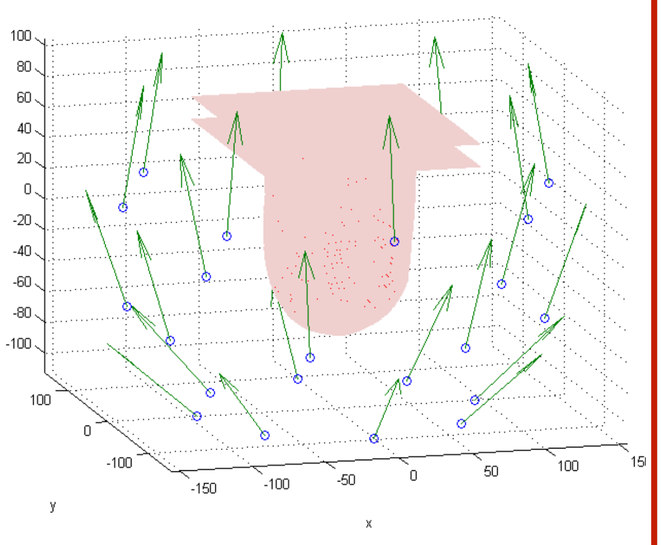
Formulation and Features

Formulation:

- Microwave frequency range 0.5~3.7GHz. Use 25 discrete frequency points
- 24 transmitters placed around the breast phantom in three horizontal rings
- Object domain size 150x150x150mm^3 with the voxel size of 2mm

Features:

- Time-domain data
- Super-resolution
- Include conductivity and dispersion
- Low permittivity contrast ratio
- GPU acceleration



Nonlinear Inversion Algorithm

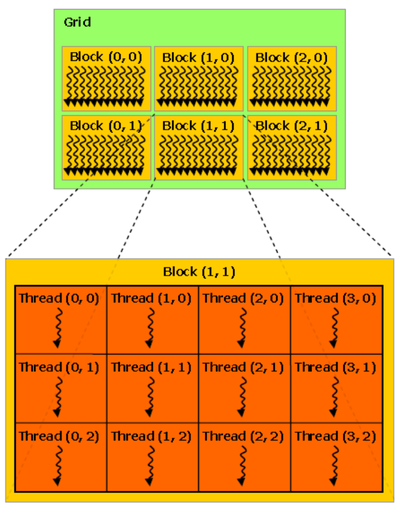
- Based on 3D Born iterative method
- Forward problem solver: Auxiliary Differential Equation Finite Difference Time Domain method (ADE FDTD)
- Inversion: conjugate gradient method with Tikhonov Regularization

1. Without the object , use FDTD to compute the incident field
2. With the object, use FDTD to simulate the measured field
3. Start iteration with Born approximation. Compute the scattered field
4. Solve the inverse problem with CGS and Tikhonov regularization method
5. Update the object function. Compute the new scattered field
6. Compare the new scattered field with measured field. If error is acceptable, stop. Other wise go to step 3

GPU Acceleration

Both the forward problem solver and the inversion are paralleled and optimized by the Nvidia GPU

- Hardware: Nvidia Tesla C2075 GPU with 448 cores in 16 stream multi-processor
- Software: Computer Unified Device Architecture (CUDA)
- Forward Solver ADE FDTD is accelerated by a factor of 25 for problem size 150x150x150
- Conjugate gradient inversion is accelerated by a factor of 5



Sample GPU FDTD code:

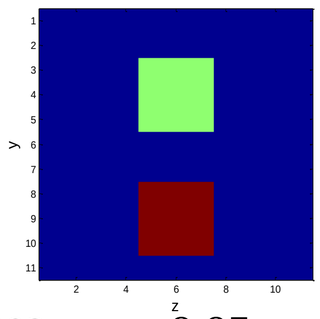
$$\text{int } fid = threadIdx.x + blockIdx.x \times numofthreads;$$

$$Ex[fid] = ca[fid] \times Ex[fid] + cb[fid] \times$$

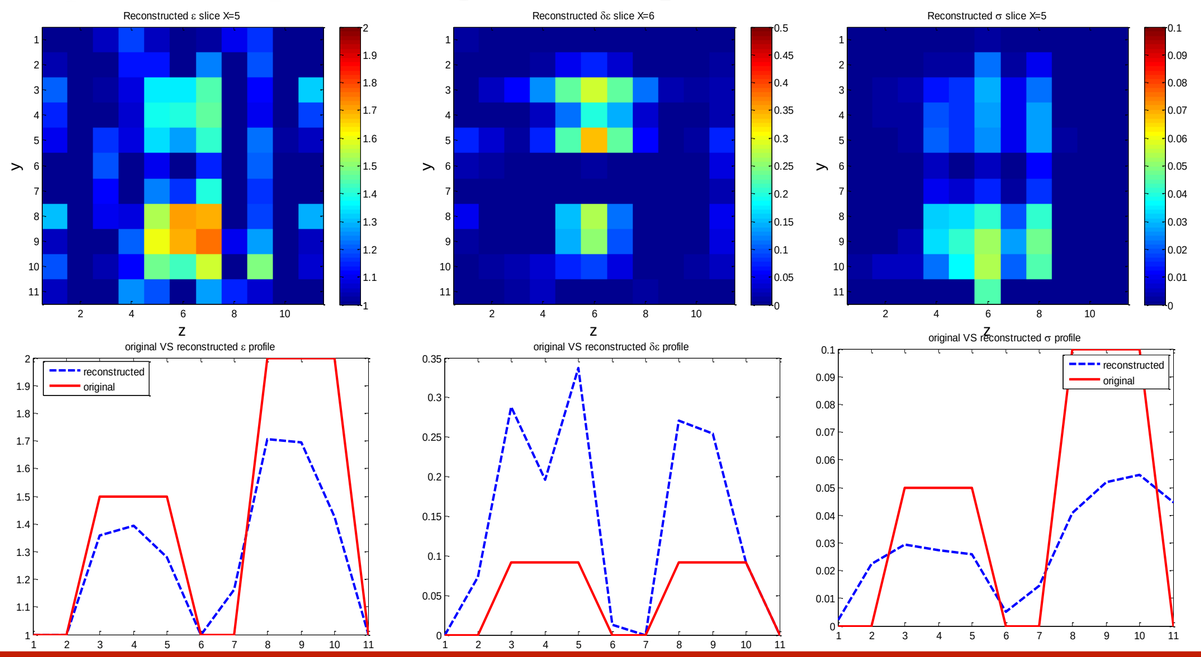
$$(-hy[fid] + hy[fid - IJ] + hz[fid] - hz[fid - I]);$$

Preliminary Imaging Results

- Two cubes shown in the right figure, each with the size of 18x18x18mm^3
- Two cubes are located 12mm away



$\varepsilon_{\infty 1} = 1.5 \quad \varepsilon_{\infty 2} = 2 \quad \Delta\varepsilon_1 = 0.092 \; \Delta\varepsilon_2 = 0.092 \quad \sigma_1 = 0.05 \; \sigma_2 = 0.1$



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