Dissertation Defense

Iterative Polyenergetic Digital Tomosynthesis Reconstructions for Breast Cancer Screening

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Abstract: In digital tomosynthesis imaging, multiple projections of an object are obtained along a small range of incident angles in order to reconstruct a pseudo 3D representation of the object. This technique is of relevant interest in breast cancer screening since it eliminates the problem of tissue superposition that reduces clinical performance in standard mammography. The challenge of this technique is that it is computationally and memory intensive, as it deals with millions of input pixels in order to produce a reconstruction composed of billions of voxels. Standard approaches to solve this large-scale inverse problem have relied on simplifying the physics of the image acquisition model by considering the x-ray beam to be monoenergetic, thus decreasing the number of degrees of freedom and the computational complexity of the solution. However, this approach has been shown to introduce beam hardening artifacts to the reconstructed volume. Beam hardening occurs when there is preferential absorption of low-energy photons from the x-ray by the object, thus changing the average energy of the x-ray beam.

This thesis presents an interdisciplinary collaboration to overcome the mathematical, computational, and physical constraints of standard reconstruction methods in digital tomosynthesis imaging. We begin by developing an accurate polyenergetic mathematical model for the image acquisition process and propose a stable numerical framework to iteratively solve the nonlinear inverse problem arising from this model. We provide an efficient and fast implementation of the volume reconstruction process that exploits the parallelism available on the GPU architecture. Under our framework, a full size clinical data set can be reconstructed in under five minutes. The implementation presented reduces storage and communication costs by implicitly storing operators and increasing kernel functionality. We show that our reconstructed volume has no beam hardening artifacts and has better image quality than standard reconstruction methods. Our reconstructions also provide a quantitative measure for each voxel of the volume, allowing the physician to see and measure the contrast between materials present inside the breast. The research presented in this thesis shows that large-scale medical imaging reconstructions can be done using physically accurate models by effectively harnessing the multi-threading power of GPUs.

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