Rapid Acquisition Tomosynthesis System for 3D Mammography

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Abstract

Three-dimensional imaging of the breast promises significantly improved performance compared to standard mammography by reducing structured noise in mammograms caused by superposition of tissue. This work describes a new GE mammography tomosynthesis prototype that enables rapid acquisition of a sequence of low dose x-ray images of the breast at appropriate projection angles. Enabled by advanced tube and detector technology, the system acquires 21 projection images over a 60 degree angular range in approximately 8 seconds, and creates a 3D volumetric image from the projections. Initial images acquired with the system and characterization of the depth resolution of the system are presented.

Introduction

A new mammography tomosynthesis prototype system has been developed for 3-dimensional imaging of the breast. Tomosynthesis is a novel method that creates 3-dimensional images of an object by acquiring multiple, low dose x-ray projection images at various orientations and combining them using an image reconstruction algorithm. The method overcomes the most significant limitation of standard x-ray imaging by essentially eliminating the masking effects of anatomical structures above and below any finding of interest and allowing more accurate characterization of breast tissue.

In the last several years, the major trend in x-ray imaging has been the replacement of film-based imaging systems with digital systems. Large scale clinical studies are beginning to demonstrate the advantages of digital compared to film, and the utilization of a digital detector in the system also enables future advanced applications with an even greater potential to revolutionize healthcare. These applications typically rely on multiple, low-dose x-ray images, which is effectively impractical with film-based systems, where handling problems and film development issues make combination of multiple images awkward and difficult, and non-quantitative at best. Tomosynthesis is perhaps the most promising of these multiple image based advanced applications, because of the 3-dimensional nature of the images acquired with such a system.

The objective of this project is to design, construct, validate, and deliver prototype systems to two clinical sites, the University of Michigan Cancer and Geriatrics Center in Ann Arbor and the Via Christi Regional Medical Center in Wichita, Kansas. In addition to tomosynthesis, the system for U Michigan will provide the ability to acquire co-registered ultrasonic images of the breast for the world's first image fusion of 3-dimensional x-ray and ultrasound images.

System Development

Key subsystems include the x-ray tube and generator, the positioner, the detector, system control, reconstruction, and display. The tube and generator from the Senographe DS digital mammography system (GE Healthcare, Waukesha, WI) have been modified to provide 50% higher current on the Rh target. This allows shorter x-ray exposure times and minimizes the possibility of patient motion during the tomosynthesis exam. Heat dissipation associated with the higher current is removed by rotating the anode at higher speed (12,000 rpm vs. 9000 rpm).

The detector is a high performance, next generation a-Si/CsI flat panel design that achieves significant improvement in DQE at typical tomosynthesis dose levels (10 to 20 times lower dose per projection than standard mammography dose), based on enhancements to the CsI scintillator and the addition of a storage capacitor to each pixel [1]. The detector consists of a matrix of 1920 x 2304 detector elements, each 100µm in pitch. Detector operational parameters have been adjusted for the acquisition of low dose tomosynthesis projection images. Total tomosynthesis scan dose was selected to be between 150% and 200% of the dose of a standard Medio Lateral Oblique (MLO) mammographic view.

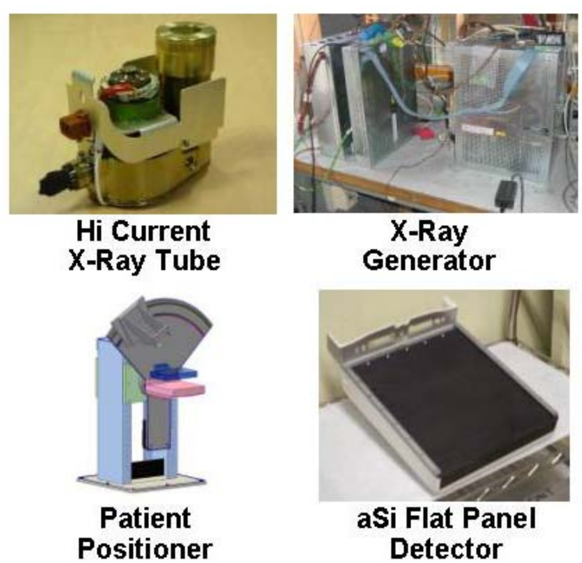

***Figure 1**. Photograph of the key components of the system. A) x-ray tube, B) generator, c) patient positioner, d) aSi flat panel digital x-ray detector.*

A specialized patient positioner was designed to provide a more flexible acquisition geometry with provision for dual modality imaging. During the tomosynthesis acquisition, the tube traverses an arc above the patient, with the point of rotation at the level of the breast support, as the compressed breast remains stationary above the non-rotating detector surface. The system acquires 21 projection images over a full angular range of 60 degrees in under 8 sec in order to minimize patient motion during the exam. The prototype system installed at the University of Michigan is shown in Figure 2.

***Figure 2**. Photograph of the prototype tomosynthesis system installed at the University of Michigan Cancer and Geriatric Center.*

Larger angular range enables enhanced depth resolution and more projections reduce the level of streak artifacts in the images. Typical results with a wire phantom are shown in Figure 3.

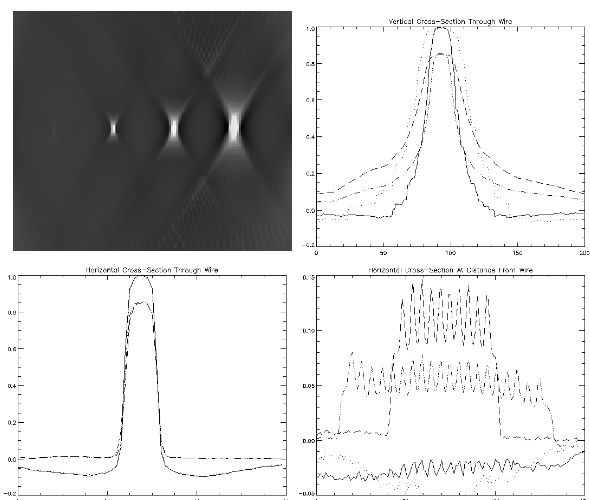

Figure 3. a) Top-left: Vertical cross-section image through a 3D reconstructed volume of a phantom containing wires of different diameter. b) Top-right: vertical cross-section through wire. c) Bottom-left: horizontal cross-section through wire. d) Bottom-right: horizontal cross-section at some distance from wire. The graphs illustrate profiles through the image, for different image acquisition scenarios and reconstruction algorithms (Solid: GFBP, 21 views, 60 degrees. Dotted: GFBP, 11 views, 30 degrees. Dash-dotted: Simple Backprojection, 21 views, 60 degrees. Dashed: Simple Backprojection 11 views, 30 degrees.)

Images acquired with the system are typically reconstructed with the Generalized Filtered Back Projection (GFBP) reconstruction algorithm [2]. Figure 3a shows a vertical slice through a reconstructed wire phantom. Figure 3b illustrates improved depth resolution with larger scanning angular range (60 degrees vs. 30 degrees), Figure 3c shows the excellent in-plane resolution of the system, and Figure 3d shows the decreasing impact of artifacts for acquisitions with more views (21 vs. 11 views) and the artifact management capabilities of generalized filtered backprojection as compared to simple backprojection (BP) [3].

Clinical Results

The system has been used to acquire images of 7 patients to date (January, 2006). A comparison of conventional mammography to a tomographic slice is shown in Figure 4. Note the soft tissue detail visible in the tomo slice and the enhanced visibility of the lateral vein in the tomographic slice, compared to the mammogram where only the thickest, central part is seen. The blood vessel present in the first tomographic slice has disappeared in the adjacent slice, 3 mm away.

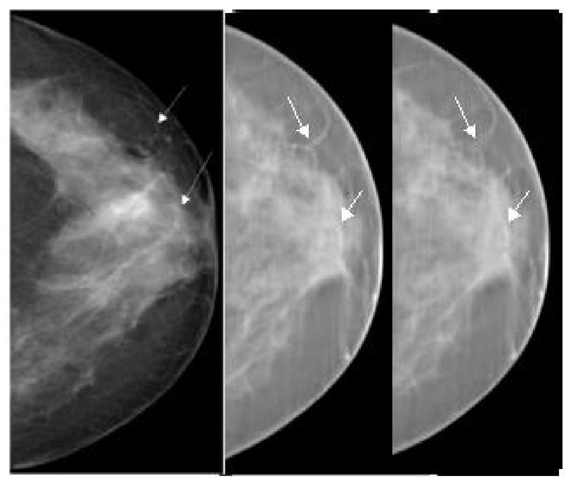

***Figure 4**. Comparison of conventional digital mammogram with tomographic slices. A. Mammogram in Cranio Caudal (CC) view. B. Tomographic slice at 25 mm deep. C. Tomographic slice at 28 mm deep. Note the disappearance of much of the 3.8 mm diameter vessel (upper arrow) in this tomographic slice (C), separated by 3 mm from (B). Note also the changing soft tissue detail throughout the two slices.*

Summary

A dual modality, x-ray tomosynthesis/ultrasound imaging prototype system has been designed, built, and tested, and characterized. Initial patient images have been acquired at the University of Michigan Cancer and Geriatric Center in Ann Arbor. A second prototype is ready for installation at Via Christi Regional Medical Center in Wichita, Kansas.

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Author Biography

Dr. Eberhard joined the staff of GE Global Research in 1977. He has conducted research in the area of imaging systems for over 20 years. He has written or co-authored over 50 technical papers and articles in his various fields of work and holds 26 U.S. patents. He received the Sylvia Sorkin Greenfield Award for Best Paper in Medical Physics in 2003 for “Tomographic mammography using a limited number of low-dose cone-beam projection images”. He served as a technical consultant to the Committee on Commercial Aviation Security of the FAA from 1991 to 1993.