Development of an Analytic Breast Phantom for Quantitative Comparison of Reconstruction Algorithms for Digital Breast Tomosynthesis

I. Reiser, E.Y. Sidky, R.M. Nishikawa, and X. Pan

Department of Radiology, The University of Chicago,
Chicago, IL 60637, USA

Abstract. We are developing an analytic breast phantom that allows for quantitative comparison of reconstruction algorithms for digital breast tomosynthesis. The phantom consists of simple shapes and aims at capturing the main features of the breast. Projection data can be computed analytically. We present volumes reconstructed from the phantom data using the filtered backprojection, expectation maximization and total variation algorithms. Our results indicate that the TV algorithm achieves highest contrast for mass lesions and best in-depth resolution.

1 Introduction

Digital Breast Tomosynthesis (DBT) is an emerging modality for breast imaging [1, 2]. Currently, several manufacturers have produced prototype units [1, 3, 4] using different imaging geometries and reconstruction algorithms, such as filtered back projection (FBP) [4, 3], iterative transmission expectation maximization (TEM) [1, 5], and matrix inversion tomography [6].

Researchers and manufacturers have presented clinical images produced by their systems, allowing only for qualitative image comparison. However, no quantitative comparison of imaging systems or reconstruction algorithms exist. Wu and coworkers [2] have compared image-quality parameters in volume images of the ACR phantom, reconstructed with the TEM, FBP and simple backprojection algorithms. The purpose of this current work is to develop a breast phantom that is composed of simple shapes, to allow researchers to easily compute analytic projection data for quantitative algorithm evaluation. A similar phantom, the well-known Shepp-Logan phantom, has been used in CT reconstruction work as a standard phantom simulating the human head.

While the Shepp-Logan phantom does not reflect every detail of a human head, it captures prominent features that can cause reconstruction artifacts, such as the highly attenuating scull. Projection data for such simple phantoms can be computed analytically, eliminating quantization errors.

The breast phantom that we are presenting in this work represents the breast as a truncated ellipsoid. It includes representations of a pectoralis muscle and fibroglandular tissue regions. In the current implementation, mass lesions are

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also included in different tissue backgrounds. If necessary, other structures, such as microcalcifications, can also readily be incorporated into the phantom. We have used existing FBP and expectation-maximisation (EM) algorithms and a new total variation (TV) algorithm to reconstruct the breast volume from a sequence of projection data generated from this new breast phantom. Imaging geometry is similar to that of the first GE prototype unit [1].

2 Methods

The breast phantom, as shown in Fig. 1, is composed of several components. Each component is either an ellipsoidal object, or a volume bound by intersecting surfaces. Surfaces can be either planar, ellipsoidal, cylindrical, or conical. This set of surfaces allows one to construct a large number of shapes while enabling analytic computation of the path integrals. In our phantom, the overall shape of the breast was a truncated ellipsoid. The pectoralis muscle was represented by a rectangular slab. The ensemble of ductal structures was represented by a crescent shaped object, created from two intersecting ellipsoids. Three mass lesions were included in the breast phantom, located within the fatty tissue, embedded in dense fibroglandular tissue, and one mass lesion within the fatty tissue but with overlaying dense tissue.

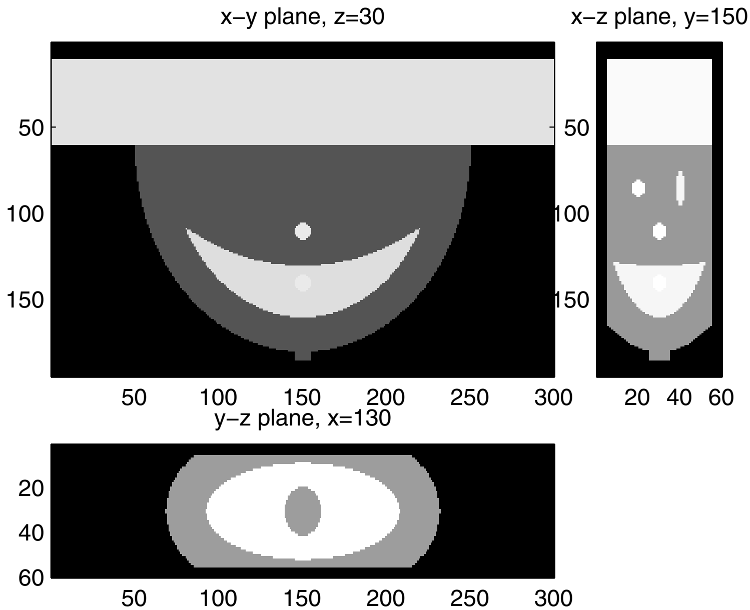

Fig. 1. Slices through the breast phantom along the three spatial directions. The difference in attenuation coefficient between the crescent-shaped fibroglandular tissue and the mass within that dense tissue is only 0.015 cm^{-1}. Axis units are mm.