

## Chapter 3

# Computer–Aided Detection and Diagnosis for 3D X–Ray Based Breast Imaging

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### ABSTRACT

*The last 15 years has seen the advent of a variety of powerful 3D x-ray based breast imaging modalities such as digital breast tomosynthesis, digital breast computed tomography, and stereo mammography. These modalities promise to herald a new and exciting future for early detection and diagnosis of breast cancer. In this chapter, the authors review some of the recent developments in 3D x-ray based breast imaging. They also review some of the initial work in the area of computer-aided detection and diagnosis for 3D x-ray based breast imaging. The chapter concludes by discussing future research directions in 3D computer-aided detection.*

### INTRODUCTION

One of the major developments in radiology over the last 15 years has been the advent of new 3D x-ray based breast imaging modalities such as digital breast tomosynthesis (Niklason, et al., 1997), digital breast CT (Boone, et al., 2006; Boone, Nelson, Lindfors, & Seibert, 2001), and stereo mammography (Getty, 2003, 2004; Getty,

D’Orsi, & Pickett, 2008). These developments are significant as they promise to alleviate the effects of a key limitation of mammography - anatomical noise caused by overlapping out of plane tissue structures on mammographic projections of the breast. Anatomical noise often hinders accurate detection and diagnosis of breast lesions in mammography. The problem posed by anatomical noise is exacerbated in mammograms of women with

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dense breasts. Anatomical noise can also mislead radiologists into believing that suspicious findings are present on a mammogram when in reality there are none. Such false positive diagnoses often result in additional imaging tests and biopsy procedures that not only inflate the monetary costs of a screening program, but are also stressful for the women undergoing these procedures. Unfortunately, the positive predictive value of mammography for routine screening of asymptomatic women is quite low (10-30%) (Karssemeijer, et al., 2009; Skaane, 2009; Vinnicombe, et al., 2009).

Computer-aided detection (CAD) systems have been developed to assist radiologists in interpreting mammograms (e.g., (Nishikawa, Giger, Doi, Vyborny, & Schmidt, 1993; Yin, et al., 1991). Commercial CAD systems for mammography have been in use for more than a decade now and recent clinical work (Gilbert, et al., 2008; Gromet, 2008; Skaane, Kshirsagar, Stapleton, Young, & Castellino, 2007), as well as a long history of encouraging laboratory studies demonstrate the high potential of these systems in assisting radiologists to detect early cancer. However, both computer systems and radiologists are constrained by the fact that mammography is a 2D imaging modality. Both human and computer vision are hindered by anatomical noise, which impacts the detection and diagnosis of breast lesions on mammography. This limitation of mammography has spurred the radiology community to develop alternate and adjuvant 3D x-ray based breast imaging modalities for early detection of breast cancer.

In this chapter, we review some of the recent developments in 3D x-ray based breast imaging. We also provide a review of the current strategies adopted in the development of CAD systems for the new breast imaging modalities. We discuss the limitations of the current strategies adopted for the development of CAD systems for 3D x-ray based breast imaging and provide suggestions for future research on the development of these systems.

## **RECENT ADVANCES IN 3D X-RAY BASED BREAST IMAGING**

### **Digital Breast Tomosynthesis**

Tomosynthesis is an old imaging technique that has gained in popularity after the advent of flat panel digital detectors with rapid read out rates (Dobbins & Godfrey, 2003). The breakthrough paper by Niklason *et al.* in 1997 demonstrated the feasibility of modifying existing digital mammography systems to acquire tomosynthesis images of the breast (Niklason, et al., 1997). Under the typical breast tomosynthesis acquisition geometry, the breast is mildly compressed and 15-30 x-ray projections are acquired over a limited scan angle (15-50 degrees) using a dose that does not exceed the dose of a traditional two-view mammographic procedure. As a result, each projection in a tomosynthesis procedure is acquired at a lower dose, and hence is consequently more noisy than a traditional two-view mammogram. Once the projection images are acquired, it is possible to computationally reconstruct multiple slices and the resulting volumetric image provides 3D visual information of the structures within the breast. However, due to limited angular sampling, the resolution between slices (in the direction perpendicular to the detector plane) is poorer than the in-plane (plane parallel to the detector plane) resolution. Present day tomosynthesis systems provide an in-plane resolution in the range of 100-150 micrometers per pixel while the resolution between slices is around 1 millimeter. Due to the anisotropic voxel resolution in breast tomosynthesis, many researchers regard tomosynthesis as providing quasi-3D information rather than true 3D information of the structures within the breast. Another issue with breast tomosynthesis is poor visibility of microcalcifications in the reconstructed slices. One of the main reasons for this is the degradation of spatial resolution on reconstruction from the low

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