Chapter X
Computer–Aided Diagnosis in Breast Imaging: Trends and Challenges

Lena Costaridou
University of Patras, Greece

Spyros Skiadopoulos
University of Patras, Greece

Anna Karahaliou
University of Patras, Greece

Nikolaos Arikidis
University of Patras, Greece

George Panayiotakis
University of Patras, Greece

ABSTRACT

Breast cancer is the most common cancer in women worldwide. Mammography is currently the most effective modality in detecting breast cancer, challenged by the presence of dense breast parenchyma, with relatively low specificity in distinguishing malignant from benign lesions. Breast ultrasound and Magnetic Resonance Imaging (MRI) are significant adjuncts to mammography providing additional diagnostic information. Various Computer-Aided Diagnosis (CADx) schemes have been proposed across modalities, acting as clinical tools that provide a “second opinion” to assist radiologists in the diagnostic task of lesion characterization by means of quantitative image feature extraction and classification methods. The advent of multimodality imaging broadens the role of CADx, in terms of complementary tissue properties analyzed. In this chapter, major stages of CADx schemes in breast imaging are reviewed, while challenges and trends are discussed and highlighted by corresponding application examples of CADx methodologies for microcalcification clusters in mammography and masses in Dynamic Contrast-Enhanced MRI.
INTRODUCTION

Breast cancer is the most common cancer in women worldwide and the second leading cause of cancer deaths after lung cancer. Lifetime risk of developing invasive breast cancer is approximately 1 in 8 women. Screen-Film Mammography (SFM), providing structural tissue properties by means of X-ray attenuation differences, is currently the most effective modality in detecting breast lesions such as masses, microcalcification (MC) clusters and architectural distortions.

SFM, although characterized by high spatial resolution (25 μm pixel size), is challenged by the relatively low image contrast, especially in case of dense breast parenchyma. Limitations of SFM are attributed to 3D information loss, due to projection geometry, and the sigmoid response curve (characteristic curve) of the screen-film, as image detector.

A natural extension of SFM is achieved by Full-Field Digital Mammography (FFDM) overcoming screen-film response limitation by the linear and broader characteristic curve of direct or indirect digital detectors (Williams et al., 2006). At present, the only technical limitation of FFDM is spatial resolution (40 μm pixel size). The higher detection accuracy of FFDM is demonstrated in screening of dense breasts (Pisano et al., 2005). Up to date, eight FFDM units have been approved by FDA1. Detection performance of FFDM is further enhanced by the capability to manipulate lesion-to-background contrast with image processing tools offered by viewing mammograms in softcopy display workstations. Recently, in an attempt to deal with 3D information loss, often resulting in misdetection of lesions obscured by overlapping dense parenchyma, Digital Breast Tomosynthesis has been introduced (Park et al., 2007). This is achieved by acquiring a small number of 2D projection images and adequately reconstructing tomographic images (slices) with respect to breast depth (z-axis).

When biological processes underlying disease are not captured by X-ray imaging, insight to additional structural and functional tissue properties as well as 3D imaging is exploited by modalities adjunct to mammography, such as Ultrasound (US) and Magnetic Resonance Imaging (MRI).

MRI acquires the nuclear magnetic resonance signal from hydrogen nuclei of tissue. By applying 3D encoded magnetic fields, time constants T1 and T2, characterizing the recovery of longitudinal and transverse magnetization respectively, provide unique biophysical properties used to differentiate contrast among tissues. In addition to 3D spatial information of anatomical structures, Dynamic Contrast-Enhanced MRI (DCE-MRI) offers a functional approach to imaging based on differentiation of malignant from benign tissue with respect to cellular composition, permeability and microvessel density. DCE-MRI data captures kinetics of contrast agents in targeted tissues (Wu & Markey, 2006).

Computer-Aided Detection and Diagnosis (CADe and CADx) schemes have been proposed across breast imaging modalities, acting as clinical tools that provide a “second opinion” to radiologists, with mammography being the most successful paradigm (Sampat et al., 2005).

CADe systems have been developed to improve radiologists’ performance in detecting breast lesions, by identifying suspicious regions of masses and MC clusters. CADe methodologies employed and performances achieved are provided in excellent reviews (Tourassi, 2005; Chan et al., 2005; Sampat et al., 2005). High performance mammographic CADe schemes have been incorporated in commercially available, FDA approved systems2. The impact of CADe systems, i.e. significant increase of breast cancers detected with an acceptable increase of recall rate, is reported in peer-reviewed retrospective and prospective studies, although with some criticism (Fenton et al., 2007).

CADx systems in breast imaging aim to assist radiologists in the diagnostic task of lesion