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A review of computer-aided diagnosis of breast cancer: Toward the detection of subtle signs☆

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Abstract

Mammography is the best available tool for screening for the early detection of breast cancer. Mammographic screening has been shown to be effective in reducing breast cancer mortality rates: screening programs have reduced mortality rates by 30–70%.

Mammograms are difficult to interpret, especially in the screening context. The sensitivity of screening mammography is affected by image quality and the radiologist's level of expertise. Computer-aided diagnosis (CAD) technology can improve the performance of radiologists, by increasing sensitivity to rates comparable to those obtained by double reading, in a cost-effective manner. Current research is directed toward the development of digital imaging and image analysis systems that can detect mammographic features, classify them, and provide visual prompts to the radiologist.

Radiologists would like the ability to change the contrast of a mammogram, either manually or with pre-selected settings. Computer techniques for detecting, classifying, and annotating diagnostic features on the images would be desirable. This paper presents an overview of digital image processing and pattern analysis techniques to address several areas in CAD of breast cancer, including: contrast enhancement, detection and analysis of calcifications, detection and analysis of masses and tumors, analysis of bilateral asymmetry, and detection of architectural distortion. Although a few commercial CAD systems have been released, the detection of subtle signs of breast cancer such as global bilateral asymmetry and focal architectural distortion remains a difficult

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problem. We present some of our recent works on the development of image processing and pattern analysis techniques for these applications.

Keywords: Breast cancer; Computer-aided diagnosis; Mammography; Calcifications; Breast masses; Breast tumors; Asymmetry; Architectural distortion; Enhancement; Segmentation

1. Screening for breast cancer

Breast cancer is the most frequently diagnosed cancer in women. According to the National Cancer Institute of Canada, the lifetime probability of developing breast cancer is one in 8.9, and the lifetime probability of death due to breast cancer is one in 26.8 [1]. Breast cancer has the highest prevalence among all cancers in the female population, with 1.0% of all women living with the disease [1].

Early detection of breast cancer is of utmost importance: localized cancer leads to a 5-year survival rate of 97.5%, whereas cancer that has spread to distant organs has a 5-year survival rate of only 20.4% [2]. Breast self-examination is not adequate: many studies indicate that there is no evidence of a reduction in the mortality rate due to breast cancer in women who practice regular breast self-examination, compared to those who do not [3,4].

Mammography is, at present, the best available examination for the detection of early signs of breast cancer [3]. It can reveal pronounced evidence of abnormality, such as masses and calcifications, as well as subtle signs such as bilateral asymmetry and architectural distortion [5]. Mammographic screening has been shown to be effective in reducing breast cancer mortality rates: screening programs have reduced mortality rates by 30–70% [6], [7, Chapter 19]. Cady and Chung [8] discuss the validity of mammographic screening programs, highlighting the reduction in mortality achieved by several screening programs in Sweden, the Netherlands, the UK, Finland, Italy, and the USA. The drawbacks of screening are also discussed, such as the higher incidence of unnecessary biopsies, cost and quality of interpretation of mammograms versus the experience of the radiologists, and the psychological consequences of errors, such as the anxiety caused by a false-positive result and the wrongful reassurance provided by a false-negative test. It has been concluded that the benefits of screening surpass the drawbacks, and that the practice of mammographic screening must be encouraged and expanded.

However, interpreting screening mammograms is not easy: the sensitivity of screening mammography is affected by image quality and the radiologist's level of expertise. Another factor that affects a radiologist's performance is the high volume of cases examined in a screening program. The lack of expert radiologists to analyze mammograms in remote or rural areas is also a matter of concern. Bird et al. [9] estimated the sensitivity of screening mammography to be between 85% and 90%. Misinterpretation of breast cancer signs accounted for 52% of the errors, and overlooking signs corresponded to 43% of the missed abnormalities. In a study by van Dijck et al. [10], minimal signs of abnormalities were found to be present on screening mammograms taken previously in many cases of screen-detected cancers. Double reading of screening mammograms was found to provide greater sensitivity than single reading without increasing recall rates, in a comparative analysis by Blanks et al. [11], but the manpower required may render such an approach impractical.