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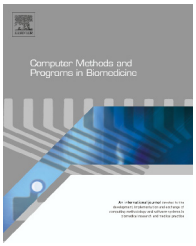

Evaluating geodesic active contours in microcalcifications segmentation on mammograms

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ABSTRACT

Breast cancer is the most commonly occurring type of cancer among women, and it is the major cause of female cancer-related deaths worldwide. Its incidence is increasing in developed as well as developing countries. Efficient strategies to reduce the high death rates due to breast cancer include early detection and tumor removal in the initial stages of the disease. Clinical and mammographic examinations are considered the best methods for detecting the early signs of breast cancer; however, these techniques are highly dependent on breast characteristics, equipment quality, and physician experience. Computer-aided diagnosis (CADx) systems have been developed to improve the accuracy of mammographic diagnosis; usually such systems may involve three steps: (i) segmentation; (ii) parameter extraction and selection of the segmented lesions and (iii) lesions classification. Literature considers the first step as the most important of them, as it has a direct impact on the lesions characteristics that will be used in the further steps. In this study, the original contribution is a microcalcification segmentation method based on the geodesic active contours (GAC) technique associated with anisotropic texture filtering as well as the radiologists' knowledge. Radiologists actively participate on the final step of the method, selecting the final segmentation that allows elaborating an adequate diagnosis hypothesis with the segmented microcalcifications presented in a region of interest (ROI). The proposed method was assessed by employing 1000 ROIs extracted from images of the Digital Database for Screening Mammography (DDSM). For the selected ROIs, the rate of adequately segmented microcalcifications to establish a diagnosis hypothesis was at least 86.9%, according to the radiologists. The quantitative test, based on the area overlap measure (AOM), yielded a mean of 0.52 ± 0.20 for the segmented images, when all 2136 segmented microcalcifications were

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considered. Moreover, a statistical difference was observed between the AOM values for large and small microcalcifications. The proposed method had better or similar performance as compared to literature for microcalcifications with maximum diameters larger than 460 μm. For smaller microcalcifications the performance was limited.

1. Introduction

Cancer is the name given to a group of more than 100 diseases, whose common characteristic is the uncontrolled growth of cells that can potentially invade other tissues and organs in the body, and its main types are lung, prostate, cervical, breast and skin cancers [1]. Breast cancer is the most commonly occurring type of cancer among women, and it is the major cause of female cancer-related deaths worldwide. Its incidence is increasing in developed as well as developing countries, and it accounts for around 22% of new cancer cases that are reported each year [2]. Breast cancer is also one of the leading causes of female deaths in Brazil. INCA predicted the occurrence of 57,120 new cases of this disease in 2014 [3]. Although breast cancer is more common in women, it can also occur in men. According to INCA, in 2010, breast cancer was responsible for 147 male deaths, corresponding to 1.14% of the total deaths (12,852) due to breast cancer in Brazil [2].

In Brazil, death rates related to breast cancer are high, mainly because of late diagnosis, i.e., when the disease is already in an advanced stage [2]. Efficient strategies to reduce such high death rates include early detection and tumor removal in the initial stages of the disease. Clinical and mammographic examinations are considered the best methods for detecting the early signs of breast cancer; the objective of the latter is to identify non-palpable breast lesions [4].

Nevertheless, several factors, such as physician knowledge and experience, equipment quality, and the presence of adipose and glandular tissues, may affect the diagnostic accuracy in breast cancer screening. Even if the mammographic procedure is carried out by an experienced technician using adequate equipment, the final mammography quality is highly dependent on the breast tissue itself; the more the adipose, the easier is the analysis and diagnosis [5]. Furthermore, the sensitivity of mammography is very low for patients younger than 40 years, because they have highly dense parenchyma, and for patients older than 70 years owing to the composition of the breast tissue beyond this age [6].

In routine mammography, microcalcifications are considered as significant signs of the existence of malignant lesions, as they occur in most breast cancer cases. Microcalcifications are small granular deposits of calcium that appear in a mammogram as small bright dots. Microcalcification detection is often difficult, requiring a radiologist to carefully examine the mammogram; the microcalcifications may be hidden, especially in dense tissues [7].

Despite their frequent occurrence in mammograms, only 30–50% of microcalcifications in breast carcinoma are detected via mammographic examination, whereas 60–80% are detected via histological examination [7]. The difficulty in detecting microcalcifications in mammograms is due to their variation in shape (from granular to rod shapes), orientation, brightness, and diameter, as well as the density of the surrounding tissue [8].

In an effort to facilitate microcalcification detection and diagnosis, computer-aided detection (CADe) and computer-aided diagnosis (CADx) systems have been developed [9,10]. Such systems can minimize the false-positive and false-negative rates in breast cancer diagnosis, and they are usually based on parameters extracted from microcalcifications; for example: mean microcalcification area, mean microcalcification orientation, compactness, roughness, number of microcalcifications in a cluster [11,12].

CADe systems allow automatic detection of lesions (including microcalcifications), whereas CADx systems are employed for classification of lesions; in general, the latter are used to provide a second opinion, thereby increasing the accuracy of a radiologist's final diagnosis [9,10,13–16]. CADx systems basically involve three steps [17,18]: (i) segmentation, (ii) parameter extraction and selection of the segmented microcalcifications and their clusters, and (iii) lesion classification. Although improvements to any of the individual steps could enhance the performance of the entire system, the segmentation step is considered to be the most important step [17–19], because it defines the characteristics of the microcalcifications to be used in the following CADx steps.

Several techniques have been adopted for segmenting microcalcifications, such as active contours [18,20–22], gray-level histogram features associated with fuzzy rule-based classifiers, methods based on image entropy [23], wavelet analysis [14,24,25], and morphological filters [7,26]. More recently, researches pointed out the importance of some microcalcifications segmentation techniques with good results for this task. These researches are mainly based on active contours [17], wavelet analyses [27] and mathematical morphology [28].

Arikidis et al. [17] presented a multiscale active contours method to segment microcalcifications in mammographic exams, which also employs radiologists' intervention for manually defining a seed point to initialize the method. A ROI was defined as a square of 81×81 pixels, centered at the seed point. The authors assessed the results by comparing the obtained segmentation areas with the ones manually defined by a radiologist, and pointed out a mean value of area overlap measure of 0.61 ± 0.15.

Batchelder et al. [27] used the 2D wavelet transform modulus maxima method (WTMM) to detect microcalcifications in human breast tissue in mammograms and to characterize the fractal geometry of benign and malignant microcalcification clusters. They estimated a 3D fractal structure of a breast lesion by pairing the information from two separate