Computers in Biology and Medicine 50 (2014) 32–40

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

Breast peripheral area correction in digital mammograms

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ARTICLE INFO

Article history:
Received 14 November 2013
Accepted 24 March 2014

Keywords:
Mammography
Image processing
Radiographic image enhancement
Computer-assisted diagnosis
Image quality

ABSTRACT

Digital mammograms may present an overexposed area in the peripheral part of the breast, which is visually shown as a darker area with lower contrast. This has a direct impact on image quality and affects image visualisation and assessment. This paper presents an automatic method to enhance the overexposed peripheral breast area providing a more homogeneous and improved view of the whole mammogram. The method automatically restores the overexposed area by equalising the image using information from the intensity of non-overexposed neighbour pixels. The correction is based on a multiplicative model and on the computation of the distance map from the breast boundary. A total of 334 digital mammograms were used for evaluation. Mammograms before and after enhancement were evaluated by an expert using visual comparison. In 90.42% of the cases, the enhancement obtained improved visualisation compared to the original image in terms of contrast and detail. Moreover, results show that lesions found in the peripheral area after enhancement presented a more homogeneous intensity distribution. Hence, peripheral enhancement is shown to improve visualisation and will play a role in further development of CAD systems in mammography.

1. Introduction

As a consequence of the current digital revolution, traditional film-based hospitals are converting to digital hospitals, where patient medical records, chart information, and test results are easily available electronically for physicians from anywhere in the hospital and beyond. As such, full-digital mammography is gaining importance compared to conventional film-screen mammography due to the possibility of separating and individually optimising digital acquisition, digital storage, and digital display [1–3].

Digital detectors offer higher quantum efficiency and higher resolution than traditional screen-film receptors [4]. These characteristics translate into both lower dose and improved image quality mammograms. Berns et al. [5] showed that digital mammography acquisition is a highly significant 35% shorter acquisition in time. Once images are acquired, the Digital Imaging and Communications in Medicine (DICOM) [6] standard handles the storage and communication protocol. This allows enabling the integration of different imaging devices, such as scanner machines, displays, and workstations in a fully digital system, usually referred to as the Picture Archiving and Communication System (PACS). From there, the images are sent to the screening workspace, where one or more experts analyse and diagnose cases.

In contrast with film-screen imaging, in digital imaging experts view images on electronic displays (also called soft-copy displays). These systems offer new opportunities. For instance, there is experimental evidence that alternating current and prior mammograms on the same display allows better evaluation of temporal changes than conventional display of images next to each other [7]. However, a faulty, inadequately calibrated, or improperly set up display can compromise the overall quality of a diagnostic procedure [8].

In order to help radiologists during breast imaging evaluation, different image processing algorithms are being developed to improve the visualisation of digital mammograms. This may be achieved by either enhancing some image features to allow the detection of different types of lesions [9,10] or by improving the quality of the mammograms to compensate for possible acquisition limitations [11]. This paper focuses on the latter, specifically on the correction of the presence of an overexposed boundary area in the majority of mammograms, as shown in Fig. 1(a). This effect is due to breast thickness variation during mammographic acquisition, and cannot be solved by modifying the typical contrast parameters that viewers provide (window width and window centre). During acquisition, the breast is compressed with a tilting

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http://dx.doi.org/10.1016/j.compbiomed.2014.03.010
0010-4825/

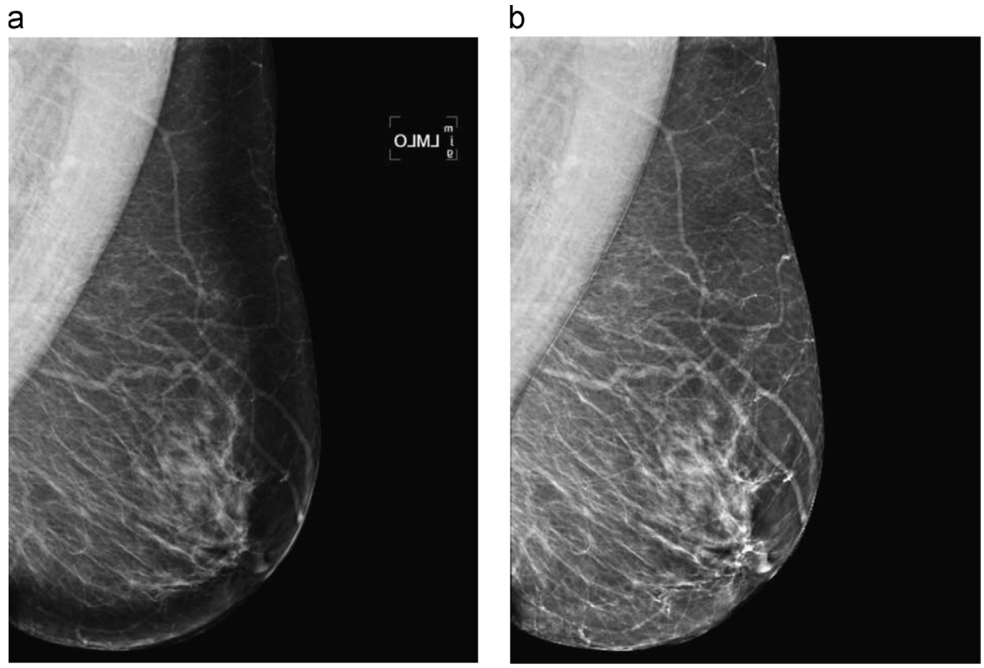

Fig. 1. Example of the peripheral enhancement: (a) original and (b) enhanced images. The images are obtained after the best manual window width and window centre configuration.

compression paddle; hence breast thickness is non-uniform across the mammogram, being thinner in the periphery and thus overexposing this area. To compensate for thickness variations in the breast periphery, we propose an automatic peripheral enhancement algorithm.

The proposed enhancement method applies a multiplicative correction factor for each pixel of the overexposed area. This factor depends just on the pixel intensity and its neighbourhood with already corrected intensities. Hence, the procedure starts correcting the overexposed pixels adjacent to the non-overexposed area and iteratively corrects the other pixels. This process stops at the skin-line, which is defined as the boundary between the breast and the dark background. Notice how the use of a multiplicative factor guarantees grey-level continuity. Fig. 1(b) shows an example of the application of this algorithm. Note that the correction of the overexposed area also affects the behaviour of the window width and windows centre contrast adjustments. The proposed peripheral enhancement not only represents an improvement in the appearance of the images but also for breast cancer detection [12,13].

The rest of the paper is structured as follows. Section 2 reviews the literature on peripheral breast enhancement. Section 3 describes the proposed method. Results are shown in Section 4. Section 5 shows the benefits of our approach in two different applications. The paper ends with discussion.

2. Background

Several methods have been proposed for overexposed area correction in mammography, which can be classified into non-parametric [14–16] or parametric [17–21] approaches. The former ones try to adjust the intensity of overexposed areas by means of traditional image processing techniques, like segmentation and equalisation. On the other hand, parametric approaches adjust the intensity of the images according to a given model, which may be as specific as the type of digital detector [17] or as general as a 3D representation of the breast [18–21]. A different approach was proposed by Goodsitt et al. [22,23] who designed physical filters to adjust x-ray beam distribution in order to compensate the tissue thickness.

In this work, we focus on a non-parametric approach for image correction. Non-parametric approaches allow improving the quality of a single image without needing extra information. In traditional non-parametric approaches, the correction of the overexposed area follows an additive approach. Thus, a specific factor is added to the pixel intensities appearing in order to obtain a more homogeneous intensity distribution throughout the breast. The different approaches may vary in the determination of the correction area and in the factor which is added. Regarding area, algorithms can be either applied to the whole area [14] or just to a region determined by a segmentation algorithm [11]. In the first case, the correction in the inner part of the breast is inappreciable, since the additive factor is assumed to be zero in that part. In the second case, authors segment the breast using intensity based features in order to locate overexposed areas, and the correction algorithm is limited to this part. Regarding the correction factor, Bick et al. [14] generated a curve based on the mean grey level intensity of all points lying at the same distance from the skin line. A second curve was generated by subtracting this intensity curve from the mean intensity value of the image. The intensity value of this second curve at each distance was then added to the corresponding pixels. Karssemeijer and te Brake [16,24] first computed a smoothed version of the mammogram. Subsequently, all pixels below a threshold were corrected by subtracting from the original intensity the smoothed intensity and adding the mean value of the inner part of the breast. A similar approach was also developed by Byng et al. [15]. The underlying assumption of these approaches is that thickness variations are smoother than density variations.

3. Peripheral area correction

Fig. 2 depicts our proposal for breast peripheral enhancement. The method can be divided into two main steps: (1) determining overexposed and non-overexposed areas and (2) equalising the mean intensities of both areas. The goal is to enhance the