Mammographic Registration: Proposal and Evaluation of a New Approach*

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Abstract. The detection of architectural distortions and abnormal structures in mammographic images can be based on the analysis of bilateral and temporal cases. This paper presents a novel method for mammographic image registration inspired by existing robust point matching approaches. This novel method is compared with other registration approaches proposed in the literature using both quantitative and qualitative evaluation based on similarity metrics and ROC analysis (ground truth provided by an expert radiologist). Initial evaluation is based on mammographic data of 64 women with malignant masses which indicates the accuracy and robustness of our method.

1 Background

Image registration has been widely used in medical applications for quite a while now, and the analysis of mammographic images is not an exception. An added difficulty of trying to register mammographic images is their projective nature. Nevertheless, different approaches have been adopted to obtain an alignment and minimise effects due to acquisition factors such as patient movement, breast compression and other image related factors (film exposure and energy). Most of the published approaches (including the early works of Sallam and Bowyer [1] and Karssemeijer and te Brake [2]) use breast boundary information as it is relatively easy to extract and provides important information about the breast deformation. Another group of approaches can be classified as being intensity based, where the deformation is recovered maximising a measure of similarity between images. The use of an intensity measure to recover global transformations has been reported to obtain robust results [3], but can not account for severe local distortions and additional steps are needed. In addition to the breast boundary, information about the deformation of internal regions is also necessary in order to obtain a robust registration. This has been used by different authors [4,5,1].

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Although non-linear registration (warping methods) of mammographic images has been regarded by some authors as non-appropriate [3], it is our belief, which is corroborated by other authors [5], that non-linear transformation can also be successfully used. However, special care has to be taken in choosing the transformation function and its parameters (in particular, regularisation factors which ensure smoothness and continuity). It is true that a naive implementation can lead to non-realistic transformations.

The method presented here is an evolution of our initial proposal [4], focusing now on providing a robust framework for establishing point correspondence between mammograms. The novelty of this paper is twofold. Firstly, we introduce and adapt different concepts of robust point matching approaches to the proposed registration approach. Secondly, an evaluation is presented comparing our method to other existing approaches in terms of similarity measures and ROC curves using a relatively large number of cases. Although initial results, this work shows that image registration can be successfully used to asses temporal changes in mammograms such as involution of breast tissue, the detection of masses or architectural distortions.

2 Method

The registration methodology presented here is based on robustly matching interest points in two mammographic images of the same view (either MLO or CC). The algorithm extracts interest points found in the boundary and the internal breast region, and applies a robust point matching approach obtaining a non-linear transformation. Registered images are used for detecting possible abnormalities in contralateral mammograms (comparing left and right breasts) by subtracting images and measuring local measures of similarity.

An initial pre-processing step segments the breast boundary and extracts interest points from the boundary and internal regions. A distinction between boundary and internal structures is made. Boundary information is used to restrict the detection area of internal structures and is also a good initial estimate of the breast deformation. In this paper, the breast boundary is obtained by simple thresholding and morphological opening operations. Subsequently, interest points are obtained from this boundary by computing their maximal local curvature. Interest points internal to the breast are also extracted using a criteria of local maximal curvature after a line detection algorithm is applied to the breast region. This pre-processing is similar to the one presented in [4].

2.1 Point Matching Algorithm

The idea behind the registration methodology of this paper is inspired by robust point correspondence methods proposed by various authors [6,7,8]. The common approach from the cited methods is the use of an iterative process in order to minimise correspondence errors. Those errors are related to a cost matrix (C_{ij}) which describes the cost of matching one point i in one image (row i) with a point j in the second image (column j). The elements of this matrix are