

An Unsupervised Method for Suspicious Regions Detection in Mammogram Images

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Abstract: Over the past years many researchers proposed biomedical imaging methods for computer-aided detection and classification of suspicious regions in mammograms. Mammogram interpretation is performed by radiologists by visual inspection. The large volume of mammograms to be analyzed makes such readings labour intensive and often inaccurate. For this purpose, in this paper we propose a new unsupervised method to automatically detect suspicious regions in mammogram images. The method consists mainly of two steps: preprocessing; feature extraction and selection. Preprocessing steps allow to separate background region from the breast profile region. In greater detail, gray levels mapping transform and histogram specifications are used to enhance the visual representation of mammogram details. Then, local keypoints and descriptors such as SURF have been extracted in breast profile region. The extracted keypoints are filtered by proper parameters tuning to detect suspicious regions. The results, in terms of sensitivity and confidence interval are very encouraging.

1 INTRODUCTION

Breast cancer is the most common form of cancer in the female population. Optical mammography aims to detect breast cancer by characterizing the physiological state. The detected optical signals (red and infrared light) provide informations on the spatial distribution of the breast tissue properties. Screening mammography is a cost-effective method to detect early breast cancer. Many researchers proposed biomedical imaging methods for computer-aided detection and classification of suspicious regions in mammograms. Mammogram interpretation is performed by radiologists by visual inspection and examination of the images in search of abnormalities that may be malignant. The large volume of mammograms to be analyzed makes such readings labour intensive and often inaccurate. Several studies have shown a percentage between 10% and 25% of missed tumors in current breast cancer screening. CAD (Computer Aided Diagnosis) methods are used as a "second opinion" by the radiologists. The objective of CAD methods is to

perform preprocessing steps to give some suggestions to the radiologists in mammograms analysis. The difficulty of the diagnostic task have generated an increasing interest in developing computer-aided detection methods (Doi, 2007). The identification of masses is a difficult task because of the borders of the masses are often ill-defined making difficult to distinguish between parenchyma's tissue structures and masses. Many radiologists use the following standard tissue classification (Wolfe, 1976): Fibro-adipose tissue: indicates a fat breast with little fibrous connective tissue; Glandular tissue: indicates the presence of prominent duct pattern; Dense tissue: indicates a dense breast parenchyma. Radiologists stated that a patient has breast cancer if some types of masses of calcifications are detected in mammogram. As described in (Cheng, 2005), the most popular mass detection methods consist of six steps: 1) Digitizing Mammogram; 2) Image Preprocessing; 3) Image Segmentation; 4) Feature Extraction and Selection; 5) Classification; 6) Evaluation. Image preprocessing can suppress noise and improve the

contrast of the image, image segmentation is defined about mass detection as locating the suspicious regions. Features extraction and selection are defined to classify different types of lesions and to reduce false positives. Masses are grouped with respect to their size (Kom, 2005): small size (3-15 mm), middle size (15-30 mm) and large size (30-50 mm). Masses of size smaller than 5 mm or larger than 50 mm are left out during detection for diagnosis. In this paper we proposed a new method for suspicious regions detection in mammograms based on two steps: preprocessing; features extraction. In preliminary experiments we achieved a good sensitivity accuracy in suspicious regions detection. The paper is organized as it follows: in section 2 we give an overview of the state of the art methods; in section 3 we describe the proposed method; in section 4 we show the experimental results; section 5 ends the paper with conclusions and future works.

2 STATE OF THE ART

Several research works, in last decades, tried to develop computer aided diagnosis tools to help the radiologists in the interpretation of the mammograms.

Some methods aimed to enhance the digitized image prior to object identification (breast cancers, microcalcifications, lesions). te Brake and Karssemeiger (te Brake, 1998) proposed a method to identify stellate distortions by using an orientation map of line-like structure where the location of possible tumors can be detected. Petrick et al (Petrick, 1996) performed a two-stage adaptive method, based on contrast enhancement filtering along with edge detection and morphological features classification, for the segmentation of masses in mammograms. In (Gupta, 1995) the authors used Laws filters to identify suspicious regions in mammography. Viton (Viton, 1996) performed a method based on the degree of spiculation and the presence of fuzzy areas in the boundary of the tumor. Li et al (Li, 2001) proposed a method based statistical modelling using bayesian relaxation labelling for the identification of suspicious regions. In (Highnam, 1999) the authors described some methods to detect the presence or the absence of lesions from the mammograms. When mammograms manifest masses, this could correspond to the detection of suspicious regions (nodular opacities, clear masses with lobed edges, stellar opacities, microcalcifications).

Several image processing methods have been

proposed to perform suspicious regions detection. Some methods aimed to enhance the digitized image prior to object identification. The structural asymmetry between the right and the left breast images is used to determine mass locations (Lau, 1991). Several methods for masses detection in mammograms are based on segmentation techniques (Kekre, 2009). In (Kekre, 2009) the authors proposed a tumor detection in mammography images using vector quantization technique. Template matching is one of the most common approaches for medical image segmentation, it is also used to segment possible masses from the background of mammograms using prototypes. Masses prototypes are created based on the characteristics of the targeted masses, such as in (Tourassi, 2003). In (Rogova, 1999) the authors performed an approach to detect all different lesions by unsupervised segmentation method. Fuzzy logical (Sameti, 1996) also has been introduced for segmenting suspicious regions. The features extraction is a fundamental step in mass detection since the performance of CAD (Computer aided diagnosis) depends on the selection and optimization of the features than the classification method. Features, such as the size, shape, density, smoothness, texture descriptors, can be calculated from the region of interest (ROI), otherwise, excessive features may degrade the performance of the classifier. Significant features mainly include (Li, 2001) four considerations: discrimination, reliability, independence, optimality. Some supervised methods used ANN (artificial neural network), BBN (Bayesian Belief Network) (Zheng, 1999) linear discrimination, genetic algorithm (GA) (Sahiner, 1998). The classifiers can be combined to improve the classification rate: in (Constantinidis, 2001) five different classifiers such as multivariate Gaussian classifier (MVG), radial basis function (RBF), Q-vector median (QVM), 1-nearest neighbour (1NN) and hyperspheric Parzen Windows (PZN) are combined to detect masses in mammograms. Cascio et al. in (Cascio, 2006) performed a method for detecting masses in mammographic images consisting of two steps: image segmentation by contour searching and mass lesions classifications with neural network. A method for automatic detection of mammographic masses is performed by Dominguez and Nandi (Dominguez, 2008), it is based on regions segmentation and ranking. The regions are segmented via thresholding at multiple levels, then a set of features is computed for each of the segmented regions. The region ranking identifies the

regions most likely to represent abnormalities based on features computed. Multiresolution local binary pattern texture analysis and variable selection for false-positive reduction are used in (Choi, 2012) computer aided detection of breast masses on mammograms. Supervised methods require the training stage to optimize their performance. In unsupervised methods (Oliver, 2010) the performance of the algorithm depends almost entirely on tuning parameters, i.e. adjusting a threshold value to find the balance between sensitivity and specificity. Muramatsu et al. (Muramatsu, 2013) performed a method based on multidimensional scaling (MDS), more precisely they constructed similarity maps which can visually present the relationships between the lesions, with supplemental information to the reference images. In (Natarajan, 2013) Natarajan et al. focused their attention upon the detection of a tumor in the breast mammogram images by utilizing various techniques such as filtering, contrast adjustment, image stretching, image subtraction, transformation operations, flood fill operations and segmentation. Alias and Paulchamy (Alias, 2014) performed a new method based on artificial neural networks and likelihood function for breast tumor detection. In (Farruggia, 2014), the authors presented a technique for mammogram images retrieval and classification based on Bayesian Naive classifier.

In the next section we give a brief description of SURF (speeded up robust features) keypoints and descriptors. SURF are used in our method to detect the masses on mammograms.

2.1 SURF (Speeded up Robust Features)

SURF (Speeded Up Robust Feature) (Bay, 2008) is an interest point detector and descriptor, designed to be robust against scaling and rotation transforms, and to be faster than earlier methods. The speed gain is achieved by taking profit of integral images and a fast non maximum suppression algorithm. It is based on three steps: interest points extraction, repeatable angle computation and descriptor computation. Local keypoints are detected by using the Fast-Hessian Detector. Location and the scale of the points are calculated by the determinant of the Hessian matrix. Given a point $x = (x,y)$ in an image I , the Hessian matrix $H(x, \sigma)$; in x at scale σ is defined as it follows:

$$H(x, \sigma) = \begin{bmatrix} L_{xx}(x, \sigma) & L_{xy}(x, \sigma) \\ L_{xy}(x, \sigma) & L_{yy}(x, \sigma) \end{bmatrix} \quad (1)$$

$L_{xx}(x, \sigma)$ is the convolution of the Gaussian second order derivative with the image I in point x , similarly for $L_{xy}(x, \sigma)$ and $L_{yy}(x, \sigma)$.

Invariance to image rotation, is achieved by using the Haar wavelet responses in horizontal and vertical direction. The maximum angle of the gradients surrounding the interest point is chosen as the direction of the feature. Finally, a square region is generated around each interest point, aligned to the selected orientation and split into in 4x4 sub-regions. In each sub-region Haar wavelets are extracted at regularly spaced sample points. Wavelet responses in horizontal and vertical directions are summed up over each sub region and the resulting SURF descriptor vector is of length 64.

3 THE PROPOSED METHOD

The proposed method allows the identification of pathological areas in mammographic images on patients who show adipose or fibro-adipose structure of the breast tissue.

Suspicious areas, probably attributed to benign or malignant tumor, are identified through an unsupervised algorithm. The most important objective of our method is to perform an aid to clinical diagnosis. The proposed method consists of two phases: preprocessing of the image and the feature extraction. The preprocessing step consists of image global transforms, resulting in two images with different contrast level; SURF Keypoints descriptors (Bay, 2008) are used to identify areas of interest. In the next subsections a more detailed description of the steps of the proposed method is given.

3.1 Image Preprocessing

Mammogram images generally are represented with 14-bit grayscale, otherwise the reading process assigns an array of 16-bit $m \times n$, where m and n represent the resolution of the image. An image with 14-bit grayscale, allocating 16-bit, is a low key image (Figure 1) with a consequent loss of details of crucial importance for the diagnosis of pathological areas. For this reason we perform some global transforms on the images, to improve the dynamic range of the mammogram image. The techniques used for the enhancement of these types of images mainly consists of the analysis and modification of the histogram. The proposed method automatically identifies the proper range of gray levels desired for a good representation of the visual information of

the mammograms. We convert the pixel values in double format, then we analyze the histogram (Figure 1). As seen in figure 1, the first part of the histogram of a mammogram contains informations only on background of the image, this informations are unnecessary with respect to the identification of suspicious regions. For this reason we decide to do not take into account background histogram information (the first curve, on left side of the histogram, see figure 1). For this purpose we apply a simple gray levels mapping transform.

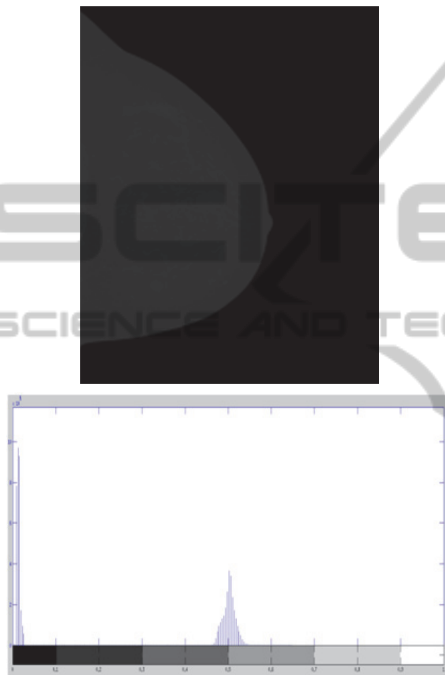


Figure 1: Mammogram image and the related histogram.

More in details, we calculate the following equation (eq. 2):

$$\Delta N_{Bin} = NumBin(i) - NumBin(i+1); \quad (2)$$

ΔN_{Bin} is the difference between the number of occurrences (NumBin(i)) for a given greylevel (i) and the number of occurrences (NumBin(i+1)) of the next greylevel (i+1). ΔN_{Bin} is computed until it is lower than a fixed threshold (5×10^5).

Then, we select the coordinates of Bin(i+1) corresponding to last ΔN_{Bin} value. We need Bin(i+1) coordinates to map histogram values. This transform is simply a gray levels mapping described in the following formula:

$$S = T(r) \quad (3)$$

$$T(r) = \begin{cases} 0 & \rightarrow r < (i + 1) \\ r & \rightarrow r \geq (i + 1) \end{cases}$$

From the eq. 3, (i+1) is greylevel referring to Bin(i+1).

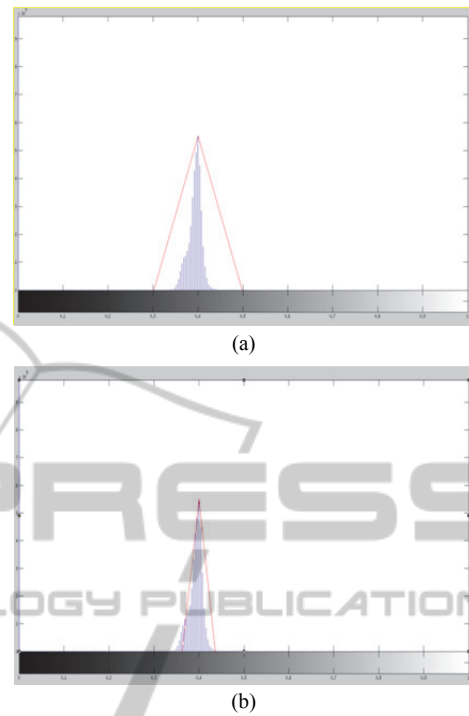


Figure 2: The identification of the first (a) and second (b) gray levels dynamic range.

After the mapping transform (equation 3), the mammogram histogram (figure 2) simply shows the informations referred breast tissue (the curve highlights the gray levels of breast tissue).

We want to detect and analyze suspicious regions in mammogram images. For this purpose we decide to analyze two versions of the the same image with different levels of contrast. The objective is to validate the detected suspicious regions by the intersection of visual informations identified on two version of the same mammogram. More simply, we decide to generate two version of the same mammogram based on histogram specifications based on a larger and a lower dynamic gray levels range (Figure 3). The gray levels ranges are detected by two triangles in the histogram (Figure 2). The following part of this section describes how to identificate the triangles.

We need to identify the coordinates of the vertices of the first triangle in the histogram. The higher vertex of the triangle corresponds to the second maximum value of the histogram (figure 2). The others vertices of the triangle are detected experimentally: starting from the coordinates of the first vertex, we select the 25th bin position on the left

side (in order of decreasing bins) with respect to the second maximum value of the histogram. Third vertex is detected by mirroring the 25th bin position with respect to first vertex of the triangle. The same technique is used to locate the second triangle vertices, otherwise we select the 2th position instead of the 25th.

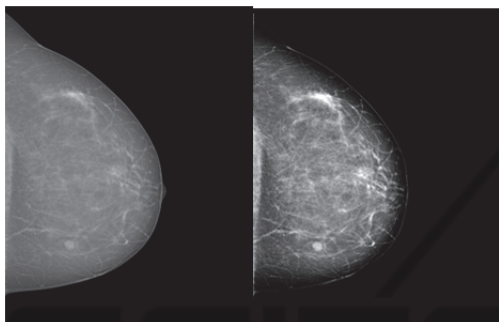


Figure 3: The results of histogram specification by the first dynamic grayscale range (Figure 2a) and by the second dynamic grayscale range (Figure 2b).

3.2 Features Extraction

In scientific literature several local keypoints and descriptors have been proposed for image processing applications. We used the SURF (Bay, 2008) descriptors to extract accurate informations on the mammogram images, to detect the suspicious regions for computer aided diagnostic with a good level of sensitivity. The extractions of SURF keypoints allow us to highlight important visual informations corresponding to suspicious regions of the image. The extraction of the keypoints can be tuned with respect to some parameters, such as scale, orientations, radius, thresholds. We extract SURF keypoints on the two mammogram versions (figure 3). The extraction of SURF keypoints with default parameters (figure 4) can generate a too large number of keypoints. Only a few of this points are located in suspicious regions. Each step of the method in feature extraction has been conducted on the two images resulting from preprocessing step (gray levels mapping and histogram specifications).

Several tests have been conducted attempting to set the optimal combination of parameters: the value of the threshold was changed from 2×10^{-4} to 5×10^{-4} . In figure 5 the SURF keypoints extracted with threshold value equal to 5×10^{-4} . Furthermore many tests have been conducted with respect to radius parameters, this parameter is very important because corresponding to the size of possible suspicious objects or regions in mammogram images. We are

not interested to analyze the keypoints located on the edge of the breast because this locations do not identify suspicious regions. For this reason we discard the Keypoints having Laplacian value lower than zero (figure 6).

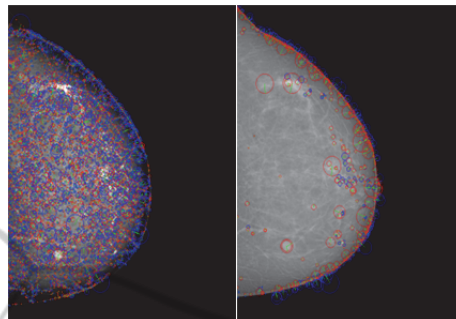


Figure 4: Features extraction with default SURF parameters.

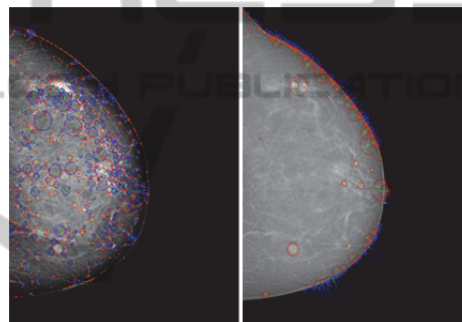


Figure 5: Features extractions with modified SURF parameters.

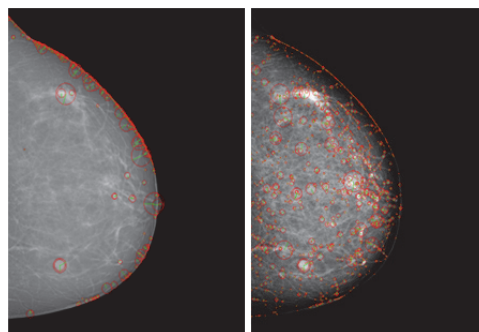


Figure 6: Features extraction with positive Laplacian values.

The thresholding of the radius parameter (90) allows us to achieve higher accuracy values. (Figure 7).

Then we consider the intersections of local keypoints of the two images (the intersection of keypoints with the same or similar position in the two images) as a good information to confirm the

"suspiciousness" of the regions detected. For this purpose, we used the Euclidean distance between the coordinates of the points (belonging to the two images). If the euclidean distance is lower than a certain threshold, local keypoints will be considered as points of interest, otherwise the keypoints are discarded (Figure 7), then the suspicious region detected can be cropped (Figure 8).

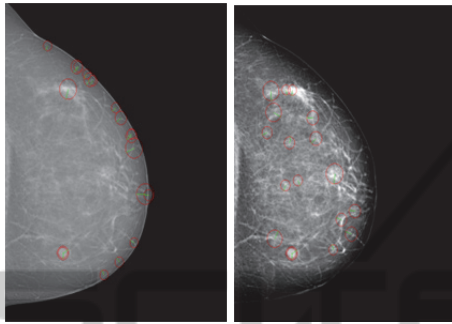


Figure 7: Feature extraction with threshold on radius.

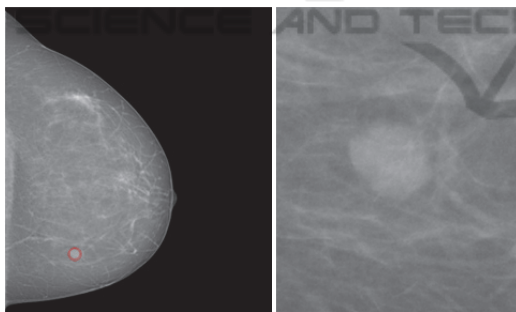


Figure 8: The identification of suspicious region after the proposed method is applied (left) and the crop of suspicious region detected (right).

4 EXPERIMENTAL RESULTS

The proposed method has been implemented in Matlab. The used dataset is composed of mammograms belong to sixty female pathological patients. The format of the mammograms is DICOM, the spatial resolution is 3484x2816 with 14-bit depth. We compute the percentage of True Positives (TP), False Negatives (FN) with respect to the total number of lesions. The results also have been analyzed by radiologist, to validate the performance of the method. For a more detailed measure of the method accuracy, Sensitivity and Confidence Interval have been computed (eq 4-5).

$$Sensitivity = \frac{TP}{(TP + FN)} \quad (4)$$

$$CI = TP \pm 1.96 \times \sqrt{\frac{S(1-S)}{N}} \quad (5)$$

In equation 5 CI represents the Confidence Interval, S represents the Sensitivity (equation 4), N is the number of cases, 1.96 is a constant value used for 95% confidence interval. The results are shown in tab.1.

Table 1: Statistical accuracy results.

Number of cases	Sensitivity	Confidence Interval
60	0.89	0.81 -- 0.97

The Sensitivity is almost 90%, this is very encouraging because indicating a very low number of false negatives. On the other hand some false positives are detected by the method and this is measured by precision index. In terms of Computer Aided Diagnostic, high values of Sensitivity are very promising and suggest to continue the tests of our method on a larger number of images.

5 CONCLUSIONS & FUTURE WORKS

In this paper we proposed a new method for computer aided diagnostic to detect suspicious regions in mammograms. This method is unsupervised and consists of two main steps: preprocessing; features extraction and selection. By using appropriate gray levels mapping and histogram specifications we achieved a dynamic range of grayscale representations. Then we used SURF keypoints and descriptors to detect and analyze suspicious regions of the mammogram images. The results, in terms of sensitivity are very encouraging. Moreover, the results revealed a not negligible number of false positives. Future works will be aimed to use some adaptive histogram transforms instead of fixed thresholds with respect to maximum value of the histogram.

Furthermore we want to extend the experiments by using a larger testset and some others local keypoints descriptors based on mathematical operators, different from Hessian (on which is based SURF).

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