Automatic Segmentation on Thermograms in Order to Aid Diagnosis and 2D Modeling

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Abstract. *This paper presents a method for automatic segmentation of the region of interest of thermographic breast images. This method can be applied to frontal images. The region of interest of each breast (left and right) is extracted. A main use of the approach includes automatic detection of pathologies by texture symmetric analysis. Other possible application is on the tridimensional reconstruction of the breast's geometry.*

Resumo. *Este artigo apresenta um método de segmentação automática da região de interesse de imagens termográficas da mama. Este método é aplicado em imagens frontais da paciente. A região de interesse de cada mama (esquerda e direita) é extraída. O sistema pode ser utilizado para detecção automática de patologias através de análise de simetria da textura das distribuições de temperatura. Outras aplicações, como reconstrução tridimensional, também são discutidas.*

1. Introduction

The variations in human body temperature may give a valuable information regarding to physiological disorders. So the use of thermal images has grown in medical applications [Herry et al. 2001]. Those images represent the infrared radiation naturally emitted by the body. This radiation is captured by cameras sensitive to infrared. The infrared cameras convert the temperature information into pseudo-color images in real-time, using different palletes at user's choice. Figure 1 shows examples of infrared images.

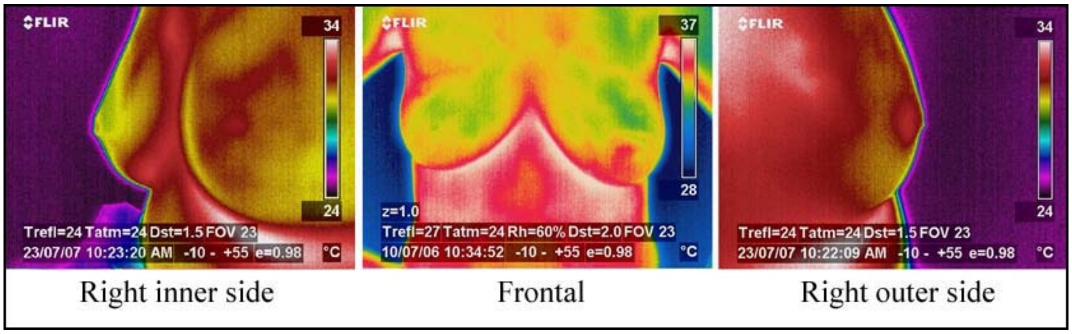

Figure 1. Examples of infrared images in three projections

Infrared images do not use ionizing radiation, venous access or others invasive procedures, besides being painless and not having contact with the skin surface. Thus, the exam does not cause any nuisance to the patient. Also it is relatively cheap compared to traditional methods, such as mammography, ultrasonography and magnetic resonance [Herry et al., 2001, Amalu et al., 2006, Arora et al., 2008].

Classified as a functional image technology, the infrared image of the breast provides physiological information of normal and abnormal functioning of sensorial and sympathetic nervous system, vascular system, as well as inflammatory processes. [Amalu et al., 2006]. For this reason, automatic diagnosis systems have been developed aiming to aid medical doctors detecting breast pathologies. These techniques usually take into account the asymmetry in temperature distribution as a signal of any disorder or illness, extracting thermal parameters, performing analysis between both breasts [Arora et al. 2008].

This work's proposal is a fully automatic method to segment those images, separating the regions of interest (ROI) as much symmetrically as possible, as well as extracting curves of the contour of the breast. A 2D model may help building a future 3D model of the breast [Castro et al. 2009].

The next sections are disposed as follows: Section 2 describes briefly how the images are captured. Section 3 presents some related works. The methodology is presented in Section 4, followed by the results obtained and the conclusions in Sections 5 and 6, respectively. Finally in Section 7 we suggest some future work.

2. Image acquisition

The camera used in this work (FLIR ThermaCam S45) was acquired by the Federal University of Pernambuco (UFPE) in January 2005. At the same year, a project called "Analysis of the feasibility of using themographic camera as a tool in the diagnosis of breast cancer in public hospitals located in tropical climate" was approved by the Ethics Committee from the university. It was registered at the Brazilian Ministry of Health under the number CEP/CCS/UFPE Nº 279/05. Since then patients older than 35 years are examined at the Clinical Hospital of UFPE and sign a consent form allowing the use of their images [Bezerra, 2007].

When the patients come to the hospital in order to acquire the images they wait about 10 minutes for acclimatization and to stabilize the metabolism. These procedures improve the capture quality. The information about the relative humidity and the temperature of the room are taken into account and set into the camera during the capture. Bezerra (2007) also says that the images from thermographic cameras have 84% of sensibility. It is similar to mammography (83%).

Since it is still a method under testing, there is no standard protocol to acquire the images; however, the most common positions are outer side (left and right), inner side (left and right) and frontal; the last one is the one used in this and related works. Other projections and images used in our tests can be found in an infrared images database [PROENG 2010].

3. Related work

Extracting the object's limits in the infrared images is a hard task due to the image's amorphous nature and lack of clear limits [Zhou et al. 2004]. For this reason, some authors prefer manual segmentation. Schaefer et al. (2009) use statistical methods and *Fuzzy* classification to diagnose breast cancer, but say that the ROI segmentation was done manually by an expert medical doctor because there is no robust method for this.

Herry et al. (2001) made statistical analysis and a comparison of the intensity distribution in both breasts symmetrically. The classification was done by extracting the contours using a simple contour detector and morphological operations, but the authors say that the segmentation may be done automatically or not [Herry et al. 2001].

However, other authors addressed this problem. Qi et al. (2008) applied segmentation techniques based on edges, but they found several curves inside the body, which would make segmentation harder. For that reason they chose the Hough transform (HT) to detect the inframammary fold, since it is parabolic in shape. The body borders were easily identified using the edge method. The segmentation is done using 3 points (axillas derived from the greatest curvature from the chest border and the intersection point between the parabolas as central point), together with the found parabola. Figure 2 describes the steps followed by Qi et al. (2008).

Figure 2. Steps of Qi et al.'s algorithm. Source: Qi et al. (2008)

Some problems may be observed in their result, such as some breast region loss, highlighted by the red circle in Figure 3, which may discard regions with a possible lesion and the lack of symmetry, which might disturb some automatic diagnosis methods based on comparison [Filho et al. 2009, Serrano et al. 2009].

Scales et al. (2004) used 8 segmentation steps: 1. Manual removal of upper body borders, e. g. shoulders, and waist; 2. Contour detection by means of several Canny detectors; 3. Isolation of the left, the right and the upper body limits; 4. Detection of breast bottom limits (using connected components detector or HT); 5. Second-order interpolation of the curves found in step 4; 6. Detection of the region with greatest curvature in left and right sides of the body; 7. Estimation of the breast upper limit using empirical rules and body regions; 8. Isolation of the region of interest based on the frontiers found in steps 3, 6 e 7 [Scales et al. 2004]. Figure 3 illustrated the described steps.

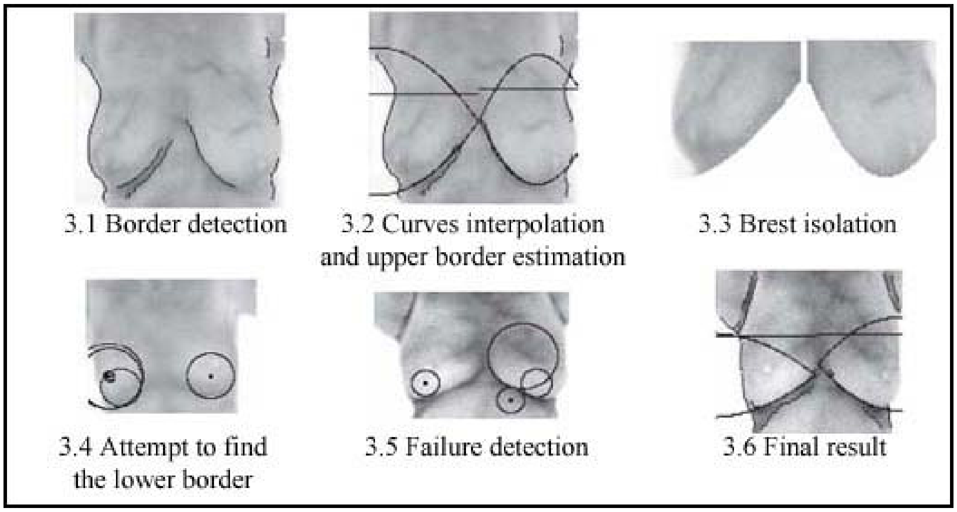

Figure 3. Steps from Scales et al.'s algorithm. Source: Scales et al. (2004)

Besides not being fully automatic, it is possible to see the asymmetry in the obtained ROI, which, again, may be a problem for automatic diagnosis algorithms based on comparison.

4. Proposed methodology

In this work, we propose a segmentation method based on automatic thresholding, automatic border detection, mathematical morphology, curve extraction and interpolation, among other computer vision techniques, separating both breasts as much symmetrically as possible.

All images are 320x240 pixels in size, grayscale, in which white pixels represent the lowest temperatures and black, the highest ones.

4.1. Inframammary fold detection and lower segmentation

To find the curve that best describes the inframammary folds, we use a threshold based on highest temperatures. This hypothesis is valid, since this region retains more body heat due to tissue superposition in almost all patients. Other regions which may also show high temperatures are the axillas and abdomen but they do not disturb the segmentation since they are discarded in further steps. After applying this threshold, the wanted curve is still not highlighted. To accomplish this, a thinning filter is applied scanning vertically each column of the image, keeping only the first three white connected pixels. Then a morphological opening with a 3x3 square structuring element centered at (1,1) is used in order to erase isolated pixels. Now, it is enough to search the image for the lowest pixel and set its coordinate as the lower limit. Figure 4 describes these steps.

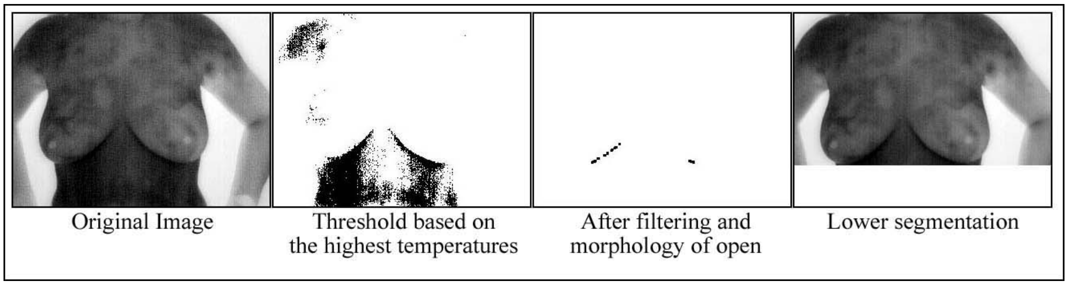

Figure 4. Step described in Section 4.1.

4.2. Background segmentation

The following steps are performed in order to segment the background and it can be seen at Figure 5.

1. An automatic Otsu threshold [Otsu 1979] is applied. Since this method uses global variance, some parts of the patient's body may be ignored due to the low contrast in some images. This issue is addressed in following steps;

2. The greatest contour inside the image, based in 8-pixel neighborhood, is detected;

3. This border is traversed by a moving window (size 10x10), in search for a region with the smallest gray level variance in the original image;

4. Inside the region detected by the previous item, the mean gray level value is used as the new threshold to the segmented image obtained in 4.1. This is done because the window with smallest variance is normally the region where a contour failure occurred because of the presence of gray tones above the value calculated by Otsu's methods;

5. Some gaps inside the body can appear, but they are easily fixed by applying a morphological closing with the same structuring element used before, in the opening operation.

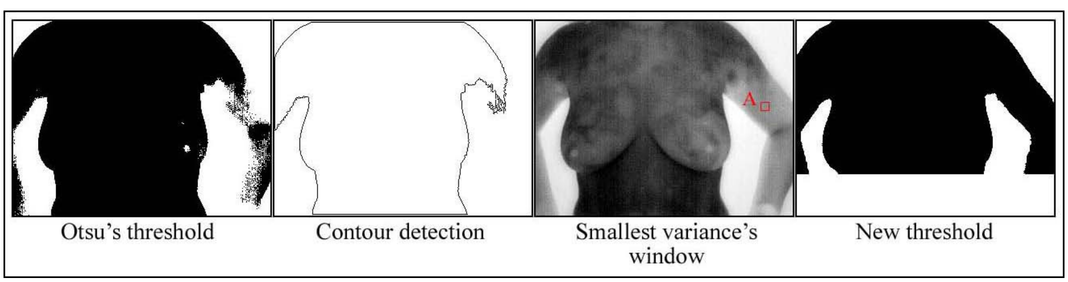

Figure 5. Steps described in Section 4.2

4.3. Axilla detection and upper segmentation

To find the upper segmentation coordinate, the external body border is need, but easily found using the edge method on the binary image obtained in step 4.2.5. Next we traverse the image from top to bottom in horizontal lines. At the local where a line intercepts at least four pixels from the external body, the border will be set as the upper limit. Figure 6 shows these steps.

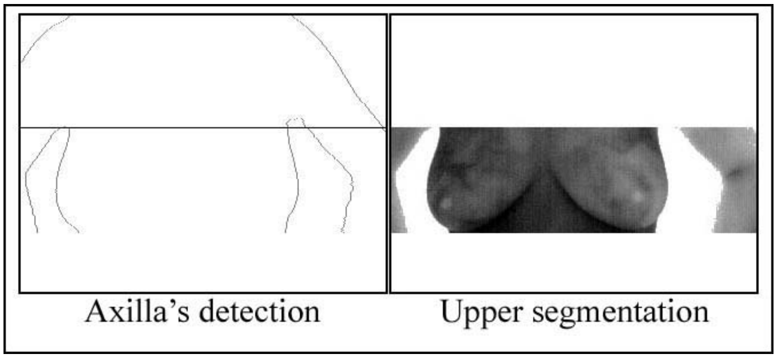

Figure 6. Steps for axilla detection.

4.4. Arms and external objects removal

This segmentation is easily obtained by detecting the largest object in the image, which is easy to grasp because no other object will be connected to the breast at this step.

Here, the region of interest is fairly highlighted. It is only left to split the ROI into left and right breasts as much symmetrically as possible.

4.5. Central axis discovery and breast separation

In this step, we traverse the image in order to search of the largest horizontal distance. The central axis is set as the half of the width of this distance. A rectangular bounding window is defined using the lower and upper limits and the central axis, separating the image in right and left breasts. Figure 7 shows the result.

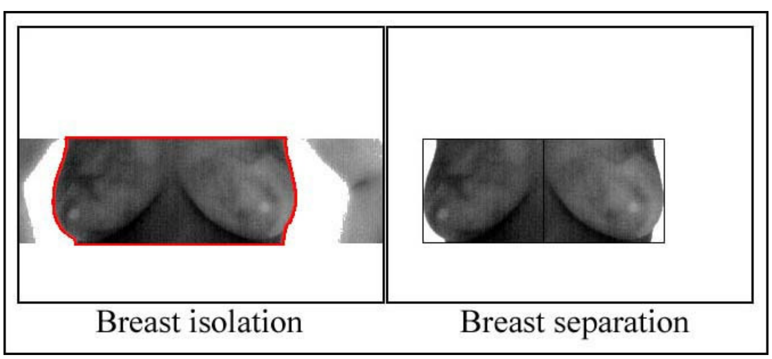

Figure 7. Steps described in Sections 4.4 and 4.5.

In this particular example the obtained image is practically symmetric, but in other cases this does not happen. Other modifications are needed in this case. To better show the subsequent steps, we will use another sample image in which the breast is naturally asymmetric. In order to aid the symmetry we will make a 2D model of the patient's body in the next step.

4.6. 2D modeling

In order to model the body it is necessary to obtain the side borders, which is easily found since the image is segmented. Next, using a curvature analysis, the first pixel at the external body border that belongs to the external breast border is selected.

Some other points are necessary for an interpolation to approximate the inframammary fold. Thus, the procedure described in Section 4.1 is repeated, excluding the morphological operation, since the abdomen, which would disturb the process, is not present. The upper, the lower and two more pixels from the result are selected.

Those five points from each breast are interpolated using cubic splines, implemented in the GSL library [GSL 2010]; the curves of both inframammary folds and, consequently, a 2D model, are obtained. Figure 8 illustrates this step.

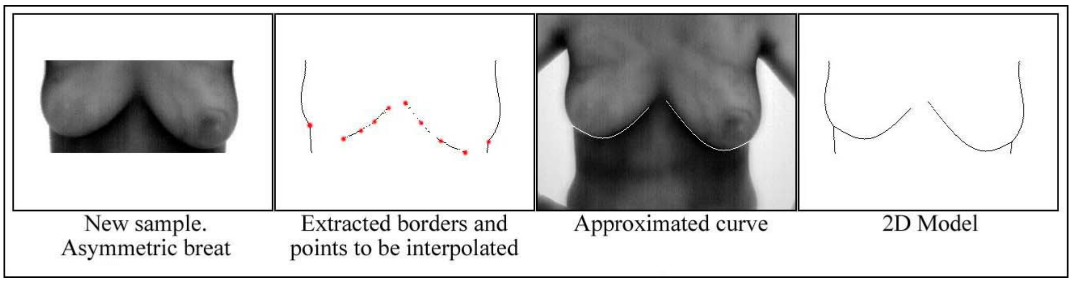

Figure 9. Steps described in Section 4.6.

4.7. Vertical displacement

Using the curve obtained in Section 4.6, the distance from this curve to the bottom of the bounding rectangular window is calculated. If it is greater than zero a vertical displacement is performed. Figure 9 shows the final result.

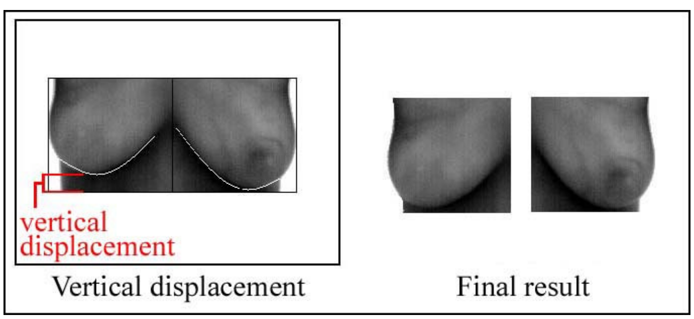

Figure 9. Steps described in Section 4.7.

5. Results

Until now the results verification has been done visually, even by medical specialists (empirical validation). However, numerical methods are being developed to assess the similarity between the regions obtained as the Higuchi's Fractal Dimension and Signal Complexity, among others. Some results of the proposed segmentation are available at PROENG (2010). Figure 10 shows some of these.

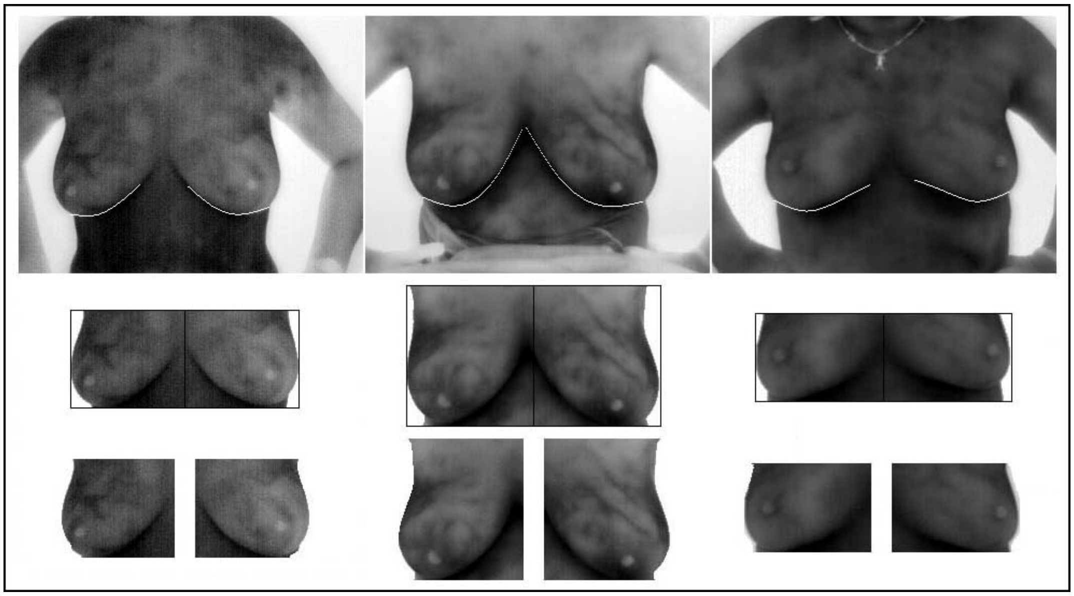

Figura 10. Results.

6. Conclusion

This study aimed to the automatic segmentation of breast infrared images, preventing errors caused by several reasons, such as fatigue, inattention or simply from the limitations of the human visual system. Therefore, it is important to design an automatic approach to eliminate human factors and guarantee repeatability and robustness of the results. Techniques of artificial intelligence and machine learning are already being implemented in regions of interest similar to those obtained in this work, aiming to assist the early detection of breast diseases [Filho et al. 2009, Serrano et al. 2010, Serrano 2010]. However these works extract the ROI manually. Based on this, it is possible to say that the objective of this study was well reached.

7. Future work

As future work we can highlight the automatic segmentation of other breast infrared images captured from different perspectives, e. g. in outer/inner side views [Castro et al., 2009]. This might generate curves that, together with the ones obtained in this study, may produce a 3D model of the breasts. This model might be used not only in automatic diagnostics but also to simulate the tridimensional temperature profiles, by correctly positioning the lesion in internal meshes. It might allow the merge with meshes obtained by more traditional examinations, such as mammography, magnetic resonance or ultrasonography. Another possible use is the virtual surgery simulation, to name some applications among others [Santos et al. 2009].

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