Automatic Registration of Printed Analog Screen-Film Mammograms

Mario Mustra [1], Danijel Mileta [2], Mislav Grgic [1]

[1] University of Zagreb, Faculty of EE and Comp, Unska 3, HR-10000 Zagreb, Croatia

[2] Ministry of the Sea, Transport and Infrastructure, Prisavlje 14, HR-10000 Zagreb, Croatia

mario.mustra@fer.hr

Abstract **- Computer aided detection (CAD) in mammography relies on accurate image segmentation. If we consider using CAD on non-digital mammograms, one of the steps which need to be performed is scanning. After scanning, images have to be segmented and this is more complicated than segmentation of digital mammograms. In this paper we propose a method for automatic registration of printed and scanned mammograms. This process allows efficient manual segmentation which gives as accurate as possible results. To translate manual segmentation results performed by radiologists from paper to digital format, image needs to be registered. Manual image registration generally takes too much time and therefore is not as efficient as automatic. This paper considers automatic registration of scanned images using Hough transform. Accurate detection and alignment of marker lines on scanned images gives the correct angle of rotation, as well as translation and resizing coefficient.**

Keywords **- Image Registration; Hough Transform; Computer Aided Detection**

I. INTRODUCTION

Computer aided detection (CAD) is an important and developing field in modern medical systems. It allows integration between automatic knowledge extraction and professional diagnosis performed by radiologists. In case of screen-film mammography (SFM), one additional task should be performed before CAD systems can be used. That task is image A/D conversion or digitalization of mammogram films. Besides that the digitalization process requires additional effort, it also presents problems with the digitalization output. Films usually suffer from imperfections and different sensitivity which causes non-uniform background and light leakage. This presents a problem to an automatic segmentation algorithm because breast skin-air interface has similar intensity and therefore is hard to detect the actual breast boundary. Another problem caused by scanning is alignment of images. For CAD purposes, images need to have known orientation and rotation. Incorrect positioning and rotation can be introduced by scanning process and should be corrected. Manual rotation and alignment are time consuming and the idea is to make them automatic. Image segmentation is the first (pre)processing step in development of any CAD system [1]. In the case of mammography CADs, segmentation of the breast tissue from the background is the necessary first step because SFM suffers from uneven background and identification tags which need to be removed [2]. In the case of digital mammograms captured with direct conversion mammography devices, segmentation of the breast tissue from the background is much easier task, because precalibration of the device makes sure that background intensity is zero. In this paper we propose a method for semi-automatic breast segmentation. The method includes image printing and automatic registration after scanning in order to align image with the digitally stored original. The goal is to make automatic system for manual segmentation. The result of this process will be image segmentation masks which can be used to test automatic segmentation algorithms and decide which one gives the best results. In the process of developing image registration methods, we have used mini-MIAS database [3]. This is publicly available database is consisted of 322 scanned SFM mammograms. All images are of the same size, 1024×1024 pixels with 8 bits per pixel.

There are many different methods to achieve image registration [4]. For this purpose we have chosen feature detection method. Features which should provide image transformation correctly are corner positions. Corner detection has been achieved through line detection using Hough transform [5]. In this case we do not have to compute image transformation matrices, but only gather corner coordinates from which scanned images can be arbitrary rotated and resized to match the size of original image. This registration method has similar properties to the rigid image transformation [6].

This paper is organized as follows. In Section II the registration procedure is explained. In Section III experimental results are presented and discussed. Section IV draws the conclusion.

II. IMAGE REGISTRATION METHOD

The image registration method, which we have chosen to automatically align scanned images to the original ones, is feature based. Around each image we have placed a black border which is 2 pixels thick. This results in an image which size is 1028×1028 pixels. To make border more visible and to reduce printer toner consumption, all images have been inverted to negatives. Figure 1 shows an example of original image and the image prepared for printing.

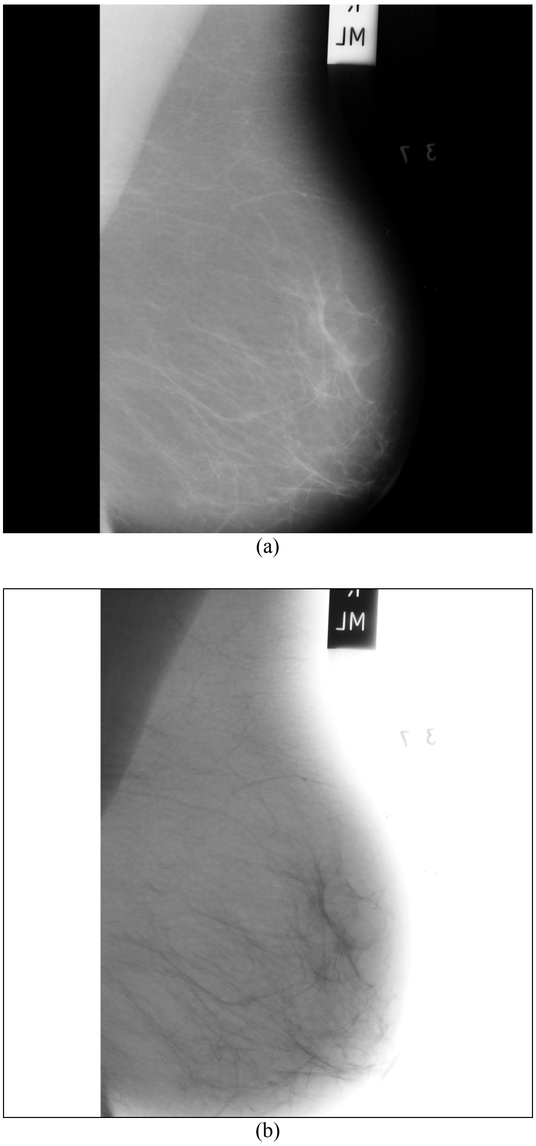


Figure 1. (a) Original image "mdb006". (b) Same image inverted with added border prepared for printing.

Images have been printed on a standard monochrome laser printer where resulting size of each image, including border, was 16×16 cm. Scanning process returned images which need to be registered to match the originals. Because of non-perfect printing and scanning conditions, scanned images suffer from slight rotation and translation in both horizontal and vertical direction. It is important to stress out that these imperfections are different for each image and therefore each image requires registration using different coefficients. Fig. 2 shows how the resulting scan of the printed image looks like.

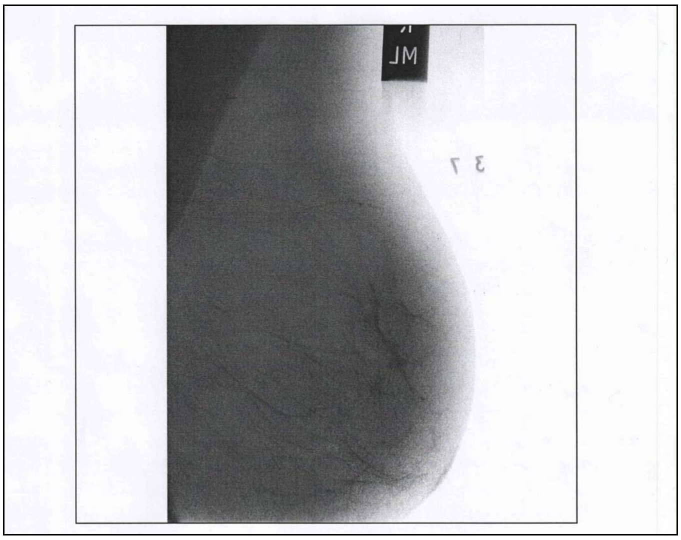


Figure 2. Scanned image which was printed on a monochrome laser printer.

The image shown in Fig. 2 needs to be registered so that we can align it with the original. It is obvious that this process mostly introduce horizontal and vertical shift while rotation does not have a big influence. Corner detection, needed to detect area of interest in the entire scanned image, is performed through a straight line detection using Hough transform. This procedure makes detecting edge coordinates easier. The entire registration process is shown in Fig. 3.

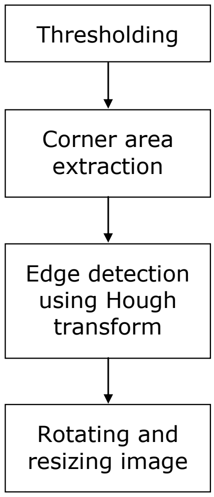


Figure 3. Diagram of the entire registration procedure.

Scanned images are stored with 8 bits per pixel, which gives 256 discrete intensities. Thresholding has been applied to intensities [0,100). From the binary image obtained with thresholding, we have extracted areas which should contain corners. To those areas, which are significantly smaller that the entire image, we have applied Hough transform (1):

$$r = x\cos(\theta) + y\sin(\theta), \tag{1}$$

where r represents the distance between the line and the origin, while θ is the angle of the vector from the origin to the observed point. The origin coordinates are (1, 1) in the actual image. In the area which contains corner, as shown in Fig. 4 (a), there are only two dominant lines which, when converted to Hough space, are represented as two bright points. In the Hough space it is easy to detect maximums which now represent two longest lines in the image, as shown in Fig. 4 (b).

(a) (b)

Figure 4. (a) Thresholded area which contains corners. (b) Corner area converted to Hough space.

To eliminate detection of other unwanted lines which can exist in the area of the image around corner that we want to detect, it is possible to limit the search area in the Hough space. Since we know that the corner we are trying to detect cannot be rotated and translated too much, we have chosen to limit the detection of vertical lines between 75º and 105º and detection of the horizontal lines lies between 345º and 15º. After detecting two best candidates, their intersection is taken as the corner coordinate. To be able to calculate intersection point, we had to calculate the exact equation of each straight line. After calculating coordinates for all four corners it is possible to calculate the rotation angle and possible variation between horizontal and vertical dimension. The rotation angle has been calculated as the mean value of differences between corner coordinates on each of four edges (2):

$$\varphi = \arctan\left(\frac{n2 - n1 + n4 - n3 + m3 - m1 + m4 - m2}{m2 - m1 + m4 - m3 + n3 - n1 + n4 - n3}\right), \qquad (2)$$

where mi and nj are x and y coordinates of the detected corners, as shown in Fig. 5.

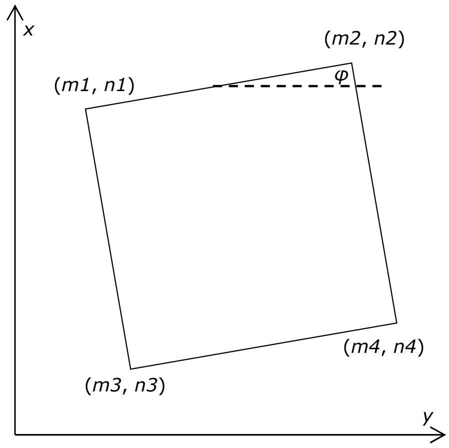


Figure 5. Corner coordinates and rotation angle φ of the scanned image.

After rotating image for the calculated angle φ, we have to crop image outside of the detected edge. This results in final image which needs to be resized to match the dimensions of the original image which are 1028×1028 pixels including the border. Differences in dimensions between original and rotated image result in two scaling factors, s_h and s_v which are being used for image resizing (3):

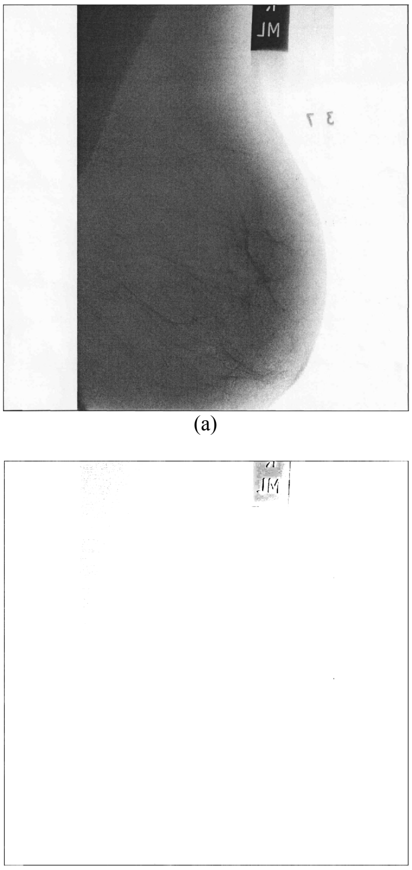
$$s_{h,v} = \frac{H_{orig}, V_{orig}}{H_{scan}, V_{scan}}, \qquad (3)$$

where H and V are horizontal and vertical dimension in pixels respectively. Image resizing has been achieved using bi-linear interpolation.

III. Experimental Results

The experimental test set which we have used is consisted of 322 8-bit grayscale images with size of 1024×1024 pixels. All images are publicly available and form the mini-MIAS database. All images have been prepared for printing and printed on standard monochrome laser printer. Resulting images have size of 16×16 cm on A4 paper format. After printing, images have been scanned and stored in JPEG format. Resulting image size was 3507×2550 pixels. Automatic registration algorithm has been applied to all images in the test set. Registration accuracy has been tested by comparing registered scan images with originals. For better error visualization, we have subtracted original image from registered images. Resulting difference images have been inverted in order to show differences more clear.

There are many possible methods to calculate and present registration accuracy. If the images are, as in our case, marked with any kind of known-position markers, we can simply calculate translation accuracy in vertical and horizontal dimension and rotation angle. The other approach would be calculating the mean square error, but that method is not very exact because image contents would have a large impact on achieved accuracy, because images containing low spatial frequency components would achieve much better results than images containing mostly high spatial frequencies. Fig. 6 (a) presents registered image and (b) inverted difference image between original and registered image.



(a)

(b)

Figure 6. (a) Registered image. (b) Difference image between original and registered image.

Fig. 6 (b), which represents differences, is shown with boosted contrast to make differences more visible. It is clear that after the proposed registration process images are almost perfectly aligned and difference between them is very small which is important for the extraction of segmentation masks performed by radiologists.

IV. Conclusion

In this paper we have presented an image registration method which uses markers to align original images with printed and scanned images. As markers, we have used image corners which were detected using Hough transform. The proposed method has been tested on the mini-MIAS database containing 322 images. The registration method aligns images by horizontal and vertical translation and rotation. Comparison of registered images with originals using mean square error calculation could give misleading results because printing and scanning process change local intensities and error would be significant even in the case of perfectly aligned image. Therefore we could only compare accuracy of horizontal and vertical translations by comparing edge alignments. The overall translation accuracy is within 2 pixels in both horizontal and vertical directions which is acceptable for larger images. This accuracy would be similar even for larger images, because it is mostly caused by printing and scanning imperfections. Our future work will include converting images which are manually segmented by radiologists using the method proposed in this paper to digital breast segmentation masks which would make possible to compare quality of automatic segmentation algorithms with manual segmentation, where manual segmentation can be considered as ground truth.

Acknowledgment

The work described in this paper was conducted under the research project "Intelligent Image Features Extraction in Knowledge Discovery Systems" (036-0982560-1643), supported by the Ministry of Science, Education and Sports of the Republic of Croatia.

References

[1] T. Ojala, J. Nappi, O. Nevalainen, "Accurate segmentation of the breast region from digitized mammograms", Computerized Medical Imaging and Graphics, Vol. 25, Issue 1, pp. 47-59, January 2001.

[2] S. Tzikopoulos, H. Georgiou, M. Mavroforakis, N. Dimitropoulos, S. Theodoridis, "A fully automated complete segmentation scheme for mammograms", 16th International Conference on Digital Signal Processing, pp. 1-6, 5-7 July 2009.

[3] J. Suckling, J. Parker, D.R. Dance, S. Astley, I.Hutt, C.R.M. Boggis, I. Ricketts, E. Stamatakis, N. Cernaez, S.L. Kok, P. Taylor, D. Betal, J. Savage, "The Mammographic Image Analysis Society Digital Mammogram Database", Proceedings of the 2nd International Workshop on Digital Mammography, York, England, pp. 375-378, 10-12 July 1994.

[4] B. Zitova, J. Flusser, "Image registration methods: a survey", Image and Vision Computing, Vol. 21, Issue 11, pp. 977-1000, 2003.

[5] D.H. Ballard, "Generalizing the Hough transform to detect arbitrary shapes", Pattern Recognition, Vol. 13, No. 2, pp. 111-122, 1981.

[6] J.B.A. Maintz, M.A. Viergever, "A survey of medical image registration", Medical Image Analysis, Vol. 2, Issue 1, pp. 1-36, March 1998