PROCESSING OF THERMAL IMAGES
TO DETECT BREAST CANCER: COMPARISON WITH PREVIOUS WORK

Monique Frize[1,2], Christophe Herry[1], Roger Roberge[3]
[1]Department of Systems and Computer Engineering, Carleton University, Ottawa, Ontario, Canada
[2]School of Information Technology and Engineering, University of Ottawa, Ottawa, Ontario, Canada
[3]The Moncton Hospital, Moncton, New Brunswick, Canada

*Abstrac*t- **In the early 1980s, thermography began to be used to detect pain and breast cancer. However, the images were interpreted through the naked eye, and thus subtle differences were difficult to identify. More recently, widespread use of PCs led to the application of computer processing to the analysis of thermal images. For example, Head et al. [1] reported three methods to calculate temperature differences between the right and left breast to help detect and diagnose breast cancer. Their analysis of 13 patients had better results with their 3rd method than with their methods 1 and 2, but still showed 3 false positives out of 10 patients who were diagnosed as "normal" and 1 false negative out of 3 patients diagnosed with cancer. We applied these authors' three techniques to nine of our patients (6 with a diagnosis of normal and 3 with cancer) and found that only method 3 provided reliable results. With the lower threshold of 1 degree C suggested by Head et al. [1], we had 2 false positives. However, when we raised the threshold to of normalcy to 1.5 degrees C (instead of 1), we found no false negatives or false positives on this sample of nine patients. Future work should focus on improving the third approach and find new ways of enhancing differences, which would be significant for a correct diagnosis. These preliminary results are encouraging but a properly designed prospective clinical trial needs to be done to show if this technique can play a useful role in the future or not.**
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I. INTRODUCTION

The use of thermography in applications of detection of pain, or in identifying the presence of breast cancer is not new [2-4]. However, in spite of the enthusiasm of its early proponents, making a diagnostic simply through the naked human eye, to differentiate a number of levels of gray, made it very difficult to detect small differences in symmetry between the right and left breast, or asymmetries in the detection of pain. With advances in computer technology and the power available in current PCs, the possibility of performing digital processing of these thermal images, to detect subtle difference in symmetry, became an exciting prospect to explore the potential of thermography used for medical diagnoses problems. The current most "trusted" test for the detection of breast cancer is mammography, but that involves the use of ionizing radiation and uncomfortable tests such as high compression of the breasts. Thermography, on the other hand, involves no ionizing radiation and the test is quite comfortable and analogous to the simple taking of a photograph. There is no contact with the patient. Moreover, early researchers such as Gautherie et al. believed that thermography would have potential in detecting early changes in blood flow which would show as an asymmetry between the two breasts.

II. METHODOLOGY

At a breast cancer screening clinic at The Moncton Hospital, between March and November 1984, thermal images of 86 patients (mostly women and a few men) were recorded. Patients were referred to Dr. Roberge and the images were taken and recorded by Monique Frize and Yves Poussart. The equipment was a first generation thermographic camera Thermovision 680 (Agatronics) and connected to an OSCAR 780 (Off-line System for Computer Access & Recording (Agatronics). We designed our own computer interface to transfer the images on a PC. In 1984, we had a Radio Shack first generation computer, which severely limited the type of analysis we could do. To collect our data in Moncton, a rigid protocol was followed to ensure best results. The tests were performed in the week following menstruation or between the 6th and 10th day of the cycle, up to the 13th day. The patient was asked to avoid alcohol. Caffeine, pain medication lotions, and stop smoking two hours before the test. The chest area was cooled slightly with a fan for approximately 10 minutes just prior to the image taking. The room was at approximately 22 degrees C. and darkened during the test. Then the images were taken and stored on a digital tape recorder for later playback and analysis. This approach provides the best temperature contrast between hot and cold areas on the body. The matrix for each image consists of 128 X 128 pixels. The gray scale values range from 0 to 255 and were mapped to temperature values using the mean temperature value obtained from the camera as a reference. Using an IBM PC, we applied the three analytical methods reported by Head et al. [1] to our own database of thermal breast images, compared our results with these authors, and then with real data obtained for our patient base.

For our current analysis, we decided to first use an existing set of tests and compare our results with these authors' results. Head et al [1] suggested calculating the mean, median, standard deviation, skewness, and minimum and maximum temperature for each breast. As per his suggestion, our program also allows users to select the region that needs to be analyzed (called region of interest, or ROI). Then the program computes the statistics of thermal distribution as described above for each breast. Head et al.'s 3 methods were applied to our own images in the following manner:

(1) The mean temperature of each breast was compared and if the difference was greater than 0.5 degree C, the test was called "abnormal".

(2) This method consisted of the calculation of a score based on the addition of scores to create an index; if the mean temperature of a quadrant was 0.5 to 1 degree C higher than the same quadrant of the opposite breast, then a score of 0.5 was assigned. When a quadrant had a mean temperature greater than 1 degree C, then a score of 1 was assigned. The index is created by adding together the scores for the comparisons of all four quadrants and the index could have a value of between 0 and 4. The authors considered an index greater than 1 to be abnormal.

(3) This method involved the simple addition of the mean differences of the quadrants comparing left and right breasts and absolute differences greater than 1 were considered abnormal.

To Head et al.'s methods, we added the creation of histograms for each breast in order to present a quick visual display of the temperature distribution in each breast and identify cold and hot spots.

III. RESULTS

Of Head et al's methods, only method 3 worked well on our database and only if we changed the threshold of abnormalcy. Head et al.'s results with method 3 reported 7 true negatives and 3 false positives for 10 normal patients and 1 false negative and 2 true positives for patients diagnosed with cancer. In our case, if we use Head et al.'s method 3 as it was presented [1], we find 2 false negatives. However, if we raise the threshold of normalcy to more than 1.5 degrees C, then method 3 was able to identify all normals and all abnormals correctly for our nine patients. The other two methods produced results that accurately tagged only half of our patients correctly. A table of results of the three methods with our data will be presented at the conference as well as histograms of normal and abnormal breast temperature patterns.

Temperature differences obtained with Method 3 were: For 6 patients later diagnosed as normal, values were: 1.23, 0.175, 1.009, 0.138, 0.064, 0.999; for 3 patients later diagnosed with cancer, values were: 1.895, 6.963, 2.398.

IV. CONCLUSION

In the early days of thermographic imaging, it was difficult to identify abnormalities in breast tissue, particularly if these were characterized by very small temperature differences. The availability of powerful desk top PCs have allowed the development of analytical techniques and refine the interpretation of thermograms. The technique is not expensive, fairly easy to use, does not involve ionizing radiation, and is quite comfortable for patients. It is important to point out that the methods described by Head et al. and reproduced here with our own data used an arbitrary threshold to classify patients predicted to be normal and those with cancer. There needs to be much more substantial work done on large numbers of patients in order to assess the validity of such choices.

Future work should focus on improving the third approach and find new ways of enhancing differences which would be significant for a correct diagnosis. These preliminary results are encouraging but a prospective study with a much larger sample is needed to establish whether this technique can play a useful role in the future or not. Improvements can be made in an iterative manner until the method is ready for a clinical trial. One study done by literature search (PubMed) has concluded that there was a similar performance in the specificity and sensitivity (true negatives and true positives respectively) of the thermogram results and those achieved by the mammogram [5]. Prior to changing attitudes on the use of this technology, it would be helpful to carry-out well-planned with rigid standardized protocol to compare the performance of these two technologies. Thermography, if improved and tested to the point of clinical applicability, would be a complementary technique to mammography and ultrasound, with a primary function in screening dense breasts and women at risk could be tested more frequently than mammograms allow.

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