

A Computer-Aided Diagnosis Tool For Objective Assessment Of Tumors Using Infrared Imaging

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Abstract - Medical imaging has become an essential and integrated part of modern medical care and is depended upon a wide range of medical specialists. Infrared thermography has become a diagnostic aid for monitoring the therapeutic effect and disease progression. Thermal imaging or Infrared Imaging refers to mapping of temperature profiles on the surface of an object. It has been investigated that it is a potential tool for the detection of breast cancer. To delineate the breast region and get the exact boundaries from the unsharp IR image, Hough transform has been used. Thermal Image processing is also done to diagnose the Diabetes Mellitus in defined automated way. The Optimal methods identified can have prediction of diabetes at an earlier stage. The objective is to develop a Computer aided diagnosis (CAD) tool for objective assessment of tumor response to therapy and it provides quantitative parameters representing the tissue composition of the tumor these results should assist in planning therapy and delayed surgery. Sensitivity of the technique can be improved by a hybrid method in which it is combined with Ville Marie grading score which gives additional mean temperature difference taken in the foot region. This paper uses thermal images of diabetic foot instead of mammograms.

Key words: Infrared Imaging, Computer-Aided Diagnosis

I. INTRODUCTION

Mammography is used to examine human breast and is used as a diagnostic tool. The advantage of mammography is early detection of masses. Mammography remains difficult in some places to detect suspicious region of interest. Region of interest is segmented to analyze abnormalities. The segmented region of interest is then classified to mass or non mass [1]. CAD helps to detect true positive masses and remove false positives. In order to reduce the increasing workload and improve the accuracy of interpreting mammograms, a variety of CAD systems, that perform computerized mammographic analysis have been proposed. These systems are usually employed as a second reader, with the final decision regarding the presence of a cancer left to the radiologist. Thus, their role in modern medical practice is considered to be significant and important in the early detection of breast cancer. All of the CAD systems require, as a first stage, the segmentation of each mammogram into its representative anatomical regions, i.e., the breast border and pectoral muscle. The breast border extraction is a necessary and cumbersome step for typical CAD systems, as it must identify the breast region independently of the digitization

system, the orientation of the breast in the image and the presence of noise, including imaging artifacts.

II. LITERATURE SURVEY ON NATIONAL & INTERNATIONAL SCENARIO

The research on Breast Cancer is on higher note both clinically and technically. Breast cancer is the second leading cause of cancer deaths in women today (after lung cancer) According to WHO, more than 1.2 million people will be diagnosed with breast cancer every year worldwide. Every two minutes a woman in the US is diagnosed with breast cancer and one woman dies from the disease every 13 minutes Breast cancer incidence in women has increased from one in 20 in 1960 to one in seven today.

Thermography is best suited for Breast Imaging; Twenty-five percent of women die within the first year after diagnosis. Seventy percent of breast cancers occur in women with no family history of breast cancer. Over ninety percent of women with stage one breast cancer are alive five years later, but only fifty eight percent of breast cancers are diagnosed at this stage. When breast thermography is the first sign of a developing cancer, there is a 61% increase in survival rate. So there is need of Accurate and consistent analysis in earlier detection of breast cancer. So many educational programs started in India on this issue to create awareness but it is not reaching the masses as many are illiterates and are in rural areas. Now there is an urgent need to bridge the link between diseases and its related complications by making the efforts to make India free from deadly diseases by solving complications from Thermography Images.

III. EXISTING SYSTEM

Magnetic resonance imaging (MRI), computed tomography (CT), digital mammography, and other imaging modalities provide an effective means for noninvasively mapping the anatomy of a subject. Mammography is a low dose x-ray procedure for the visualization of internal structure of breast. Mammography has been proven to be the most reliable method and it is the key screening tool for the early detection of breast cancer. Mammography is highly accurate, but like most medical tests, it is not perfect. On average, mammography will detect about 80–90% of the breast cancers in women without symptoms. Mammography is used to examine human breast and is used as a diagnostic tool. The advantage of mammography is early detection of masses. Mammography remains difficult in some places to detect suspicious region of interest. Region of interest is segmented to analyze abnormalities.

IV. PROPOSED SYSTEM

For early detection of breast cancer considerable research efforts have been devoted to develop Computer-Aided Detection (CAD) systems, which would be beneficial for detecting breast lesions. CAD alerts radiologists to locate suspicious locations on the images during mammographic reading. CAD helps to detect true positive masses and remove false positives. The steps in breast cancer detection using CAD are

- 1) Pre-processing
- 2) ROI Segmentation and Feature Extraction
- 3) Denoising Using Filter
- 4) Edge Detection
- 5) Thresholding
- 6) Hough transform

The block diagram shown in Figure1 is the proposed method which was implemented using Beagle Board.

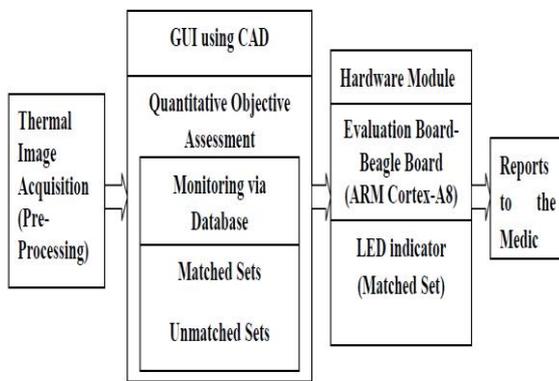


Figure1. Block diagram of the proposed method

A. PREPROCESSING

CAD systems generally consist of the following four stages: image preprocessing (enhancement), ROI segmentation, feature extraction, and classification. Image preprocessing techniques are necessary, in order to find the orientation of the mammogram, to remove the noise and to enhance the quality of the image. Before any image-processing algorithm can be applied on mammogram, preprocessing steps are very important in order to limit the search for abnormalities without undue influence from background of the mammogram. Digital mammograms are medical images that are difficult to be interpreted, thus a preparation phase is needed in order to improve the image quality and make the segmentation results more accurate. The main objective of this process is to improve the quality of the image to make it ready to further processing by removing the unrelated and surplus parts in the back ground of the mammogram. Preprocessing may also involve in creating mask for pixels with highest intensity, to reduce resolutions and to segment the breast.

The Arithmetic and Logical operation are performed on a pixel- by-pixel basis between two images. Addition of images results in a new image whose pixel at coordinates (x, y) is the sum of pixels at the same location in the two images being added. The other arithmetic operations like Subtraction, Multiplication and Division also involve the same process.

Intensity operations are used either to enhance or degrade the intensity values of pixels in an image thereby overall image intensity either gets increased or decreased.

$b = \text{imadd}(a, 50);$

$c = \text{imsubtract}(a, 50);$

$\text{IM2} = \text{imcomplement}(\text{IM})$ computes the complement of the image IM. IM can be a binary, grayscale, or RGB image. IM2 has the same class and size as IM.

$d = \text{imcomplement}(a);$

In the complement of a binary image, zeros become ones and ones become zeros; black and white are reversed. In the complement of an intensity or RGB image, each pixel value is subtracted from the maximum pixel value supported by the class (or 1.0 for double-precision images) and the difference is used as the pixel value in the output image. In the output image, dark areas become lighter and light areas become darker.

B. ROI SEGMENTATION AND FEATURE EXTRACTION

ROI segmentation and feature extraction are prerequisite steps prior to performing classification of ROIs. In Segmentation the inputs are images and, outputs are the attributes extracted from those images. Segmentation divides image into its constituent regions or objects. The level to which segmentation is carried out depends upon the problem being solved. The CAD systems used Fourier Transforms with convolution for the segmentation and feature extraction.

Fourier Transform is an integral transform of one function into another. The Fourier Transform is an important image processing tool which is used to decompose an image into its sine and cosine components. The output of the transformation represents the image in the Fourier or frequency domain, while the input image is the spatial domain equivalent. In the Fourier domain image, each point represents a particular frequency contained in the spatial domain image. In image processing, Fourier Transform is used in a wide range of applications, such as image analysis, image filtering, image reconstruction and image compression. From the variants of the Fourier Transform Discrete Fourier Transform (DFT) is the variant used in digital image processing. The DFT is the sampled Fourier Transform. That is why DFT does have all the frequencies which form the image, but only a set of samples which is large enough to fully describe the spatial domain image. The number of frequencies corresponds to the number of pixels in the spatial domain image, i.e. the image in the spatial and Fourier domains are of the same size. For a square image of size $N \times N$, the two-dimensional DFT is given by:

$$F(k, l) = \frac{1}{N^2} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} f(i, j) e^{-2\pi i \left(\frac{ki}{N} + \frac{lj}{N} \right)}$$

$f(i, j)$ is the image in the spatial domain and the exponential term is the basis function corresponding to each point $F(k, l)$ in the Fourier space. The equation can be interpreted as: the value of each point $F(k, l)$ is obtained by multiplying the spatial image with the corresponding base function and

summing the result. The basis functions are sine and cosine waves with increasing frequencies, i.e. $F(0,0)$ represents the DC-component of the image which corresponds to the average brightness and $F(N-1,N-1)$ represents the highest frequency. In a similar way, the Fourier image can be re-transformed to the spatial domain. The inverse Fourier transform is given by:

$$f(i, j) = \frac{1}{N^2} \sum_{k=0}^{N-1} \sum_{l=0}^{N-1} F(k, l) e^{2\pi i \left(\frac{ki}{N} + \frac{lj}{N} \right)}$$

To obtain the result for the previous equations, a double sum has to be calculated for each image point. However, because the Fourier Transform is separable, it can be written as:

$$F(k, l) = \frac{1}{N} \sum_{j=0}^{N-1} P(k, j) e^{-2\pi i \left(\frac{lj}{N} \right)}$$

Where

$$P(k, j) = \frac{1}{N} \sum_{i=0}^{N-1} f(i, j) e^{-2\pi i \left(\frac{ki}{N} \right)}$$

Using those last two formulas, the spatial domain image is first transformed into an intermediate image using N one-dimensional Fourier Transforms. This intermediate image is then transformed into the final image, again using N one-dimensional Fourier Transforms.

Expressing the two-dimensional Fourier Transform in terms of a series of $2N$ one-dimensional transforms decreases the number of required computations. The ordinary one-dimensional DFT still has complexity which can be reduced with the use of Fast Fourier Transform (FFT) to compute the one dimensional DFTs. It is a significant improvement, in particular for large images. There are various forms of the FFT and most of them restrict the size of the input image that may be transformed, often to where n is an integer. The Fourier Transform produces a complex number valued output image which can be displayed with two images, either with the real and imaginary part or with magnitude and phase. In image processing, often only the magnitude of the Fourier Transform is displayed, as it contains most of the information of the geometric structure of the spatial domain image. The Fourier image can also be re-transformed into the correct spatial domain after some processing in the frequency domain (both magnitude and phase of the image must be preserved for this). The Fourier domain image has a much greater range than the image in the spatial domain. Hence, to be sufficiently accurate, its values are usually calculated and stored in float values.

C. DENOISEING USING FILTER

One of the most important problems in image processing is denoising. Usually the procedure used for denoising, is dependent on the features of the image, aim of processing and also post-processing algorithms. Denoising by low-pass filtering not only reduces the noise but also blurs the

edges. Spatial and frequency domain filters are widely used as tools for image enhancement. Low pass filters smooth the image by blocking detail information. Image noise is random (not present in the object imaged) variation of brightness or color information in images, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is an undesirable by-product of image capture that adds spurious and extraneous information.

Salt-and-pepper noise

Fat-tail distributed or "impulsive" noise is sometimes called salt-and-pepper noise or spike noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. This type of noise can be caused by analog-to-digital converter errors, bit errors in transmission, etc. It can be mostly eliminated by using dark frame subtraction and interpolating around dark/bright pixels. Salt and pepper noise is a form of noise typically seen on images. It represents itself as randomly occurring white and black pixels. An effective noise reduction method for this type of noise involves the usage of a median filter, morphological filter or a contra harmonic mean filter. Salt and pepper noise creeps into images in situations where quick transients, such as faulty switching, take place.

Gaussian filter is a filter whose impulse response is a Gaussian function (or an approximation to it). Gaussian filters have the properties of having no overshoot to a step function input while minimizing the rise and fall time. This behavior is closely connected to the fact that the Gaussian filter has the minimum possible group delay. It is considered the ideal time domain filter, just as the sinc is the ideal frequency domain filter. These properties are important in areas such as oscilloscopes and digital telecommunication systems. Mathematically, a Gaussian filter modifies the input signal by convolution with a Gaussian.

Gaussian noise

Principal sources of Gaussian noise in digital images arise during acquisition eg. sensor noise caused by poor illumination and/or high temperature, and/or transmission eg. electronic circuit noise. The standard model of this noise is additive, independent at each pixel and independent of the signal intensity, caused primarily by Johnson-Nyquist noise (thermal noise), including that which comes from the reset noise of capacitors ("kTC noise") Amplifier noise is a major part of the "read noise" of an image sensor, that is, of the constant noise level in dark areas of the image. In color cameras where more amplification is used in the blue color channel than in the green or red channel, there can be more noise in the blue channel.

D. EDGE DETECTION

Edge detection is the name for a set of mathematical methods which aim at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. The points at which image

brightness changes sharply are typically organized into a set of curved line segments termed *edges*. The same problem of finding discontinuities in 1D signal is known as step detection and the problem of finding signal discontinuities over time is known as change detection. Edge detection is a fundamental tool in image processing, machine vision and computer vision, particularly in the areas of feature detection examples of operators such as Canny, Sobel, Kayyali,...etc. and feature extraction.

Sobel edge detection

The gradient of the image is calculated for each pixel position in the image. The magnitude of the vector Δf is denoted as,

$$\Delta f = \text{mag}(\Delta f) = [G_x^2 + G_y^2]^{1/2}$$

where G_x is for x direction and G_y for y direction. The Sobel masks (3x3):

$$\text{For x-direction} \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$\text{For y-direction} \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Canny edge detection

John Canny considered the mathematical problem of deriving an optimal smoothing filter given the criteria of detection, localization and minimizing multiple responses to a single edge. He showed that the optimal filter given these assumptions is a sum of four exponential terms. He also showed that this filter can be well approximated by first-order derivatives of Gaussians. Canny also introduced the notion of non-maximum suppression, which means that given the pre smoothing filters, edge points are defined as points where the gradient magnitude assumes a local maximum in the gradient direction. Looking for the zero crossing of the 2nd derivative along the gradient direction was first proposed by Haralick. It took less than two decades to find a modern geometric variational meaning for that operator that links it to the Marr-Hildreth (zero crossing of the Laplacian) edge detector. That observation was presented by Ron Kimmel and Alfred Bruckstein. Although his work was done in the early days of computer vision, the Canny edge detector (including its variations) is still a state-of-the-art edge detector. Unless the preconditions are particularly suitable, it is hard to find an edge detector that performs significantly better than the Canny edge detector.

The Canny-Deriche detector was derived from similar mathematical criteria as the Canny edge detector, although starting from a discrete viewpoint and then leading to a set of recursive filters for image smoothing instead of exponential filters or Gaussian filters.

The differential edge detector described below can be seen as a reformulation of Canny's method from the viewpoint of differential invariants computed from a scale space representation leading to a number of advantages in terms of both theoretical analysis and sub-pixel implementation.

E. THRESHOLDING

The simplest approach to segment an image is using thresholding. If $f(x, y) > T$ then $f(x, y) = 0$ else $f(x, y) = 255$.

Threshold Techniques: These techniques are based on the postulate that all pixels whose value (gray level, color value, or other) lies within a certain range belong to one class. Such methods neglect all of the spatial information of the image and do not cope well with noise or blurring at boundaries. For mammograms, thresholding usually involves selecting a single gray level value from an analysis of the grey-level histogram, to segment the histogram into background and breast tissues. All the pixels with grey level value less than the threshold are marked as background and the rest as breast [14]. Thresholding uses only grey level value and no spatial information is considered. Therefore, the major shortcoming of the threshold is that there is often an overlap between grey levels of the objects in the breast and the background.

Otsu's method

A measure of region homogeneity is variance (i.e., regions with high homogeneity will have low variance). Otsu's method selects the threshold by minimizing the within-class variance of the two groups of pixels separated by the thresholding operator. It does not depend on modeling the probability density functions, however, it assumes a bimodal distribution of gray-level values (i.e., if the image approximately fits this constraint, it will do a good job).

F. HOUGH TRANSFORM

The Hough transform is a feature extraction technique used in image analysis, computer vision, and digital image processing. The purpose of the technique is to find imperfect instances of objects within a certain class of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough transform. In automated analysis of digital images, a sub problem often arises of detecting simple shapes, such as straight lines, circles or ellipses. In many cases an edge detector can be used as a pre-processing stage to obtain image points or image pixels that are on the desired curve in the image space. Due to imperfections in either the image data or the edge detector, however, there may be missing points or pixels on the desired curves as well as spatial deviations between the ideal line/circle/ellipse and the noisy edge points as they are obtained from the edge detector. For these reasons, it is often non-trivial to group the extracted edge features to an appropriate set of lines, circles or ellipses. The purpose of the Hough transform is to address this problem by making it possible to perform groupings of edge points into object candidates by performing an explicit voting procedure over a set of parameterized image objects.

V. IMPLEMENTATION

The project is implemented using Beagle Board; Beagle boards are tiny computers with all the capability of today's desktop machines, without the bulk, expense, or noise. Besides, it supports the following features:

Built-in networking

Not only does the Beagle Bone have an on-board Ethernet connection, but all the basic networking tools that come packaged with Linux are available. You can use services like FTP, Telnet, SSH, or even host your own web server on the board.

Remote access

Because of the built-in network services, it makes it much easier to access electronics projects remotely over the Internet. For example, if you have a data-logging project, you can download the saved data using an FTP client or you can even have your project email you data automatically. Remote access also allows you to log into the device to update the code.

Timekeeping

Without the need for extra hardware, the board can keep track of the date and time of day and can be updated by pinging Internet time servers using the network time protocol (NTP), ensuring that it's always accurate.

File system

Just like our computers, embedded Linux platforms have a built-in file system, so storing, organizing, and retrieving data is a fairly trivial matter.

VI. COMPUTATIONAL EFFICIENCY MEASUREMENTS

The values in Table1 are computed using MIPAV and Astroart software which gives the quantitative data for the thermal image considered.

Using MIPAV:

Image	Threshold
VOI	VOIContour_0
Number of Voxels	24759

Using Astroart:

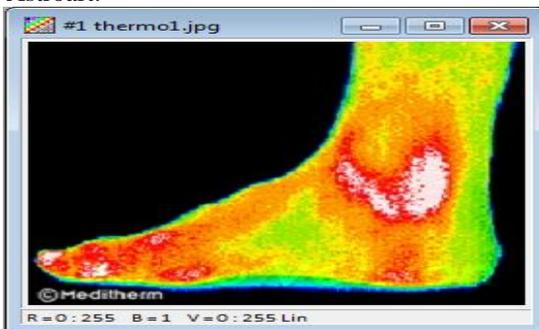


Figure2. Input Image

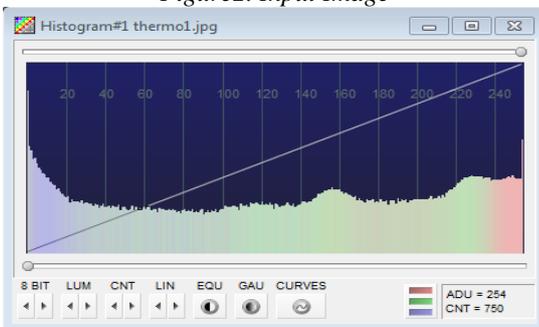


Figure3. Histogram plot of the thermal image

Use many different programming languages

You can write your custom code in almost any language you're most comfortable with: C, C++, Python, Perl, Ruby, or even a shell script.

Multitasking

Unlike a typical 8-bit microcontroller, embedded Linux platforms are capable of sharing the processor between concurrently running programs and tasks. This means that if your project needs to upload a large file to a server, it doesn't need to stop its other functions until the upload is over.

Linux software

Much of the Linux software that's already out there can be run on the Beagle Bone.

Linux support

There's no shortage of Linux support information out on the web and community help sites like Stack Overflow come in handy when a challenge comes along.

Area		24759		
Perimeter		1059.0563		
Line	Name	Mean	Standard Deviation	Length
Red	VOIContour_0	247.86073	13.726098	1059.06
Green	VOIContour_0	200.49059	84.466385	1059.06
Blue	VOIContour_0	13.633626	26.928446	1059.06

Table1. VOI properties of the thermal image.

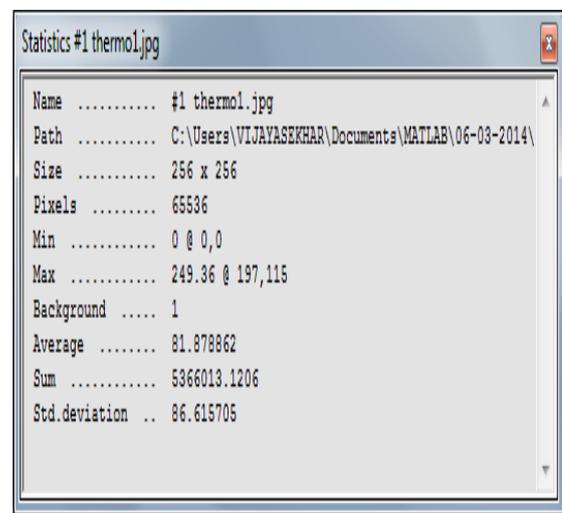


Figure4. Image Statistics

VII. EXPERIMENTAL RESULTS

Following are results obtained using MATLAB R2013a for the thermal image of a diabetic foot.

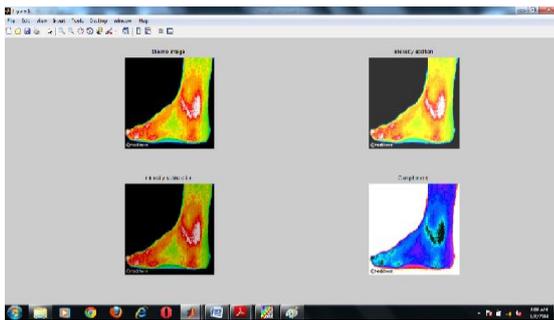


Figure5. Arithmetic operations on thermal image

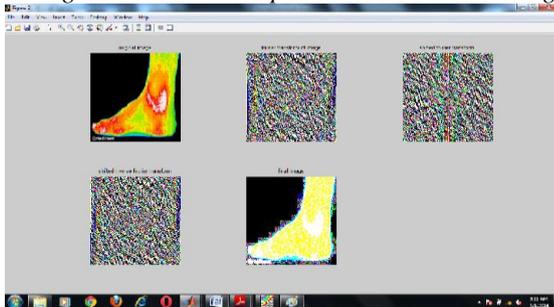


Figure6. FFT operation

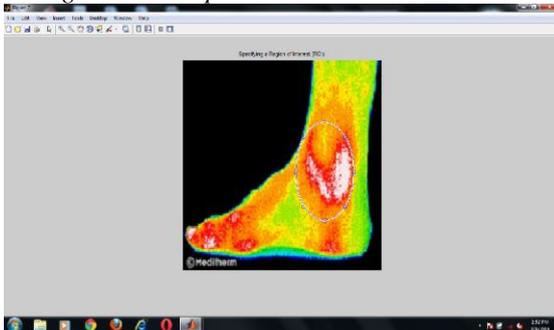


Figure7. Specifying ROI

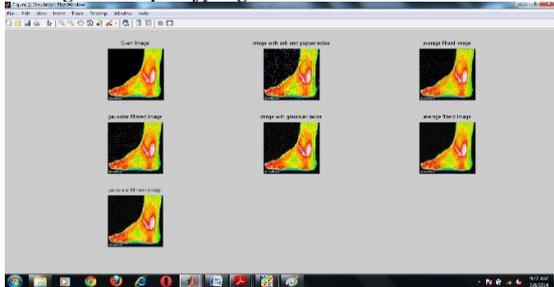


Figure8. Denoising using filters

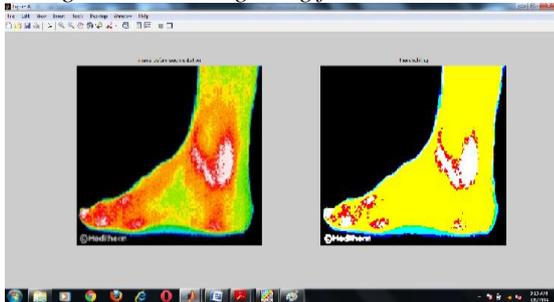


Figure9. Thresholding

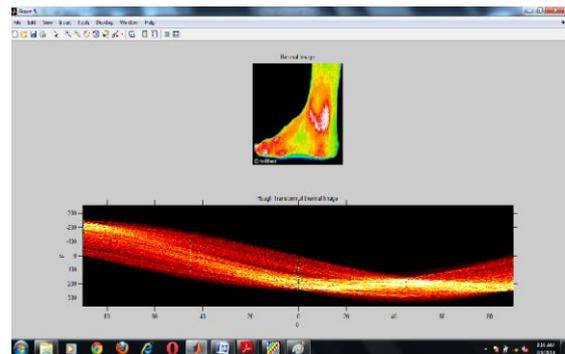


Figure10. Hough Transform

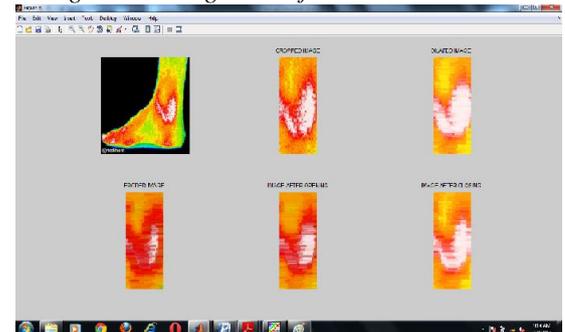


Figure11. Cropping

VIII. CONCLUSION

From the historic and simple assessment of temperature by the clinical thermometer, modern infrared technology has opened up new perspectives, especially in the use of thermal imaging to map body surface temperature with a remote sensing camera. Since the 1960s, there is now a greater understanding of thermal physiology and the relationship between skin temperature and blood perfusion. Furthermore, the examination technique, and the advantages of computer-aided digital imaging has greatly improved the reliability of this technology in medicine. Studies in diabetology have shown the value of this new facility and its relevance to clinical assessment of peripheral perfusion and tissue viability. Computer Aided Diagnosis (CAD) provides techniques for automatic detection of breast cancer. It gives benign/malignant classification. It reduces the number of unnecessary biopsies.

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