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DETECTION OF ABNORMALITIES IN THERMAL IMAGES USING ENHANCEMENT TECHNIQUES

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ABSTRACT- Digital thermal imaging is considered as a non-invasive diagnostic tool and a real-time monitoring technique for indicating the physiological changes of the underlying tissue from the superficial thermal signature. A thermal camera can detect temperature variations in the body, as low as 0.1°C. The observed colour pattern depends on the prevailing temperature of the target in a controlled environment. This colour-based thermal pattern is further processed for identifying abnormalities. This process of identification is done by applying various methods such as histogram equalisation, Otsu thresholding and morphologic function. These steps are applied to thermal images of a foot acquired from volunteers and abnormalities were identified. The identification process was based on a threshold obtained from the histogram and it was found to be in the range of 76–80.

I. INTRODUCTION

Necrotizing Enterocolitis (NEC) is the most common and devastating inflammatory disease affecting the gastrointestinal (GI) tract of neonates. In statistical analysis of the population at risk, NEC has been found to occur in roughly 7% of preterm infants with very low birth weight (VLBW). Of those patients that don't require surgery the mortality rate is 15-25%, and heightens to 40% with those that require surgery. Despite decades of research, preventative methods remain elusive and the exact mechanisms of the disease remain unknown. This complex multi-factorial disease typically presents within the first two weeks of life. NEC poses a significant clinical challenge because early signs and symptoms are subtle and nonspecific. The onset of disease can trigger an inflammatory cascade; when left untreated rapid deterioration of the body occurs, leading to the necrosis of intestinal tissue. In severe cases, intestinal perforation, sepsis, and even death can result. Available treatments are often inadequate and no preventative methods are currently agreed upon. With increased survival rates of Very Low Birth Weight (VLBW) infants owed to medical advancements, the population at risk of developing NEC is sure to increase. Several technologies have been explored in search for non-invasive tools to detect and monitor the evolution of NEC. Abdominal radiography and sonography are the current imaging modalities used for the evaluation of the disease. These methods are not suitable for the early detection of NEC and interpretations of these images are not always straightforward. Still, in most institutions modified Bell's criteria is primarily used for diagnosis of NEC. This four stage criteria is based on signs and symptoms that are not specific to NEC. It is even more challenging to diagnose stage 1; a definitive diagnosis is specified by stage 2 or higher. The need for an alternative method capable of early and reliable detection of NEC is urgent.

Interestingly, the inflammation and pain associated with NEC is experienced by infants before the appearance of significant signs on x-ray images. When detecting infrared radiation emitted from the body, infrared imaging can measure the temperature distribution of the skin. Infrared imaging is used to measure the temperature distribution of the skin, by capturing the infrared radiation emitted from the body. Inflammation and fever can be recognized through touch alone, by locating areas with higher local temperatures. Pathologies detected using thermography has been generally associated with changes in blood perfusion. Thermal abnormalities can be identified by asymmetrical thermal patterns, and/or the presence of hot and/or cold spots. IR camera technology is rapidly evolving, non-invasive, non-contact, low cost and a wide range of applications have been used to detect thermal abnormalities in a host of medical conditions. These applications include neurology, vascular disorders, breast cancer detection, rheumatic diseases and has been strongly encouraged for neonatology. NEC is an inflammatory disease primarily targeting the intestine. In this region, inflammation occurs which can drastically increase local temperatures. With possibility that abdominal infrared imaging may be suitable for the detection of inflammation associated with NEC, and because inflammation is an early symptom of NEC, its potential as an earlier diagnostic tool is plausible.

Infrared thermography is a temperature-measurement method that senses thermal radiation emitted by objects, thus not requiring contact. Temperature is registered by specific instruments called thermal cameras. These devices feature an infrared-detector array that captures several adjacent measurements from a targeted object simultaneously. The temperature data from the object's surface and surroundings can be examined

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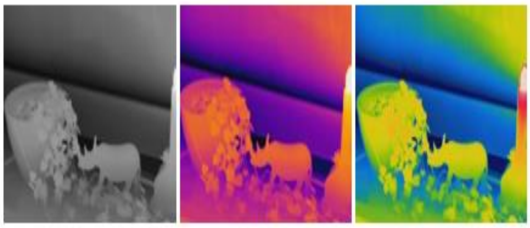
numerically and portrayed as a color-coded image named thermogram. Admittedly, the object's thermal analysis by means of a single thermogram acquisition is advantageous over multiple displaced point-wise readings, which are time-consuming and more susceptible to error. For its precision and non-contact features, infrared thermography finds numerous applications in science and engineering. The technology once served primarily restricted and military applications, yet it has gained increased popularity after thermal cameras became accessible to civilian purposes. The infrared-industry's market-growth strategy resulted in the introduction of various thermography-based solutions. For instance, manufacturers have recently showcased new portable sensors that can be physically attached to smartphones and handheld devices for basic thermal imaging functionality. These portable cameras are available online and in selected retail stores. Currently, a lower-end thermal device can be purchased from less than 300 USD (i.e., United States dollars).

The qualitative, visual inspection of a thermal image by an expert is a relevant feature of infrared thermography as it provides prompt insight about possible thermal abnormalities on a targeted scene. However, an elaborate investigation requires a quantitative approach, which can be derived from a statistical strategy or from image analysis methods. Using simple statistics, the temperature measurements are computed for the extraction of minimum, maximum, average, and standard deviation values from the image in parts or as a whole. Although informative, such approach is rather elementary. The evaluation of thermograms can be improved with the application of image analysis techniques. Nonetheless, complications arise when using digital image processing and analysis methods to thermal-imaging databases. The first problem relates to the direct application of these techniques without distinctive adjustments for infrared specifications and characteristics, since most image processing methods are tailored for visiblespectrum images. In particular, several enhancement, denoising, and filter-based imaging techniques modify the visual aspects of the input picture by changing its pixel intensities, hence altering the original content. Even though these procedures may be innocuous for visible-spectrum images, they result in data corruption when applied to thermograms. An additional issue relates to specific software applications provided by the thermalcamera manufacturers. Using the software, researchers can manually select regions of interest within the thermogram and extract particular statistics about the segmented regions. Still, only simple geometric shapes such as rectangles and ellipses are available in these applications, as they lack specific tools for a more precise selection of the designated areas. Consequently, inaccurate or incomplete information is produced. Furthermore, the analysis of how isotherm patterns change over time is a valuable asset in infrared thermography. An isotherm is a closed region with similar temperature values. Isotherms can be identified by simple means of thresholding, given a predetermined temperature range. While current software supports isotherm extraction, the procedure is deficient for specific studies involving temperature acquisitions in non-fixed experimental setups or during prolonged time frames. In these cases, the analysis of isotherms present improved complexity since temperature acquisitions may undergo uncontrolled variations, such as inexact positioning of the targeted object in relation to the camera, varying positioning of the camera itself within the experimental setup, external and environmental discrepancies, and related distortions. Therefore, comparing a time-varying series of thermograms and associated isotherms from an object may be impractical because of shifting, scaling, rotating, skewing, and other distorting factors affecting particular thermograms. In fact, because of difficulties related to the interdisciplinarity of infraredthermography research and the complexity of advanced image analysis methods, many studies report limited conclusions. Essentially, the unavailability of a structured system of advanced image analysis methods shows to restrict the evaluation of thermal imagery to elementary statistics and lead to inaccurate interpretations because of corrupted data from technique misuse and imprecise selection and registration of regions of interest.

II. EXISTING SYSTEM

Thermal imaging Thermal images are visual displays of measured emitted, reflected, and transmitted thermal radiation within an area. When presented to an operator, color maps are often used to map pixel intensity values in order to visualize details more clearly. Examples of a thermal image and widely used color maps can be seen in Fig. 2.1. Due to multiple sources of thermal radiation, thermal imaging can be challenging depending on the properties of the object and its surroundings. The amount of radiation emitted by the object depends on its emissivity as explained in the previous section. In addition, thermal radiation from other objects are reflected on the surface of the object. Therefore, it is also important to know the reflectivity of the object. The amount of radiation that reaches the detector is affected by the atmosphere. Some is transmitted, some is absorbed, and some is even emitted from the atmosphere itself. Moreover, the camera itself emits thermal radiation during operation. In order to measure thermal radiation and thus temperatures as accurately as possible, all these effects need to be considered. At short distances, atmospheric effects can be disregarded. But for greater distances, e.g. from aircrafts as in Paper 9, it is crucial to consider atmospheric effects if temperatures are to be measured correctly. However, if you are only interested in an image that looks good to the eye and not temperatures, these effects do not have to be taken into account. Materials have different properties in the thermal spectrum compared to the visual. Some materials that are reflective and/or transparent in the visual spectrum are not in the thermal spectrum and vice versa, e.g., glass. Glass is transparent in the visual spectrum while being opaque in the thermal spectrum, therefore, the lens of a thermal camera is not manufactured in glass but in germanium, a material that is opaque and reflective in the visual spectrum but transparent in the thermal spectrum.



(a) Gray (b) Iron (c) Rainbow

Fig:2.1. Example of a thermal image visualized using different color maps.

From the aspect of measuring temperatures, thermal imaging is advantageous compared to point-based methods since temperatures over a large area can be compared. However, it is not considered to be as accurate as contact methods. Compared to visual cameras, thermal cameras are favourable as soon as there is a temperature difference connected to the object or phenomena you want to detect. For example, emerging fires, humans, animals, increased body temperatures, or differences in heat transfer ability in materials. When it comes to applications, thermal cameras are especially advantageous to visual cameras in outdoor applications. Thermal cameras can produce an image with no or few distortions during darkness and/or difficult weather conditions (e.g. fog/rain/snow). This is again due to the fact that a thermal camera is sensitive for emitted radiation, even from relatively cold objects, in contrast to a visual camera that measures reflected radiation and thus depends on illumination. Image segmentation Segmentation is an essential process in image analysis. The idea is to fragment an image into sections for a distinctive evaluation. Generally, a targeted object or area needs to be extracted from the remainder of the scene represented within the image boundaries. Segmentation is considered to be a critical challenge in computer vision and pattern recognition because of the diversity of imaging applications and their specific requirements. In this context, one segmentation method may not be suitable for all classification purposes. As a result, several techniques have been proposed to cope with particular application requirements, different imaging modalities, and noise-intensive datasets, etc. Still, the general intention is to detect the region of interest. Edge detection Common edge detection techniques were tested. The authors report using the following methods: Roberts, Sobel, Prewitt, Kirsch, Laplacian, Laplacian of Gaussian, Marr–Hildreth, Canny, Shen–Castan, Watershed, and Snakes. The dataset contained thirty-five thermal images of different views of the human body. All thermograms presented regular contrast levels for thermal imagery. The optimal outlining was the one drawn manually, and the results presented using the boundary detecting approaches performed poorly. Experts subjectively evaluated the results, and the Shen-Castan method outperformed the others. Still, the contours are not fully-closed, presenting holes and unnecessary lines.

2.1 IMAGE ACQUISITION

The thermal image quality depends on controllable parameters such as ambient temperature, air flow and lighting. It is necessary to maintain the temperature at 21°C, without air draft and diffused lighting. The uncontrollable factors are patient metabolic rate and patient temperature. This can be indirectly controlled by ensuring the patient is duly rested and acclimatised to the screening environment. The thermal image can be improved further by enhancing the signal-to-noise ratio by ensuring that the patient does not apply any lotion/cosmetics in the scanned region.

2.2 HISTOGRAM METHOD

Two sets of images are considered for the analysis-thermal foot image and trial image for training. The trial thermal pattern was generated using a computational fluid dynamic software (Star CCM+).The trial image is generated such that, the colour blue MPA: medial plantar artery, LPA: lateral calcaneal artery, MCA: medial calcaneal artery, LCA: lateral calcaneal artery. Orange and blue colours denote the higher and lower temperatures, respectively depicts the lowest temperature and extends to the colour red which stands for the highest temperature. The analysis was performed in the numerically generated image and then repeated for the thermal image of the foot.

2.2.1 RGB to grey conversion: RGB is converted into grey scale image, which is the intensity image. This conversion occurs by eliminating hue and saturation and retaining luminance.

2.2.2 Noise filtering: The median filter is used in this paper for sorting out salt and pepper noise. It

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keeps the sharp edges and is a non-linear operation. For every input pixel p(x, y), the value of the pixel is found, its median is identified and the value is assigned to output pixel q(x, y). After acquiring the image, it is processed using the three types of processing techniques, namely histogram, Otsu thresholding and morphological function.

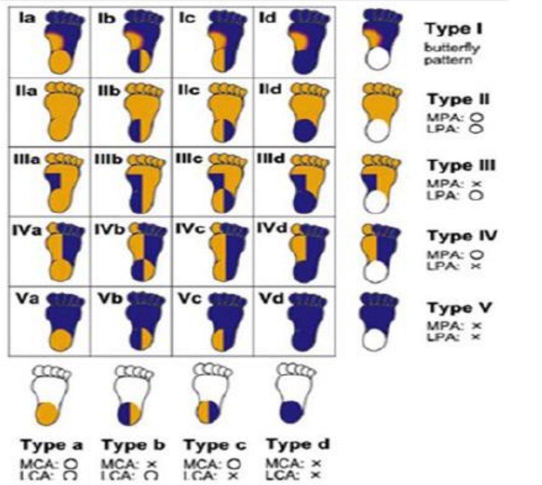

Fig. 2.2 Classification of the thermographic patterns

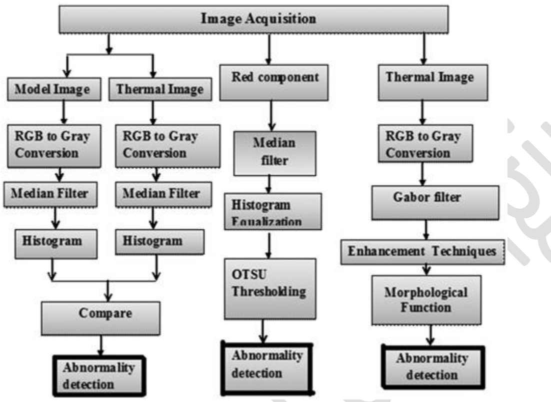

Fig. 2.3 Flowchart for the system

In the existing method, the foot ulcer is predicted by using ROI. Studies in artificial intelligence have progressed rapidly within the last couple of years; modern developments have enabled the efficient treatment of foot injuries in several medical sectors. Although support instruments to evaluate the diabetic foot are in existence, little has been done to reduce the errors in the evaluator's cumulative criteria, and the management of obtained data. The primary drawback with the existing system is that a foot ulcer cannot be predicted exactly. Often, observed skin tones are wrongly diagnosed as diabetic foot.

2.3 HISTOGRAM METHOD

The process is carried out in four images. In Fig. 2.4a, the output shows the beginning stages of the diabetic foot in the right leg because there is a light projection, as shown in the pixel value of 76. The left leg is seen to be highly diabetic as it shows a huge number of pixel values in the area of 76. In Fig. 2.4b, the output shows that both the right and left legs show no infection in the area of 76. So, it can be concluded that the person is non-diabetic. In Fig. 2.4c, the output shows that both the right and left legs show no infection with the pixel value in the area of 76. Hence it can be concluded that the person is non-diabetic. In Fig. 2.4d, the output shows the beginning of diabetes in the right leg because there is a light projection shown in the pixel value of 76. The left leg is seen to be nondiabetic as there is no projection in the histogram (Table 2.1).

Sl no.	Image	Histogram value	Observation
1	right leg	small range of pixel values in 76	initial stage of infection
	left leg	more pixel values in 76 range	diabetic
	Image_1	considering both legs, the image shown as abnormal	abnormal
2	right leg	small projection in 76	partially diabetic
	left leg	no values in the range of 76	normal
	image 2	considering both legs, the right leg image shows initial stage of infection and left leg as normal	abnormal
3	right leg	no values in the range of 76	normal
	left leg	no values in the range of 76	
	image 3	no values in the range of 76	
4	right leg	small projection in 76	partially diabetic
	left leg	no of pixel in the range of 76 is less	normal
	image 3	considering both legs, the right leg image shows initial stage of infection and left leg as normal	abnormal

Table 2.1 Histogram of normal and abnormal feet are compared and shown the observations

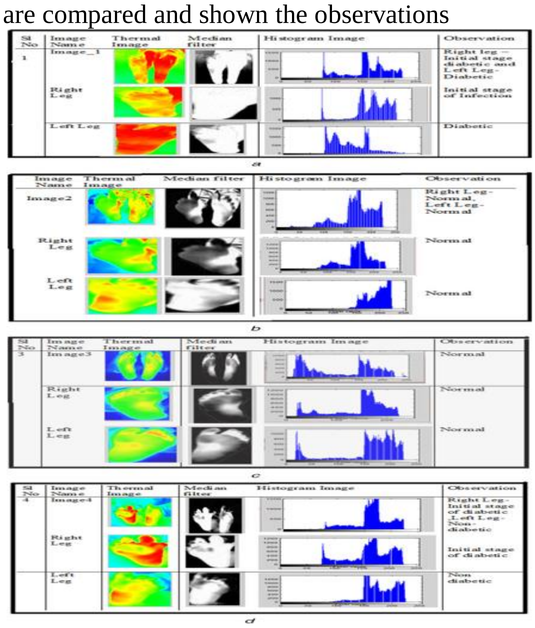

Fig. 2.4 Histogram obtained from the thermogram of (a) Image_1, (b) Image2, (c) Image3, (d) Image4

III. PROPOSED SYSTEM

The proposed method helps to evaluate a diabetic's foot through the introduction of digital image processing techniques. The use of advanced

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image segmentation techniques and a parameter that adjusts the system's sensibility until the desired results are obtained makes it possible to apply an algorithm to a series of trial images which provides positive results for wound and location detection.

The thermal analysis is processed by the following steps:

† Acquisition of the image using a thermal camera.
† Screening the image using filters.
† Enhance the image.
† Compare the results

3.1 OTSU THRESHOLDING METHOD

The acquired image is first converted to a grey image. The red component is extracted from the image and filtered using a median filter.

3.1.1 Median filter: The median filter is used in this method for preserving the edges and to remove the salt and pepper noise. The process of the median filter is the replacing of each value with the median value of the neighbouring pixel. It is calculated by first sorting all the pixel values from the window into numerical order, and then replacing the pixel being considered with the middle pixel value. The central pixel is replaced by the median of pixels in the window.

3.1.2 Histogram equalisation: The image is processed using histogram equalisation which helps to adjust the image intensities to enhance contrast.

3.1.3 Otsu thresholding: In image binarisation, Otsu threshold method helps to reduce grey level image to a binary image. In this method, all possible threshold values are iterated to calculate the spread of pixel value on both sides of the threshold value. The purpose is to find out the threshold value for classifying the person as either diabetic or non-diabetic. According to OTSU method, minimising 'within class variance' is equal to maximising 'between class variance' of segmented image. However, maximising 'between class variance' is less expensive than minimising 'within class variance'.

3.2 MORPHOLOGICAL PROCESS

3.2.1 Gabor filter: The RGB image is converted to grey image. The captured image is filtered using Gabor filter. The Gabor filter converts the image to discrete value for getting the constant region of the image. Compared to other filters, Gabor filter is primarily used for a low range of values. The filtered image is iterated for five iterations. This helps to extract particular affected area for a clearer view.

3.2.2 Enhancement techniques: In this technique, there are two types – dilation and erosion. Dilation is the process which increases the white content of the image by adding pixels to the boundary of the object. Erosion is used to increase the black content of the image by removing the pixels from the boundary of the object. The small particles in the dilated image are eroded in the erosion process.

3.2.3 Morphological function: A morphological method identifies the shape and features of a diseased area in a given image. The structuring element is placed in all possible positions in the image and it's compared with the corresponding neighbourhood of pixels. According to the output of the test, it identifies the image that fits or hits the neighbourhood pixels. Erosion strips one layer of both inner and outer boundaries. It avoids small details and enlarges holes and gaps between different regions. The boundaries are finalised by subtracting the eroded image from the original image. x = f−(f (Θ)s), where f is an image of the regions, s is a 3 × 3 structuring element, and x is an image of the region boundaries. Dilation adds one layer on both the inner and outer boundaries. It will fill in the gaps between two regions.

3.3 OTSU THRESHOLDING METHOD

The images used in the histogram method are repeated with Otsu thresholding also. So, the images can be analysed and the results are comparable. In Fig. 3.1a, the right leg shows more inflammation compared to the left leg. In Fig. 3.2b, the right leg is seen to be normal and the left leg shows a little inflammation. In Fig. 3.3c, both the right and left legs are normal. In Fig. 3.4d, the right leg shows more inflammation and the left leg is non-diabetic.

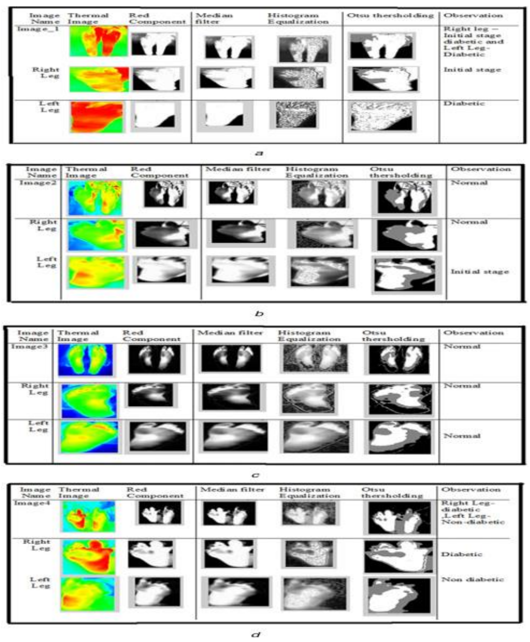


Fig. 3.1 Thresholding method in (a) Image_1, (b) Image2, (c) Image3, (d) Image4

3.4 MORPHOLOGICAL METHOD

The thermal image (Fig. 3.2a) is converted into grey scale image, and the intensity of the image is noted (Fig. 3.2b). The grey image has undergone by five iterations and all the stages are shown in Fig. 3.2c. After iteration, the figure proceeds with the morphological process. For extracting the abnormal area, the iterated image analyse with the morphological process (dilation and erosion) (Fig. 3.2d). The abnormal part of the image is extracted and it is incorporated with the original image. This helps to identify the affected part without an expert's advice Fig. 3.2e.

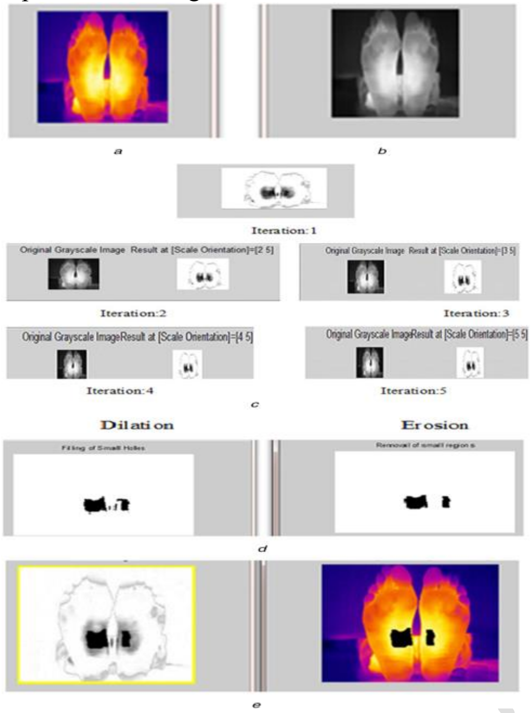
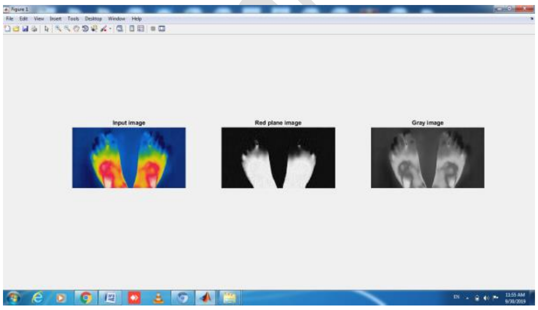
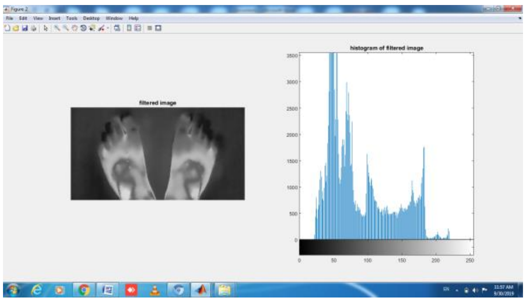


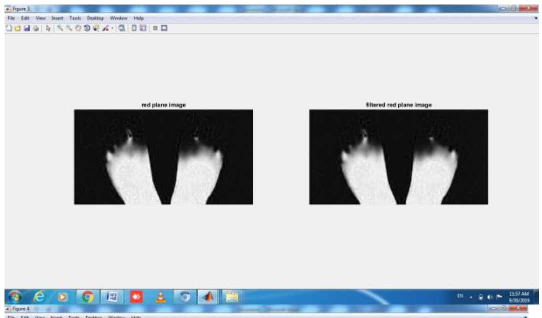
Fig. 3.2. Morphological Process in (a) Original image, (b) RGB to grey conversion, (c) After five iterations of the grey image, (d) Dilation and erosion in the given image, (e) Infected area is extracted from the original image

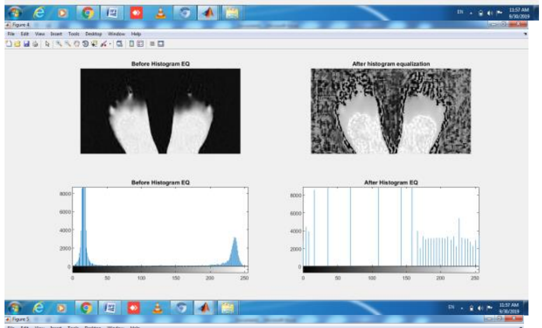
RESULTS

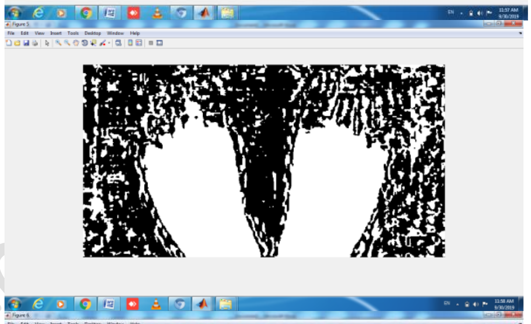
THERMAL IMAGES OUTPUT:

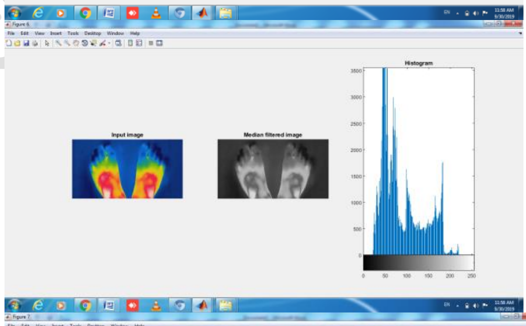


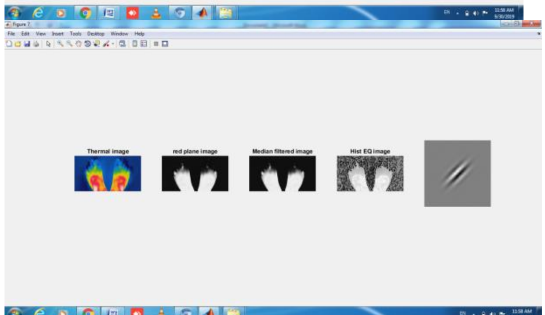


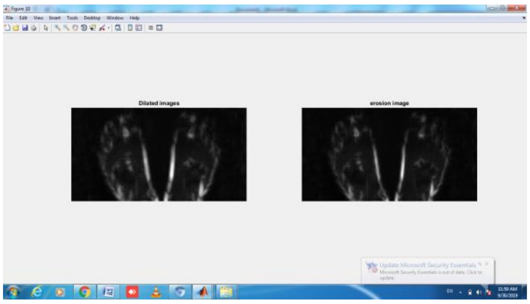












CONCLUSION

Thermography can help to identify the stage of the disease by analysing the picture which helps to start early treatment and prevent further damage. Three methods are used for the analysis of the infected foot area. It was found that all three methods are useful. In so far as histogram method is concerned it helps in identifying a diseased foot. However, the other two methods help in extracting the region of interest by enhancing the infected area.

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