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ANALYSIS OF SEGMENTATION TECHNIQUES FOR PROGRESSIVE EVALUATION OF DIABETIC FOOT ULCERS

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ABSTRACT

Diabetes Mellitus is a chronic disease that affects human body due to damaged pancreas producing insufficient amount of insulin. Diabetes is a lifelong disease that usually damage kidneys,eyes, heart and also nerve damages in the feet. Diabetes have major cause of mortality and disability from foot ulcers if left untreated. Nowadays there are different imaging techniques such as CT, MRI and PET used in diagnosis of human body. Among which Infrared thermography is best suited for interpreting the pathophysiologic information on metabolic, thermal and vascular conditions of human body. This method of scanning is noninvasive, non-destructive and do not require any physical contact for the scanned object. Studies and clinical observations proves that IR thermography detects the diseases in early phase and provides the information for suitable therapeutic treatment. It is usual fact that accuracy of diagnosis in IR imaging depends on segmentation of Region of Interest (ROI). Image segmentation algorithms automatically detect the region of interest and optimize the result for accurate extraction of measurements when compared to other methods. The present work defines some of the segmentation algorithms with various results in optimizing ROI's.

KEYWORDS: Diabetes Mellitus, Matlab, Segmentation Algorithms, ROI, IR imaging, GUI.

I. INTRODUCTION

Basically Infrared thermography (IRT) plays a vital role in image acquisition and processing of vital information from human body. IR camera use electromagnetic radiation with longer wavelengths for emitting the radiation from the object. It is known fact that any object above absolute zero (T> 0K) does emit the radiation. Usually the temperature is a function of emitted radiation as the temperature increases the intensity of radiation increases [1]. This technique is non- contact, noninvasive technology which can measure extremely hot temperature safely without any dangerous circumstances. This IR camera can detect 2D thermo-grams for any target area identified in real time. However there are no radiation effects like x-rays when used for prolonged and repeated manner [2], [3]. Skin temperature is a good indicator of health and can be used to know the illness in form of vascular disorders, neuropathy and other various medical applications. Hence radiating energy from the object dissipated as transmission, reflection and absorption [4]. These parameters are wavelength dependent where spectral reflectance is $\rho\lambda$, transmittance is $\tau\lambda$ and absorptance is $\alpha\lambda$

$\alpha\lambda + \rho\lambda + \tau\lambda = 1$ ….(1)

Hence the electromagnetic radiation using Planck's law constant is given as

$$W_{ßb} = \frac{€1h—5}{€2\ ehT - 1}$$

Where c1 and c2 are constants and T is temperature and λ is wavelength emitted from the black body, it is a function of λ and T.

Today diabetes mellitus has become a major health problem every year. According to world health organization from 1995 the prevalence of diabetes has increased to 4% every year. From the statistics in 2009 the number of patient suffering from this disease are 347 million. It is expected that by 2030 the prevalence of the disease will be increased to 500 million. From the health facts diabetes is the seventh cause of mortality in the world [1]. The major diseases affected from diabetes include eyes, kidney and foot. Some of the diseases related are peripheral

arterial, neuropathy and infection. Diabetic foot ulcers need early diagnosis and therapeutic treatment for better healthy procedures. IR thermography is used for analysis of plantar foot temperature and find early signs in reducing ulcers for diabetic foot. In the present work different IR images of foot are captured and processed using various segmentation algorithms. The diabetic foot ulcer images are used in finding the temperature variations. The work is related to blood circulation, neuropathic and infection problems of foot ulcer [5].

II. SEGMENTATION ALGORITHMS

Image segmentation is best method for image analysis and accurate detection of foot ulcers [6]. There are various segmentation methods used in image analysis which are watershed transformation, region based, edge detection, histogram and thresholding [7]. Images are classified as color and gray scale images. These different techniques are used based on the type of image and also on two parameters: one parameter is pixels in the image and other parameter is information in nearby pixels at any region of the image. The image is also represented in similarities and discontinuities of edges. Image segmentation divides the image in to smaller segments and edge segmentation divides the image based on the edges [23]. The region based methods are used to divide the image based on the threshold to separate back ground and foreground regions. The neural network based methods are used to train the segmentation process using learning algorithm [8]. The segmentation process is the main parameter to determine the quality for further processing. This segmentation mainly involves in diagnosis and analysis of many dreadful diseases. Segmentation is useful for brain, heart, knee diseases for pathology localization [9]. Basically this approach divides the image in to two parts where in the first part, it separates foreground image related with region of interest and other is back ground image.

The basic step of image processing involves de-noising and enhancement to fulfill the need. The other steps in the image processing involves dividing the image in to segments and representing each segments as color, texture and intensity [24]. However the information of the image defines the isolation of boundaries in the form of segments [10]. Therefore it is understood that selection of image segmentation technique lies in the problem domain of the work. Image segmentation technique is defined into three different types as shown in below figure 1.

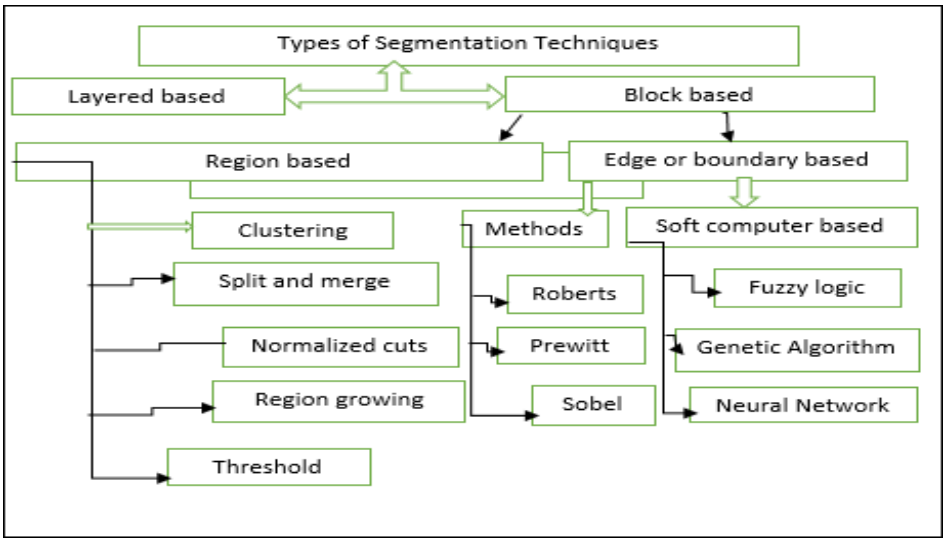

Fig-1: The methods of segmentation

III. EXPERIMENTAL RESULT

In order to test and verify each image segmentation techniques a graphical user interface is designed. In the first step the thermal images of feet are taken. In the second step the image is performed with preprocessing steps like conversion of RGB image in to gray scale and plotting the image sequence in [0, 1], histogram represents the probability occurrence of gray level values. In order to assess the risk occurrence SVM classifier is used in two terms as low risk and high risk. The image segmentation techniques employed in the carried work are

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thresholding method as global and multiple, edge based segmentation methods as sobel, canny and Robert operators used for gradient edge based methods [13]. Region based segmentation as region growing and region splitting and merging, watershed segmentation as continuous for boundaries and last method is clustering based as hard and soft clustering [14].

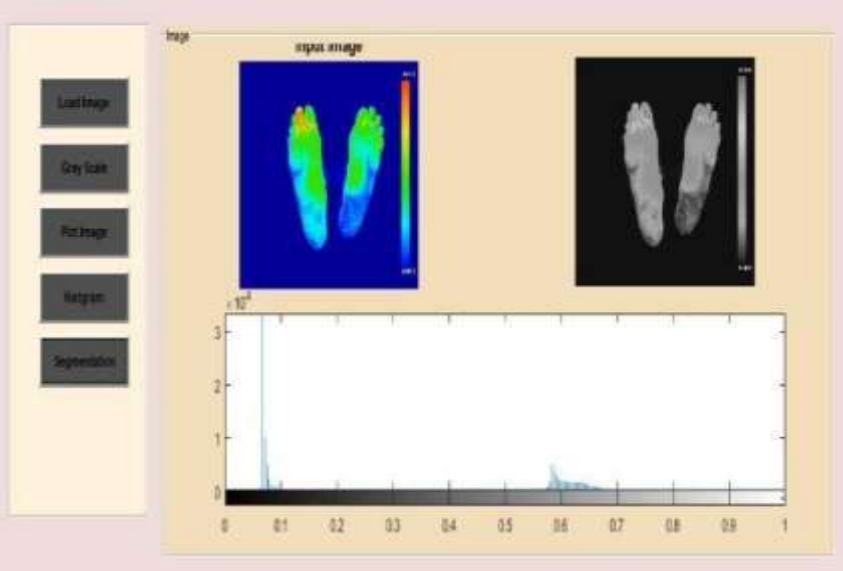

Fig-2: The GUI design for different segmentation techniques

The algorithm is depicted for each segmentation technique with processed results. The proposed work refers to a step by step process to represent any algorithm. The GUI is developed in the form of sequential steps that are mentioned in figure 2.

The Graphical user interface (GUI) designed for segmentation step is carried out with thresholding method in two ways as global and multiple thresholding.

Thresholding Method:

In this segmentation method the pixels of the image are divided with respect to intensity levels. Usually this method is operated for the light objects appearing than background. The methods can be selected in two different manners as manual and automatic [15]. The pixel operation in the images is based on the prior knowledge of image features as Global, variable and multiple thresholding.

a) Global Thresholding: The threshold value is selected by T where T value is a constant applied for the whole image. Consider the given input image as P(x, y) and on applying on transform operator the input image is obtained as q(x, y). The equation

(1) is defined in two different conditions as below:

$$q(x,y) = \begin{cases} 1, if\ p(x,y) > T \\ 0, if\ p(x,y) \leq T \end{cases} \quad (3)$$

Figure-3 indicates thresholding operator as 0.35 where the red line in the figure shows the global threshold value. The overlay of the stack as transition is also shown.

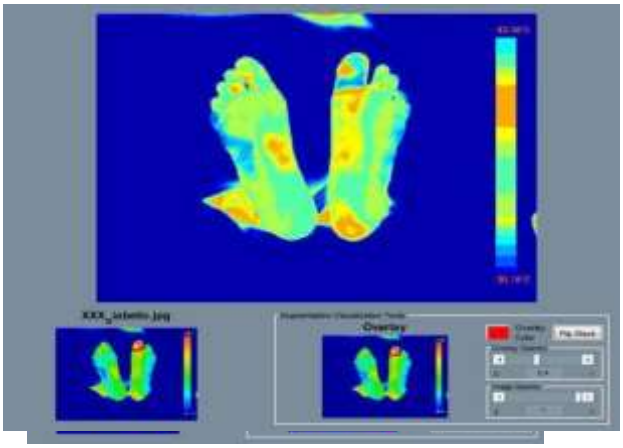

Fig-3: Shows the thresholding with global threshold value

b) Variable and multiple thresholding: In variable thresholding the value of T can be varied in two forms as local and adaptive threshold where local threshold means the value of T depends on neighborhood values and adaptive threshold depends on the function of x and y.

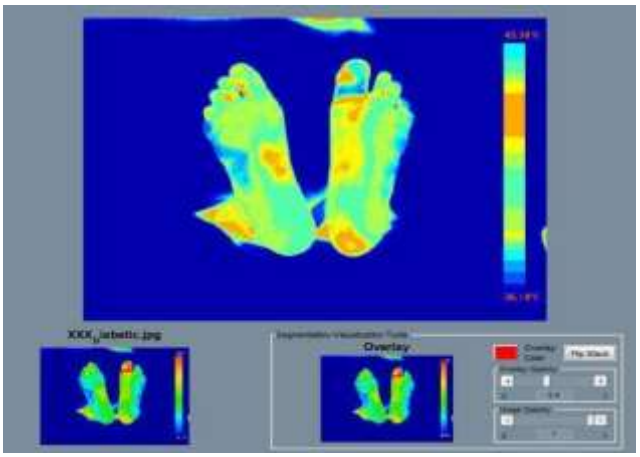

Fig-4: The value of thresholding varied from 1 to 19

The multiple thresholding can be computed with multiple threshold values as T0 and T1. The equation (4) has different computed values in two different ranges as T1 and T0.

$$q(x,y) = \begin{Bmatrix} m, if\ p(x,y) > T1 \\ n, if\ p(x,y) \leq T1 \\ o, if\ p(x,y) \leq T0 \end{Bmatrix} \quad (4)$$

Different values of thresholds are shown as in the form of histograms and computed further as shown in the figure 4. The values of thresholds can be computed with the help of the peaks of the image histograms.

Edge based method:

In this method the intensity value of the image is changed rapidly because the single intensity do not extract the edges properly. Edge detection technique is performed with first derivative where the threshold value is greater than the particular value [16].

Figure 5: Edge segmentation method using gradient operators

The second derivative involves zero crossing operatorswhich can exactly detect the boundaries of the image and can connect together for the segmented regions.

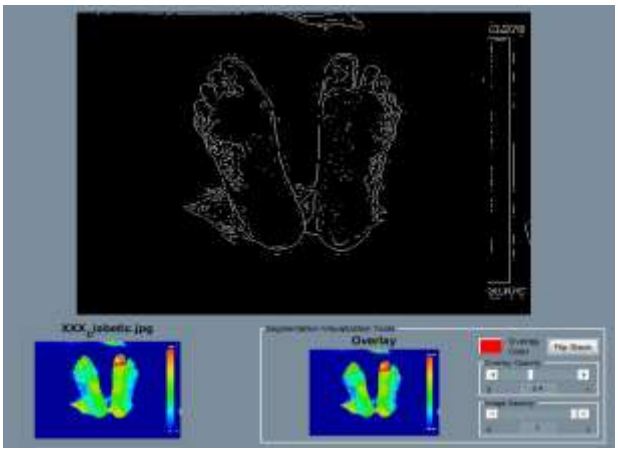

Fig-6: Edge segmentation method using zero cross operators

Basically these edge segmentation methods are of two types, the first one is gray histogram and the other is gradient based methods. The basic results shown in the image are with sobel, canny and Robert's operators [17]. The displayed results are shown in the form of binary image as discontinuity detection.

The Figure 6 shows a sensitivity threshold value of 0.002 and direction used is both horizontal and vertical in display. The sigma value in the design is 1.07 which automatically set off with the given values and it can also be changed with overlay image quality and transition.

Region based method:

This method divides the image in to different regions for different similar characteristics as region growing and region splitting and merging [18].

a) Region growing: In this method the image is segmented in to initial pixels as seeds in various regions. Manual segmentation is carried out based on the prior information or knowledge. Similarly automatic segmentation is performed by connecting the pixels based on the prior information. Based on 8 connectivity the pixels of an image are represented.

If p(x, y) as original image and s(x, y) as binary image for locating the seeds and T is used to estimate the location of (x, y)

The steps performed in region growing are

i. Define the connected components as S eroded

ii. if the original image P(x ,y) is true then the binary image can be computed as PT

iii. if the output image q(x ,y) is true then the binary image can be computed with 8-connectivity as seed The segmented regions are connected for 8 different neighbors connected.

b) Region merging and splitting method: In this method two techniques of segmentation are represented into various regions. The adjacent similar regions are characterized based on merging and splitting. The diagram shown below in figure 8 represents the original image prediction and estimation of similar pixels [19].

In this method the original image is P(x, y) and T is the operator for transformation and prediction of output image

i. In the step the region is R1=P

ii. In second step the region is divided in to four equal quadrants as T (Ri) = False.

iii. The third step indicates every region is matched for condition T (Rj) = True and then merged with two different regions T (Ri U Rj) = True.

iv. Steps are repeated based on quad tree for different regions

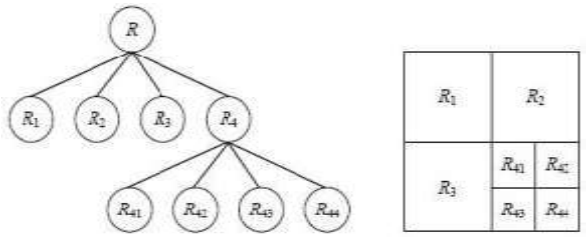

Fig-7: A quad tree showing different regions

The figure 8 shows the regional operator as minimum and maximum with 8 connectivity for quad tree where the image properties are fixed to segment the region of interest. The maximum operation is applied as signified in splitting and merging method.

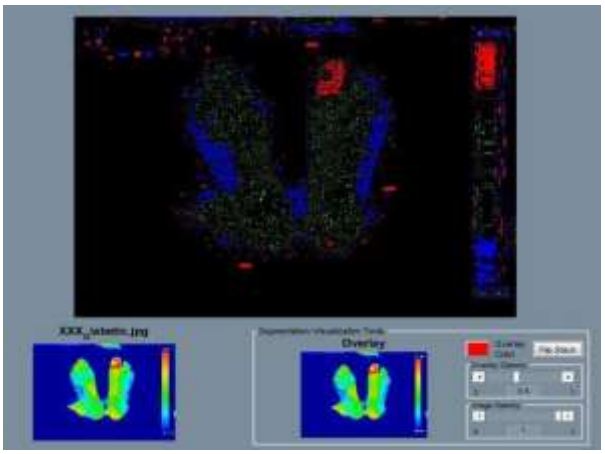

Fig-8: The regional minimum and maximum operation with 0.57 threshold value

Watershed Based Methods:

In this method the interpretation is carried out in the form of top to bottom approach. Here the intensity has minima and maxima when merging together. The regions are separated based on the borders and edges of operation. Dilation property is used as image gradient to represent image as boundaries in continuous manner [20].

The figure 9 illustrates the working of watershed algorithm as p is pixel representation and preprocessing using morphological and gradient operators. Here I is the segmented label image and f(p) is gray level value and n is the neighbor pixel and l(p) is the values stored in the matrix array and to define the distance of pixels. LMax and VMax is label and maximum distance for the considered image. Here the VMax represents the distance between the first row pixel and the last row pixel. The operation is continued to stop or continue the image scanning respectively.

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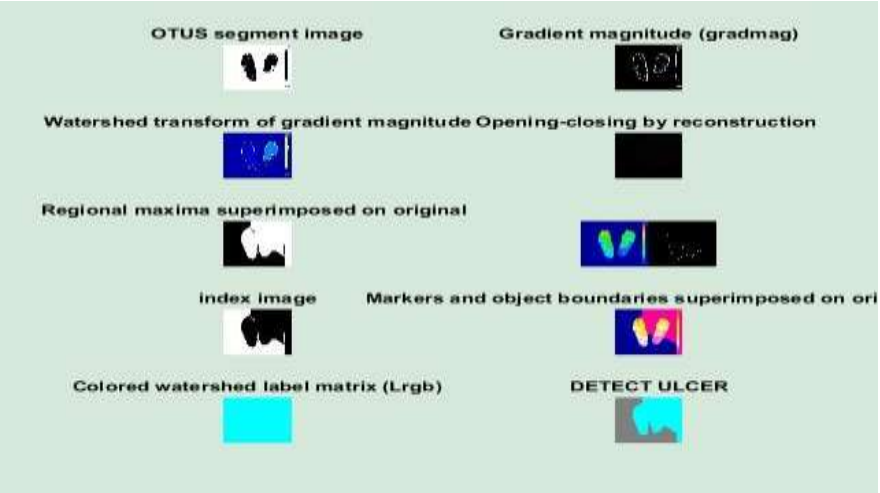

Fig-9: Watershed segmentation applied with RGB color image for different gradient image operators The figure 10 describes the point to point level to i+1 from which the equations are described.

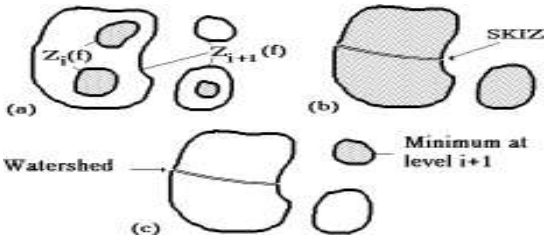

Fig-10: Geodesic skiz for watershed construction The function of minima at a height i+1 and Mi+1 (f) is given from the diagram as:

$W_{i+1}(f) = [\ IZ_{i+1(f)}(X_i(f)] \cup M_{i+1}(f)$…. (5)

The i+1 level for the minima is given

$M_{i+1}(f) = [\ Z_{i+1}(f)/\ R_{Zi+1(f)}\ Z_i(f)]$…… (6) Iterative algorithm is defined from $W_1(f) = \emptyset$

The watershed line DL(f) is equal to

$DL(f) = W^C$ (f)(given max (f) = N)….. (7) The figure 11 shows different color conversionNresults 0f RGB, HSV, Ycbcr and Lab color models.

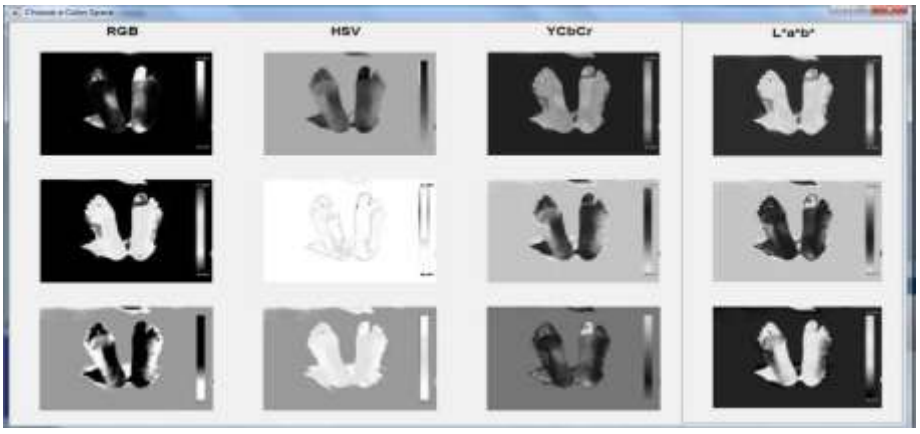

Fig-11: different color models and their illustrative results

Clustering based Methods:

In this method the image is divided as clusters where each cluster is based on the similar characteristics of each pixels. The clusters divides the data between each other based on the similarity [21]. These methods are categorized in to two ways as partition and hierarchical methods. The first method involves the classification in the form of tree where the tree has roots and the whole database represent the clusters of internal nodes. These clusters are subdivided in to hard and soft clustering in iterative manner [22]. The K- means segmentation depends on each pixels and the degree of it depends on membership values.

Fig-12: Segmentation with K-means clustering for different objects with cluster index

The image segmentation is performed with c-means clustering for a cluster index as 4 and can be extended to a maximum of 32. This operation is performed iteratively for maximum number of operations as possible.

IV. COMPARISON OF DIFFERENT SEGMENTATION TECHNIQUES

The table1 will highlight the comparative analysis of various segmentation algorithms and highlighting the advantages as well as disadvantages.

Table-1: Comparison of different segmentation techniques

Technique	Description	Advantages	Disadvant ages
Thresholding method	The optimal threshold value of 0.35 is displayed in the form histogram peaks. Similarly the variable and multiple thresholding is varied from 1 to 19.	Easy method and does not require any prior information.	Only the highest peaks are represented and there are no spatial details considered.
Edge based Method	It is based On discontinuity detection and no similarities used. When a threshold value of 0.002 and sigma of 1.07 for different operators are used, the esults coincide for different contrast intensities.	More useful for different contrast objects.	Identifies many edges or boundaries leads to confusing results.
Watershed based	Gradient image operators with different equations of partial derivative and Zero crossing are detected.	Able to operate on color images and boundaries can be easily detected.	Complex values are obtained from the gradients.

Region based	Works based on the partition of imagein homogeneous regions as minimum, maximum and regional.	Affected by more noise and can be chosen when there is more similarities in the image.	Time consuming, difficult processing and complex results.
Clustering based	Depends on the value of clusters, it performs in iterative manner and more effective in results using fuzzy logic.	Much useful in real time problems and depends totally on the user.	Require membership functions and relations.

V. DISCUSSION

The discussion is purely based on the comparison between various segmentation techniques for evaluating an accurate segmentation technique from existing algorithms. Here the higher priority is less time and accuracy. The demonstrated results from graphical user interface of Matlab provides the working results of the each algorithms in real time. The analysis of segmentation can be further extended with both subjective and objective analysis. However the results computed show the risk assessment as high for the processed images as the temperature difference is greater than 2.2^{o} C. The results computed are from 30 patients who had diabetes mellitus type-II in foot ulcers.

VI. CONCLUSION

In this research work several segmentation algorithms are presented. The results are much detailed and comparable for the different techniques. The involvement of the user understanding and training is much challenging aspect. Thermography processed images certainly lacked clarity in identifying the anatomical shape and region of interest. The IR images with temperature differences of 2.2^{O}C are considered in the proposed work and hence processed to image analysis in diabetic foot ulcers. Therefore it is found that thermography is a diagnostic tool and MATLAB GUI supports in analysis and detection ROI. The K-means segmentation proves to be more accurate in a relative sense. The comparison results showed how different segmentation techniques are evaluated in detection of diabetic foot ulcers. In order to improve thermal images characterization a computational application should be developed. The limitations of existing software can be overcome by designing an application that allows choosing any ROI, independently of its geometric shape and then optimize the ROI for further processing.

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