



ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com



Disease Diagnosis for Various Signs using Tongue Color Image Segmentation

¹G. Uma Devi and ²Dr. T. Ravi

¹Research Scholar, Dept of CSE, Anna University, Chennai -25

²Professor, Dept of CSE, Madanapalle Institute of Technology & Science, Madanapalle, Andhra Pradesh.

ARTICLE INFO

Article history:

Received 28 January 2015

Accepted 25 February 2015

Available online 6 March 2015

Keywords:

Tongue Diagnosis, Body Diseases, Quantitative, Qualitative, Image processing, Mixed Segmentation.

ABSTRACT

Today's high-tech health care worlds professionals are diagnosis the diseases with connectivity of body part one from another. The rolling tongue is many relationships and active connections in the physical body. The snap of tongue images need some specific look in the field of medical image processing and disease analysis. Tongue diagnosing plays vital role to carry out by practical understanding of the tongue, but tongue image processing is not an easy task to carry out. The main focus of our paper deals threshold of tongue signs for diagnosis the diseases. The sign classifies the tongue irregular shape, overlapping of colors, saliva on cracks, buds, pimples etc. Each signs have unique character reflections and issues. This sign factor consists of several phases; quantitative features texture measures for tongue image acquisition by using image processing and crack segmentation. Qualitative features, tongue schema edge detection and region growing algorithm. Mixed color features, pimple detection with association of color intensity extraction method and set algorithm. During the extraction, expected segmentation results will be proved. So, vast majority of the ill can discover effectively by the examination of the tongue.

© 2015 AENSI Publisher All rights reserved.

To Cite This Article: G. Uma Devi and Dr. T. Ravi, Disease Diagnosis for Various Signs using Tongue Color Image Segmentation. *Aust. J. Basic & Appl. Sci.*, 9(10): 341-348, 2015

INTRODUCTION

The tongue is a powerful tool for refining our understanding of the individual and moving us toward an effective remedy. I also appreciate that looking at the tongue lends itself easily to sharing observations and insights with whomever I am working, bringing them into the conversation more fully and helping them make sense of their own bodies. "Tongue analysis" is one of the main identification processes in the patient disease diagnosis. In all traditional structure of diagnosis, tongue is an essential part for best understanding the condition of the patient. Doctors ever ask the patient to open the mouth and show the tongue to extract the visual information. The tongue has a specific connection with the Heart. The normal tongue in old Chinese Medicine has a light red or pinkish body with a thin white coating (Chao liang, 2012). Over the years, clinical research of the tongue has head to the development of recent trends in tongue appearance. Several implicit connections to the tongue, that allows it to show the health of numerous organs in the human body. This allows the tongue to be viewed into regions that correspond to their pertaining body organs. (Chao liang, 2012) The Heart meridian links to the core of the tongue. (Lijun

Jiang, 2013) The Kidney meridian disconnects at the base of the tongue. (Yu-Cheng Hsu, 2010) The Bladder meridian has a sinew meridian that bundled to the root of the tongue. (Liu, 2007) The Triple Energizer meridian has a sinew meridian branch that links with the root of the tongue (http://www.carolinasnaturalhealth.com/article_tongueDiagnosis.asp).

Doctors are interest in the area of texture, coating and fur, size and shape of the tongue, color, thickness, fissures, swellings, and bleedings. These are the different characters of tongue. Depend on above information the doctors gained the knowledge, experience and understand the conditions of the patient. When doctors see the patients tongue the visual extraction is similar but every doctors does not have equal level of skills, knowledge and experience to diagnosis it (Yu-Cheng Hsu, 2010). Although, they also do mistakes due to their age and eye visual capability and any other reasons. So the result may negative and likely to be more dangerous and usually be failure to provide appropriate treatment. To analysis our proposed work proves multivariate quantitative features of textual measures of tongue image using image processing and crack image segmentation in section – II. The qualitative features are demonstrated in section – III. Tongue analysis

using mixed features such as tongue color analysis which proves the symptom of the diseases in section - IV. Finally, the section V concludes the tongue segmentation results which prove the symptoms of diseases in the patient body.

Quantitative image processing:

In this work, we concentrate on patients with diabetes. Tongue image processing requires some unique attention in the field of image processing and disease study, due to tongues irregular shape, color, texture, etc. The texture and appearance of the tongue says a lot in regards to the condition of our health (Jane Bianch, 2014). The technology recommends that it may soon be workable for trained physicians to conduct digital investigations of individuals' tongues to diagnose ailment. Digital imagery of tongue patterns with soft input analysis to determine whether or not a person is sick. Digitized imagery that maps the size, texture and color of a person's tongue can be utilized, to assess whether or not disease is present and treatment is needed. Tongue images are the basic features for diagnosing different sicknesses. The indications of any issues in the body, for example, Heart related issues, Kidney related issues, Stomach related issues, and will be imitated as abnormalities of the any features of the tongue. Various majority of the ill can be discovered effectively by the thorough examination of the tongue. The Reflex zones of tongue are given in Figure 1.

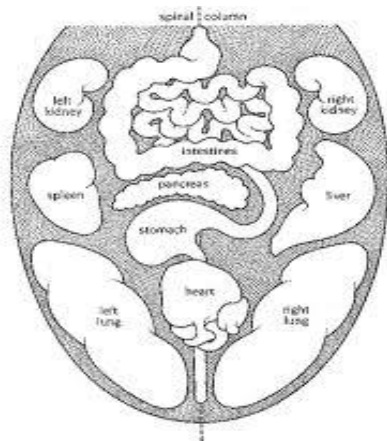


Fig. 1: Reflex Zones of Tongue.

In the previous model, textural operations are committed to create the mapping from a tongue image to corresponding diseases by a statistical way (www.vitalityplusaustralia.com). Although the digital camera snap images are being communicated, which absorbs images with high resolution and may causes run time error in program. Sometimes, even images could not be processed further. In short, High image resolution increases the Processing time and Multiple Image cannot be Process at a time are the

problems faced. These problems are overcome by the proposed method.

Tongue image acquisition and Terminology:

Any video and image caught by camera should convert in user managing schemes is called image acquisition. The image acquisition devices consider three factors when it designs. (i) Illumination, (ii) Resolution based on camera lens. (iii) The position we snap the image for process.

The tongue diagnosis treatment the illuminations of tongue research are carried out with sun light with fresh air. Next scheme is digital photography with high resolution or takes the snap using HD camera. Final factor is position of the image takes place from our camera. The above image acquisition and processing techniques are used to find the status of diabetic patients and their any other symptoms. Logical understandings of tongue snap images are monitored in various ways but the basic terminology is view out image in before food and after food.

Segmentation of Crack tongue:

The extraction of the tongue cracks classify into many categories to help doctors to diagnose disease. Inconnection with the TCM theory, there are 12 different kinds of tongue cracks as shown in figure 2. These typical tongue cracks can be objects with different shapes for observe the clinical tongue diagnosis in TCM. The cracks are classified based on shape matching.

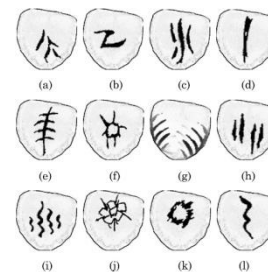


Fig. 2: (a) Typical Tongue crack categories

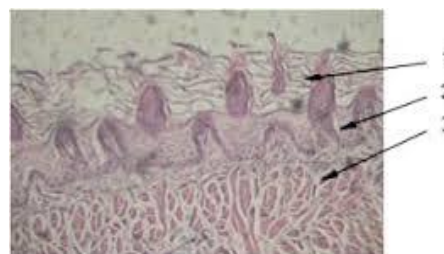


Fig. 2: (b) Tongue Image pulling serum

Tongue cracks can be assume and formed by various segments with a constant curvature. The curvature can be selected as the feature of contour-based shape descriptors and the hidden Markov model (HMM) (Thakoor, 2007) for framework of

tongue cracks modeling and classification. Then the generalized probabilistic descent (GPD) method (Katagiri, 1998) used as a training algorithm for the tongue cracks classifier. Finally, tongue cracks can be identified into different typical categories. To evaluate the hyper spectral based tongue cracks classify method, 480 scenes of hyper spectral tongue images were captured by the HTIS from in-patients at hospital. The tongue cracks are spaced into 16 typical classes named Class 1 ~ Class 12 which corresponding to figure 2 (a) ~ (l), respectively. The 12 typical tongue cracks are identified according to the diagnostic criteria commonly used by TCM doctors (Wang, 2011). The numbers of tongue cracks corresponding to each category classified by the proposed algorithm figure 2 (b) in tongue pulling serum. The correctness of each category cracks are defined based on the percentage of number of tongues. The classifications exactly proposed to the number of tongues in this category. From the table, the data can be seen that the proposed method has good performance in terms of the rates of correctness for tongue cracks classification. As a preliminary research, we just use the most simple classification method here. To classify tongue cracks more accurately, some other vector classification method will be used support vector machine (SVM).

Symptom find using tongue image:

Several causes exist in the Chinese medical model to justify this belief, including several

meridians (channels of energy and blood) that flow directly to the tongue. When we analysis the tongue, there are certain things that you look for including the color, size, shape and texture of the tongue body. We also examine the thickness, texture, and color of the tongue coating. The color of the tongue body tells the state of the blood, yin organs (non-digestive organs) and the lying or nutritive energy. Usually a tongue is pink or light red in color. A pale tongue shows deficiency in either blood or nutritive energy, while a dark or purplish tongue shows that blood or energy are stagnating in the body. Different kind of Changes in color in different regions of the tongue can show imbalances in different organs systems. For instance, a red tongue tip can demonstrate heat in the heart, which can cause insomnia, restlessness, or anxiety.

Texture Analysis:

Texture analysis (Ethan Huff , 2014) describes the symptoms of diseases and so it is considered to be an important criterion in disease diagnosis. The roughness or bumpiness refers to difference in the intensity values, or gray levels. Inflammation lesions or ulceration and deterioration associated to body part pointed out by dark red in tongue. White designates stagnation of blood; fat and mucus deposits or feebleness in the blood leading to such disorders as anemia. A disorder of the liver and gallbladder specified by yellow.

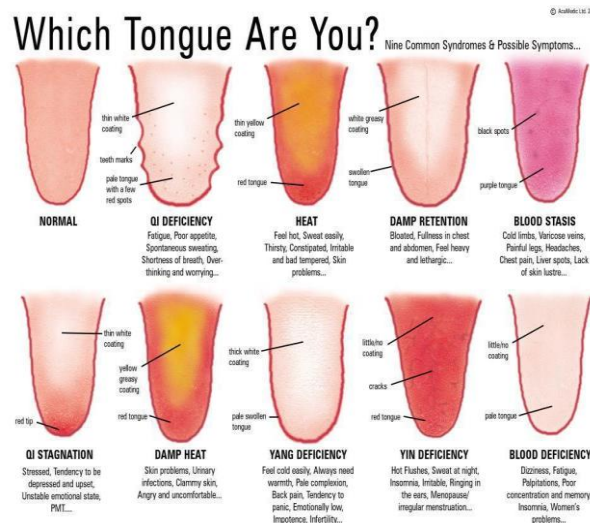


Fig. 3: Various Tongue Texture Image for Examine Disease symptom.

The figure.3 gives the results in a surplus secretion of bile, particularly in the center organs of the human body, and likely inflammation. Blue or purple shows the stagnation of blood circulation and a grave fading of the part of the digestive system that is connected to the zone of the tongue. Implicit conditions could be understood by analyzing the color on the underneath of the tongue. Surplus of

blue or Green shows maladies in the blood vessels and in blood quality and circulation. Surplus purple color mirrors ailments of the lymphatic and circulatory system. It designates a fading of the immune capacity of the blood vessels. The textural measures are extracted from tongue images by using popular digital image processing techniques that models the relationship between these quantitative

features and diseases. The effectiveness of the method is tested on a group of 100 local patients affected by 13 common diseases as well as other 40 healthy volunteers, and the diagnostic results predicted by the previously trained Bayesian network classifiers.

Qualitative tongue image detection and analysis:

An analysis of tongue is mainly focused on the shape, fur, and body of the tongue. The shape of the tongue can be medium, fat, thin, and tilted. A normal tongue should be one with a medium shape. A fat tongue indicates water toxin, while a thin tongue represents yin vacuity or qi and blood vacuity. Observation at the back of the tongue is focused on the sublingual collateral vessels, including the length, width, number of branches, solidness, and colour. By inspecting these features, a doctor can have an understanding of the patient's qi and blood circulation for identify whether the organs are functioning normally. Observation of the tongue status starts with the visible abnormality that becomes the basis for pattern identification/syndrome differentiation (Maciocia, 2004).

Edge detection techniques:

Edge detection is by far most common approach for detecting meaningful discontinuities in intensity values. Such disorders are monitored by first order and second order derivatives. The first order derivative of choice in image processing is the gradient. The laplacian is seldom used by itself for edge detection because as a second derivative, it is unacceptably sensitive to noise. Its magnitude produces double edges and it is unable to detect the edge direction (Zuo, 2004).

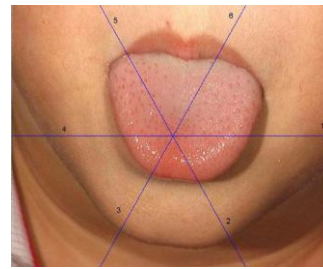
Integrating region growing and Edge Detection:

This scheme used for integrating edges and regions, first the edges of the image are detected using any optimum edge operator. Then the edge region is detected. Edge region is defined as the place where the region growing seeds will be selected. Therefore, the edge region should surround the single pixel edges derived by an edge operator. Then a region size comparing is well-done. Very small regions are removed from edge region and are removed instead of merging. Thus the effect of noise is completely eliminated. When this is done, the image is segmented in two kinds of areas, Edge region and Homogeneous region. In this work first edge detection is performed, then homogeneous region detection and then seeded region growing (Rupinder Singh, *et al*).

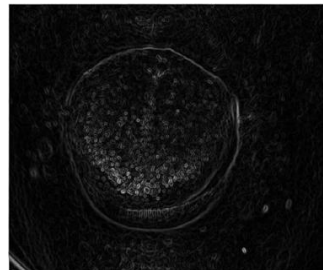
Tongue Image Polar Edge Detection:

Polar Edge Detection of a classic tongue image and the intensities in six directions are shown in Fig.4 (a).The edges of tongue body in these directions are also labeled in Fig. 4(b). It can be

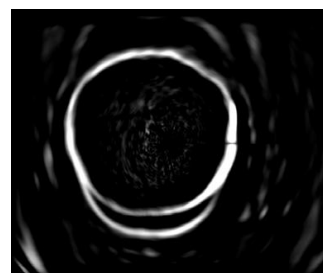
observed that the intensities of tongue boundary usually are local minimum in radial direction. Fig.4 (c) This motivates us to present a novel edge detector, polar edge detector.



(a) Original Tongue Image



(b) Edge detection image



(c) Polar edge detection Image

Fig. 4: Tongue Image edge and polar edge detection.

Given a tongue image I , let (m_0, n_0) be the origin of the polar coordinates, then each pixel $I'(r, \theta)$ in polar image can be computed by,

$$I'(r, \theta) = I(r \sin \theta + m_0, r \cos \theta + n_0) \quad (1)$$

Where $I(r \sin \theta + m_0, r \cos \theta + n_0)$ in original image is computed by bilinear interpolation. Similarly, the inverse transform can be represented as,

$$I(m, n) = I'(\sqrt{(m - m_0)^2 + (n - n_0)^2}, \arctg(\frac{m - m_0}{n - n_0})) \quad (2)$$

Where after, a horizontal Gaussian smoothing operator with windows $N \times 1$ and standard deviation σ is used to smooth the polar image. Finally we proposed an $1 \times (2k+1)$ horizontal edge detector $[1, 1, \dots, 1, -2k, 1, \dots, 1, 1]$ to detect the edge in polar image,

$$E(i, j) = \sum_{k=1}^k I(i, j + k) + I(i, j - k) - 2I(i, j), \quad (3)$$

where $I(i, j)$ is a pixel of polar image, $E(i, j)$ is the corresponding intensity of the polar edge image (http://www.carolinasnaturalhealth.com/article_tongueDiagnosis.asp).

Mixed Color detection:

The color feature is extracted with help of intensity filtering methods. We explain the color of the tongue on the basis of the intensities presented in the different areas of the tongue. Apply this feature because intensity levels of different colours and different areas of the tongue. Therefore, with help of this intensity method, we can extract the color features coating and true colour of the tongue. We identify the white coating, true colour and dominant color of the tongue through this approach. White coating may dominantly present in some tongues, it will be less dominant. The human visual system can distinguish hundreds of thousands of different color shades and intensities, however only about 100 shades of grey can be distinguished. Therefore, a great deal of extra information may be contained in the color (femail.co.uk) and this extra information can be used for image analysis.

Colour image segmentation:

Image segmentation is valuable in numerous applications. It can recognize the regions of interest in a scene or interpret the data. We categorize the existing segmentation algorithm into region-based segmentation, data clustering Segmentation, and edge-based segmentation. Region-based segmentation includes the Seeded Region Growing (SRG) and unseeded region growing algorithms. All of these techniques expand each region pixel by pixel taking into account their pixel value or quantized value so that each cluster has high positional connections. The standard methodology is to discover a point close to the center of the target image, which is utilized as the center of image, and afterward to give an initial two-dimensional curve and make it astringe to the edge of the target as per dynamics mechanism (Fu, 2006). This methodology is proper when the general form of the target is fixed. However human tongue is not generally flat when extended out of the mouth.

Tongue color factor and features:

The extraction of the features of the color can be performed in different color spaces, which usually include RGB, HSV, CIEYxy, CIELUV and CIELAB. Different from the other color spaces, the HSV color space is an intuitive system in which a specific color is described by its hue, saturation and brightness values. This color space is often used in software systems to aid in interactive selection and manipulation of color. However, the HSV space has discontinuities in the value of the hue around, which make this approach sensitive to noise (Lijun Jiang, 2013).

Definition of a region of interest: Over the original image, two points are select by the user to define a rectangular subregion (xmin, ymin), (xmax, ymax). This subregion must contain the section of the tongue that is going to be analyzed.

Learning of color regions: The user selects a polygonal for each of the following four regions: background, skin, tongue and fungiform papillae.

Transformation from RGB space to L*a*b* space: transformation to L*a*b* makes color processing less sensitive to illumination changes and is more perceptually uniform than other color spaces.

Classification of pixels according to nearest neighbor: For each of the polygonal regions shown by the user, an average color is determined. Let $P(x,y)$ be the value of a pixel in the image after transformation to L*a*b* color space, and C_j the average color of region j , where $j=1..4$. Then, $P(x,y)$ is classified in region i , if

$$\text{Minimum } \{ |P(x,y) - C_j| \}_{j=1..4}, \text{ occurs for } j=i \quad (4)$$

Where $|a|$ is the Euclidean norm in R^2 , and only the components a*b* are used for comparing colors. This is to make the color comparison insensitive to change in illumination (Fu, 2006).

Region analysis of the segmented pixels: The pixels classified as fungiform papillae are analyzed and grouped in connected regions. For each region the area, centroid and boundary is obtained. A similar analysis is applied to the pixels classified as tongue. Finally, the area proportion of fungiform papillae compared to the area of the whole tongue is obtained as follows. If A_p is the area of the fungiform papillae, A_t is the area of the tongue not including the fungiform papillae, then F_p , the fungiform proportion is obtained as:

$$F_p = \frac{A_p}{(A_p + A_t)} \quad (5)$$

Image Segmentation:

The usual approach is to find a point near the center of the target image, which is used as the center of image, and then to give an initial two-dimensional curve and make it astringe to the edge of the target according to dynamics mechanism. This approach is appropriate when the general form of the target is fixed. But human tongue is not always flat when extended out of the mouth. Some forms will be changed and therefore it is not suitable for this algorithm. We adopt the component H (Hue) and V (Value) of HSV space to decide the initial position of tongue.

Then level set algorithm is used to obtain the better segmentation (Liu, 2007).

Methodology expended:

Tongue images can be captured by using a specific set of image acquisition devices, including an advanced kernel camera and its corresponding lighting system. Segmentation methods such as "Thresholding" achieve this goal by looking for the boundaries between regions based on discontinuities in gray levels or color properties.

The proposed model is based on building a group of natural features are derived from NSS and fitting them to Multivariate Gaussian Model (MVG) model. Assessing the quality of a distorted image is then

expressed as the distance between MVG fit of the features extracted from the distorted image and the MVG model of the natural features extracted from natural images. Figure 5 block diagram of the proposed algorithm for feature extraction. Threshold techniques can be categorized into two classes global

threshold and local (adaptive) threshold. In global threshold a single threshold value is used in the whole image in the local threshold a threshold value is assigned to each pixel to determine whether it belongs to the foreground or background pixel using local information on around the pixel.

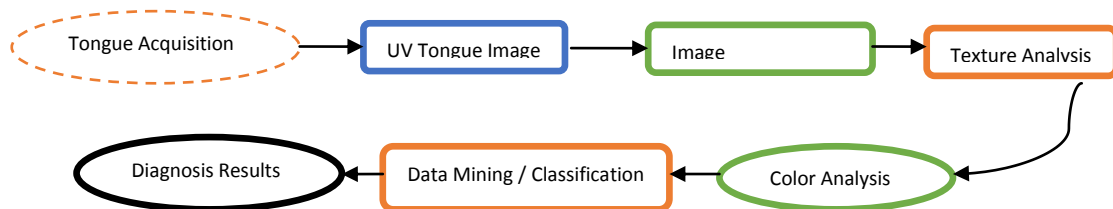


Fig. 5: Flow of Processing Methodology.

Segmentation algorithms are based on two basic properties of intensity values discontinuity and similarity. Histogram threshold approach falls under into regions that are similar according to predefined criterion. Many methods exist to select threshold value for a segmentation task. The most common methods is to set the threshold value interactively the user manipulating the value and reviewing the thresholding result until a satisfying segmentation has been obtained. The histogram is often a valuable tool in establishing a suitable threshold value. Histogram thresholding results using different threshold values obtained from the histogram Thresholding is the simplest segmentation method. The pixels are partitioned depending on their intensity value. Global thresholding, using an appropriate threshold T :

$$g(x,y) = 1, \text{ if } f(x,y) > T;$$

$$0, \text{ if } f(x,y) < T.$$

Variable threshold if T can changes over the image. Local or regional thresholding if T depends on a neighborhood of (x,y) . Adaptive thresholding if T is a function of (x,y) multiple thresholding.

$$g(x,y) = a, \text{ if } f(x,y) > T_2;$$

$$\text{if } T_1 < f(x,y) < T_1;$$

$$\text{if } f(x,y) < T_1;$$

Threshold is one of the widely methods used for image segmentation. It is useful in discriminating foreground from the background. By selecting an adequate threshold value T , the gray level image can be converted to binary image.



Fig. 6: Disease affected Tongue

The most common way to convert a gray-level image to a binary image is to select a single threshold value (T). Then all the gray level values below this T will be classified as black (0), and those above T will be white (1). The binary image should contain all of the essential information about the position and shape of the objects of interest (foreground). Figure - 7 (a) - The segmentation problem becomes one of selecting the proper value for the threshold T .

The advantage of obtaining first a binary image is that it reduces the complexity of the data and simplifies the process of recognition and classification. Histogram Dependent Technique (HDT) The histogram based techniques is dependent on the success of the estimating the threshold value that separates the two homogenous region of the object and background of an image. The figure - 7 (b) (HDT) is suitable for image with large homogenous and will separate regions where all area of the objects and background are homogenous and except the area between the objects and background.

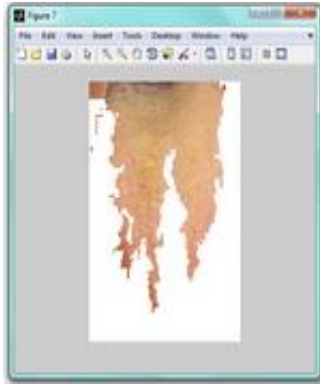


Fig. 7: (a) Segmented Tongue Image

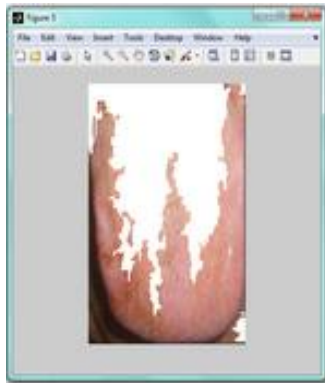


Fig. 7: (b) HDT Tongue Image

This technique can be expressed as:

$$C(T) = P1(T)\sigma1^2(T) + P2(T)\sigma2^2(T) \quad (6)$$

Where: C (T) is the within-group variance. P1 (T) is the probability for group with values less than T. P2(T) is the probability for group with values greater than T. $\sigma1(T)$ is the variance of group of pixels with values less than or equal to T. $\sigma2(T)$ is the variance of group of pixels with values greater than T. This required that, the image formation be of two homogenous well-separated regions and there exists a threshold value that separated these regions A

frequent method used to select T is by analyzing the histograms of the type of images that want to be segmented. We adopt the component of Hue(H) Saturation(s) and Value(v) space to decide the initial position of the tongue.

Experimental results:

The input tongue images are seized by a camera with specification of high quality optical zoom factor, Super macro mode and the Additional lightning system with ring flash camera, etc.. After the segmentation the process is preceded with the help of classifier. Here Neural network has been chosen as a best classifier because it works exactly like Human brain works. The neural networks perform based on the trained data. The trained neural network is called as experts. The corresponding output for the given input is obtained from the trained neural network. Then the process of seizing the image, the seized image has been taken under the control of segmentation using Histogram based threshold technique. Histogram equalization (HE) is a popular technique for enhancing the contrast of an image.



Fig. 8: (a) Segmentation of disease affected area.

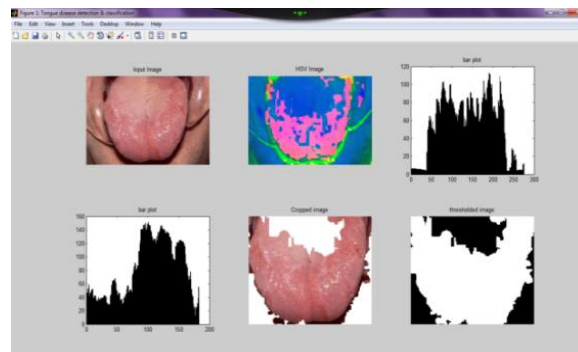


Fig. 8: (b) Response of various feature.

HE is similar to contrast stretching in that it attempts to increase the dynamic range of the pixel values in an image. Its basic idea lies on mapping the

grey levels based the probability distribution of the input grey levels. But due to the flattening property of HE either it performs over or under enhancement.

The segmentation of a disease affected tongue is carried out using Histogram based threshold technique and the segmented result is shown in the figure 8. Here the features like Mean, variance, standard deviations are the color features which are extracted and Energy, entropy, contrast, correlation and homogeneity are the extracted texture features from the segmented output.

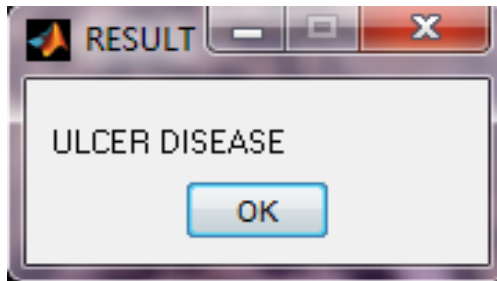


Fig. 9: Result shows the diagnosis of diseases.

Now the extracted features are then given as input for neural network for the process of classification. The features are compared with the train features and the result is produced. The produced result is shown in the figure.9. The process of improving the efficiency of this project by collecting the more number of images and several features will be extracted by the segmented image will be trained

Conclusion:

The tongue image is one of the important research methods in the tongue image processing and hence there are different methods introduced for the effective processing of tongue images. But with the one or more disadvantages in the processing, new techniques are become necessary. Thus, in our method we have introduces a method in which every process is occurring in a step by step manner. Polar edge detection we proposed an innovative polar edge detector to extract tongue boundary. In our proposed method, we have provided methods to detect the white coating, true color, cracks, pimples and buds of the tongue. Edge filtering and bi-level thresholding steps are used to filter out the unwanted edge and binarize edge image. From the evaluation of the results it is showed that the methods we proposed gives the appropriate results and is well suited for the tongue image processing. We use a heuristic initialization and active contour model for final segmentation. Further enhancement to the system can be done by improving the localized intensity methods and calculation of the features and giving an empirical table to identify the disease.

REFERENCES

- Chao liang, V dongchengshi, 2012. "A prior knowledge based algorithm for Tongue-body segmentation", IEEE transaction.
- Lijun Jiang, Wang Xu, Jianfeng Chen, 2013. "Digital Imaging System for Physiological Analysis by Tongue Colour Inspection", IEEE transaction.
- Yu-Cheng Hsu, Ying-Ching Chen, 2010. "Automatic Tongue Feature Extraction", IEEE transaction.
- Liu, Z., Y.Q. Yan, D. Zhang, 2007. Automated tongue segmentation in hyperspectral images for medicine, Virtual Journal for Biomedical Optics, (46): 8328-8334.
- Zuo, W.M., K.Q. Wang, D. Zhang, 2004. Combination of polar edge detection and active contour model for automated tongue segmentation, Third International Conference on Image and Graphics (ICIG'04), Hongkong, China, pp: 270-273.
- Fu, Z.C., X.Q. Li, F.F. LI, 2006. Tongue image segmentation based on Snake model and region grow, The 13th National Conference on Image and Graphics(in Chinese), Nanjing, China.
- http://www.carolinasnaturalhealth.com/article_to_ngueDiagnosis.asp.
- Jane Bianch, 2014. "7 things your tongue says about you", November.
- Tongue Reflexology Chart", www.vitalityplusaustralia.com.
- Maciocia, G., 2004. Diagnosis in Chinese medicine: a comprehensive guide. Edinburgh; New York: Churchill Livingstone.
- Ethan Huff, A., 2014. "Your tongue's appearance can reveal disease and nutrient deficiencies" December 08.
- Thakoor, N., J. Gao, S. Jung, 2007. Hidden markov model-Based weighted likelihood discriminant for 2-D shape classification. IEEE Transactions on Image Peocessing, 16(11): 2707-2719.
- Katagiri, S., B.H. Juang, C.H. Lee, 1998. Pattern recognition using a family of design algorithms based upon the generalized probabilistic descent method. Proceedings of the IEEE, 86(11): 2345-2373.
- Wang, K.Q., D. Zhang, N.M. Li, 2001. Tongue diagnosis based on biometric pattern recognition technology. Singapore: The World Scientific Publishers.
- Rupinder Singh., "EDGE BASED REGION GROWING", Int. J. Comp. Tech. Appl., 2(4): 1122-1126.
- Naomi Coleman, "How the color of your tongue reveals your health", femail.co.uk