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A Novel Method to Detect Diabetes Mellitus & Non-Proliferative Diabetic Retinopathy Using Features of Tongue Image

Kiran S Patil[1], Pallavi S Deshpande[2]

P.G. Student, Department of Electronics and Telecommunication, SKN College of Engineering, Vadgaon(Bk), Pune, India[1]

Associate Professor, Department of Electronics and Telecommunication, SKN College of Engineering, Vadgaon(Bk), Pune, India[2]

ABSTRACT: Diabetes mellitus is gradually becoming an epidemic, affecting almost every single country. This diabetes mellitus has given a large amount of burden on governments and healthcare officials. In this paper, we propose a method to detect DM initial stage based on three groups of features extracted from tongue images. They include color, texture, and geometry tongue color features with a log Gabor filter mechanism.A tongue colour gamut is established with 12 colours representing the tongue colour features. The texture values of 8 blocks into which the tongue surface is divided &11 features extracted from tongue images based on measurements, distances, areas, and their ratios represent the geometry features. With the combination of these features we can distinguish DM, NPDR & healthy person from their tongue images.

KEYWORDS: Diabetes Mellitus, Non proliferative Retinopathy, Colour Gamut.

I. INTRODUCTION

World Health Organization (WHO) has estimated that in 2000 there were 171 million people worldwide with diabetes mellitus (DM), and the number will increase to 366 million by 2030 making the disease among the leading causes of death, disabilities, and economic hardship in the world. Two main types of DM exist, Type 1 DM and Type 2 DM. People with Type 1 DM fail to produce insulin, and therefore require injections of it. Type 2 DM is the most common type and can be categorized by insulin resistance. Currently, there is no cure for Type 1 DM or Type 2 DM. However, Type 2 DM can be managed by eating well, exercising, and maintaining a healthy lifestyle. A fasting plasma glucose (FPG) test is the standard method practiced by many medical professionals to diagnose DM. FPG test is performed after the patient has gone at least 12 h without food, and requires taking a sample of the patient's blood (by piercing their finger) in order to analyze its blood glucose levels. Even though this method is accurate, it can be considered invasive, and slightly painful (piercing process). Diabetic retinopathy (DR) is a microvascular complication of DM that is responsible for 4.8% of the 37 million cases of blindness in the world, estimated by WHO . In its earliest stage known as nonproliferative diabetic retinopathy (NPDR), the disease if detected can be treated to prevent further progression and sight loss. Various imaging modalities such as red-free , angiography, and color fundus imaging are used to examine the human retina in order to detect DR and subsequently

NPDR. These methods are based on the detection of relevant features related to DR, including but not limited to hemorrhages, microaneurysms, various exudates, and retinal blood vessels. These imaging modalities themselves can be regarded as invasive, exposing the eye to bright flashes or having fluorescein injected into a vein in the case of angiography. Therefore, there is a need to develop a noninvasive yet accurate DM and NPDR detection method.

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Non proliferative Diabetic Retinopathy (NPDR)

The starting stage of diabetic retinopathy is known as Non proliferative Diabetic Retinopathy. ,the minute blood vessels within the retina leak blood or fluid.

Proliferative Diabetic Retinopathy (PDR)

The final stage of diabetic retinopathy is known as Proliferative Diabetic Retinopathy. The minute blood vessels within the retina leak blood or fluid which leads to traction retinal detachments.

The belief that the general health of a person is reflected in his tongue is from the days of Hippocrates.Tongue diagnosis is one of mostly widely used diagnostic methods among the four diagnostic processes in traditional Chinese

medicine (TCM). The usefulness of tongue diagnosis lies in its simplicity and immediacy-inspection of the tongue can instantly clarify one's pathologicalproblemso that people seeking health care can have their tongues routinely examined. Among all features that can be extracted, the tongues chromatic, geometric & texture features play most important role in evaluating a person's health condition.According to Traditional Chinese Medicine, TCM practitioners believe that pathological changes of internal organs can affect the colour appearance of the tongue body. The shape of a human tongue and its relation to a patients' state, either healthy or diseased (and if diseased which disease), is quantitatively analysed usinggeometryfeatures.

To do this we have extracted three major attributes of tongue- Colour, texture & geometry. We have used the Colour Gamut to showcase the possible colours observed on a tongue image. Gabor filter of second order is used to determine the texture of tongue. Geometric features are determined using mathematical formulas. A combination of all these features is used to classify a tongue image into normal, diabetic or NPDR category. There are separate researches where colour, texture & geometry features are studied solely. But when these three features are combined, it gives better results.

Paper is organized as follows. Section II describes the related work and literature survey. The features are discussed in detail in section III. Section IV describes the algorithm used in the paper. Section V presents experimental results showing results of images tested. Finally, Section VI presents conclusion.

II. RELATED WORK

1] International Diabetes Federation (IDF) Diabetes Atlas, 6th ed., Brussels, Belgium: International Diabetes Federation, 2013.

In 2013 there were 382 million people with Diabetes Mellitus (DM) worldwide, and this number is set to increase to 952 million by 2035, according to The International Diabetes Federation

(IDF) [1].

2] D. R. Matthews (1985) Homeostasis model assessment: insulin resistance and cell function from fasting plasma glucose and insulin concentrations in man," and J. D. Brunzell (1976) Relationships Between Fasting Plasma Glucose Levels and Insulin Secretion During Intravenous Glucose Tolerance Tests,"The traditional way to diagnosis DM is through a Fasting Plasma Glucose (FPG) test [2-3].

3] B. Zhang, V. Bhagavatula, and D. Zhang (2014) "Non-invasive diabetes mellitus detection using facial block color with sparse representation classifier," Described using facial block color features with the Sparse Representation Classifier (SRC) to detect DM. They classified DM vs. Healthy based on a combination of four facial blocks with the SRC [4].

4] T. P. Weldon and W. E. Higgins, (2007)"The Design of Multiple Gabor Filters for Segmenting Multiple Textures." J. W. Yang, L. F. Liu, T. Z. Jiang, and Y. Fan, (2003)

"A modified Gabor filter design method for fingerprint image enhancement," J. K. Kamaraine, V. Kyrki, and H. Kalviainen,(2006) "Invariance properties of Gabor filter-based features-overview and applications," Z. H. Sun, G.

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Bebis, and R. Miller, (2005) “On-road vehicle detection using evolutionary Gabor filter optimization,” S. E. Grigorescu, N. Petkov, and P. Kruizinga, (2002) “Comparison of texture features based on Gabor filters,”

The Gabor filter is similar to the human visual system; it is effective in feature extraction [5-9].

S. A. Dudani, (1976) “The distance-weighted k-nearest-neighbor rule,” Systems, Man and Cybernetics. M. Elad, Sparse and redundant representations: from theory to applications in signal and image processing. The mean of the vector is computed and assigned the texture value of the facial block. After extracting the facial block texture features, k-NN [10-11].

KanikaVerma et.al proposed a Detection and Classification of Diabetic Retinopathy using Retinal Images. Diabetes slowly attacks the retina of the human eye which is leading to Diabetic Retinopathy. The retinal image of human eye is acquired by camera. By using density analysis and bounding box methods, the haemorrhage candidates were detected. Finally Random Forests approach is used for classification. It classifies various stages of diabetic retinopathy which is normal, moderate and non proliferative diabetic retinopathy (NPDR) [6] .However it does not use robust classifier for achieve high Appropriateness.

K. Malathi et.al presented an Efficient Method to Detect Diabetic Retinopathy Using GaussianBilateral and Haar Filters with Threshold Based Image Segmentation. The Micro vascular complication leading to diabetes which is known as Diabetic retinopathy. In this system, Gaussian based bilateral filter is used to decrease/remove the noise of the fundus images. Here Haar filter is used to detect the diabetic retinopathy. However it does not detect fovea for improve detecting performance [7].

Bob Zhang yet.al introduced a new method for detecting Diabetes Mellitus and Non proliferative Diabetic Retinopathy which is based on tongue image features. The complication of Diabetes mellitus (DM) is known as diabetic retinopathy (DR). To detect DM and non proliferative diabetic retinopathy (NPDR), the tongue color, texture, and geometry feature are extracted. The support vector machine is used for classification [8] . The proposed method can separate Healthy/DM tongues as well as NPDR/DM-sans NPDR. However it does not suitable for large data set.

SujithKumar S B et.al [9] presented a new diabetic retinopathy detection which is performed in Non-dilated RGB Retinal Fundus Images. The small dots are appeared in the retinal fundus to form a Microaneurysms. Microaneurysms is a first symptoms of diabetic retinopathy. Earlier detection of microaneurysm can assist minimize the blindness of people. The preprocessing, feature extraction and classification methods are used to performed diabetic retinopathy detection. However it does not achieve high accuracy.

Dr.Chandrashekar et.al [10] proposed a method for Detection of Vascular Abnormalities. The proposed system detects the irregularity in the retina by utilizing morphological techniques which is used for extract the features from retina such as blood vessels, micro aneurysms and etc. To calculate the severirty of the dieasesthe ares features are extracted. Classification method is used to classify normal, mild and high severity Vascular Abnormalities. It is possible to large number of fundus images and it can be reduce the cost. However it does consider the colour feature for optimal detection.

III. TONGUE COLOUR, TEXTURE & GEOMETRY FEATURES

1) Colour Feature

Three aspects of tongue colour are considered- the tongue colour gamut to classify tongue related colours with tongue-unrelated colours, colour centres value of main colour categories and colour distribution of typical image features. Representative colours are then extracted & combined together to form the tongue colour distribution in the CIEx chromaticity diagram to provide an intuitionist way to describe all visible colours according to its colour stimulus & thus the relative position of tongue colour& its colour composition would be observed easily. 12 colour centers are predefined to meet the demanding them in tongue diagnosis of TCM

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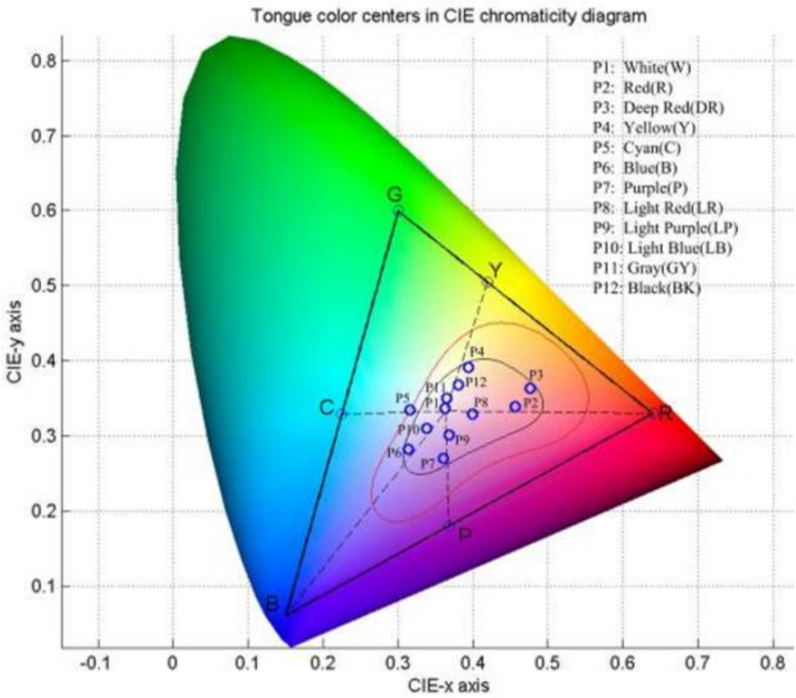

Fig 1.Definition of 12 colour centres in CIE chromaticity diagram

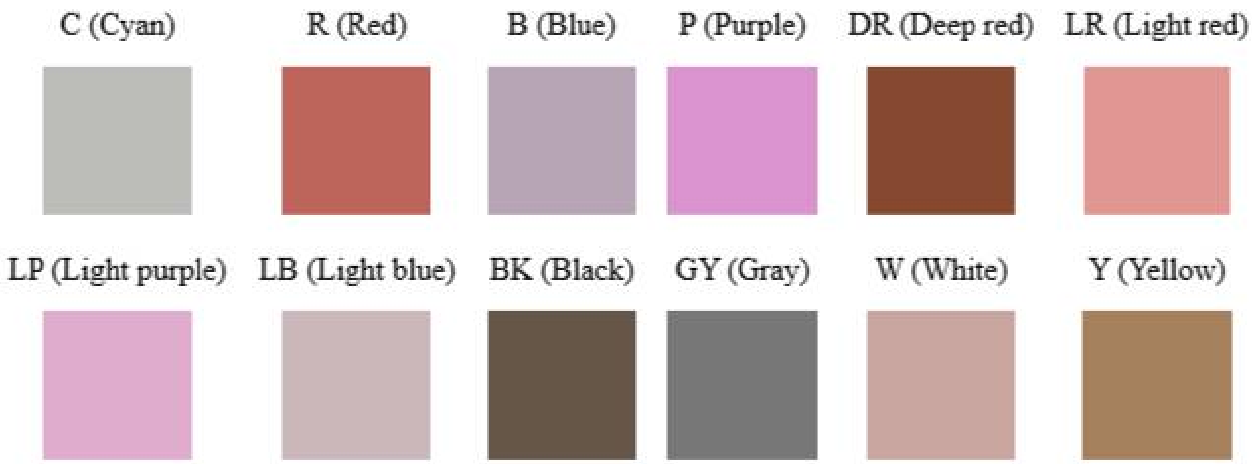

Fig 2.12 colours from the colour gamut

For each foreground pixel, corresponding RGB values are first extracted, and converted to CIELAB by transferring RBG to CIEXYZ using

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (1)$$

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Followed by CIEXYZ to CIELAB via

$$\begin{cases} L* = 166.f\left({}^{Y}/_{Y_0}\right) - 16 \\ a* = 500.\left[f\left({}^{X}/_{X_0}\right) - f\left({}^{Y}/_{Y_0}\right)\right] \\ b* = 200.\left[f\left({}^{Y}/_{Y_0}\right) - f\left({}^{Z}/_{Z_0}\right)\right] \end{cases} \quad (2)$$

where$f(x) = x^{1/3}$ if $x > 0.008856$ or $f(x) = 7.787x + 16/116$ if $x \leq 0.008856$.
X_0, Y_0 , and Z_0 in 3 are the CIEXYZ tri stimulus values of the reference white point.TheLABvaluesarethencomparedto12 coloursfromthetonguecolourgamutandassignedthe colourwhichisclosesttoit(measuredusingEuclideandistance). After evaluating all tongue foreground pixels, the total of each colour is summed and divided by the total number of pixels. This ratio of the 12 colours forms the tongue colour feature vector v,where
$v = [c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, c_9, c_{10}, c_{11}, c_{12}]$and c_i represents the sequence of colours.

2) Texture Feature

Texture feature extraction from tongue images is presented in this section. To better represent the texture of tongue images, eightblocksofsize64×64strategicallylocatedon thetonguesurfaceareused.Ablocksizeof64×64waschosendue to the fact that it covers all eight surface areas very well, while achieving minimum overlap. Larger blocks would cover areas outside the tongue boundary, and overlap more with other blocks. Smaller block sizes would prevent overlapping, but not cover the eight areas as efficiently. The blocks are calculated automatically by first locating the center of the tongue using a segmented binarytongue foregroundimage. The Gabor filter is a linear filter used in image processing, andiscommonlyusedintexturerepresentation.Tocomputethe texture value of each block, the 2-D Gabor filter is applied and defined as

$$G_k(x,y) = \exp\left(\frac{x^2+\gamma^2.y^2}{-2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}\right) \quad (3)$$

where $x' = x \cdot cos\theta + y \cdot sin\theta, y' = -x \cdot sin\theta + y \cdot cos\theta$, σ is the variance, λ is the wavelength, γ is the aspect ratio of the sinusoidal function, and θ is the orientation. A total of three σ (1, 2, and 3) and four θ (0◦, 45 ◦, 90 ◦, and 135◦) choices were investigated to achieve the best result. Each filter is convolved with a texture block to produce a response

$$R_k(x,y): R_k(x,y) = G_k(x,y) * im(x,y) \quad (4)$$

where$im(x,y)$ is the texture block and * represents 2-D convolution. Responses of a block are combined to form FR_i, and its final response evaluated as follows:

$$FR_i(x,y) = max(R1(x,y), R2(x,y), \ldots, Rn(x,y)) \quad (5)$$

which selects the maximum pixel intensities, and represents the texture of a block by averaging the pixel values of FR_i. In the end, σ equal to 1 and 2 with three orientations (45◦, 90 ◦ and 135◦) was chosen.

3) Geometry Features

In state-of-the-art computerized tongue image analysis, colour and texture features are the most prevalent. There exists little or no literature on tongue image analysis using geometry features, whereas in traditional medicines such as traditional Chinese medicine (TCM) the shape of a tongue can be used to determine a patients' illness. This includes various measurements of length, area, and angle extracted from tongue images. Every image is segmented with the background removed and tongue foreground remaining. From each tongue image consisting of a tip, body, and root, 11 geometry features derived from measurements, distances, areas, and their ratios are extracted. Using these features we define 5 tongue shapes based on TCM.

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We describe 11 geometry features extracted from tongue images. These features are based on measurements, distances, areas, and their ratios.

1) Width: The width w feature (see Fig.3) is measured as the horizontal distance along the x-axis from a tongue's furthest right edge point (x_{max}) to its furthest left edge point (x_{min})

$$w = x_{max} - x_{min} \qquad (6)$$

2) Length: The length l feature (see Fig. 3) is measured as the vertical distance along the y-axis from a tongue's furthest bottom edge (y_{max}) point to its furthest top edge point (y_{min})

$$l = y_{max} - y_{min} (7)$$

3) Length–width ratio: The length–width ratio $lw$is the ratio of a tongue's length to its width

$$lw = l/w (8)$$

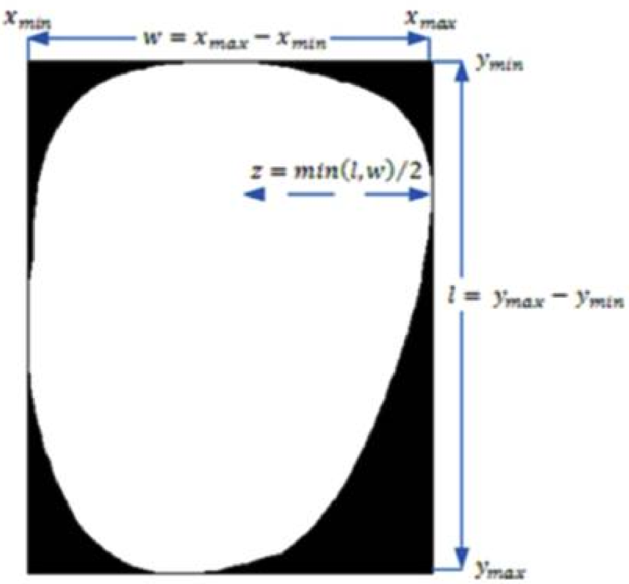

Fig.3.Illustration of features 1, 2, and 4.

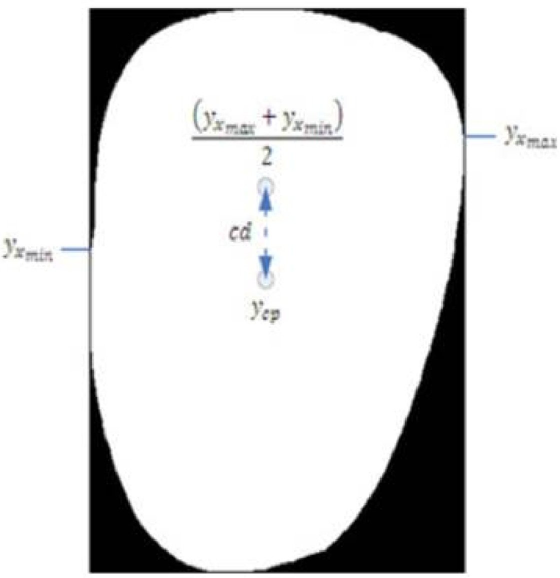

Fig: 4 Illustration of feature 5.

4) Smaller half-distance: Smaller half-distance z is the half distance of $l$or $w$depending on which segment is shorter (refer to Fig. 3)

$$z = min(l, w)/2. (9)$$

5) Center distance: The center distance (cd) (refer to Fig. 4) is distance from w'[s]y-axis center point to the center point of l (ycp)

$$cd = \frac{(max(y_{xmax})+max(y_{xmin}))}{2} - ycp \qquad (10)$$

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6) Center distance ratio: Center distance ratio (cdr) is ratio of cd to l

$$cdr = cd/l \qquad (11)$$

7) Area: The area (a) of a tongue is defined as the number of tongue foreground pixels.

8) Circle area: Circle area (ca) is the area of a circle within the tongue foreground using smaller half-distance z, where r = z (refer to Fig. 5):

$$ca = \pi r2. \qquad (12)$$

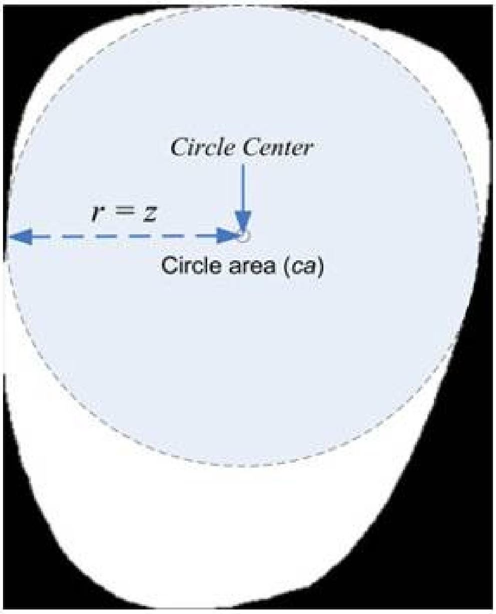

Fig 5 Illustration of feature 8

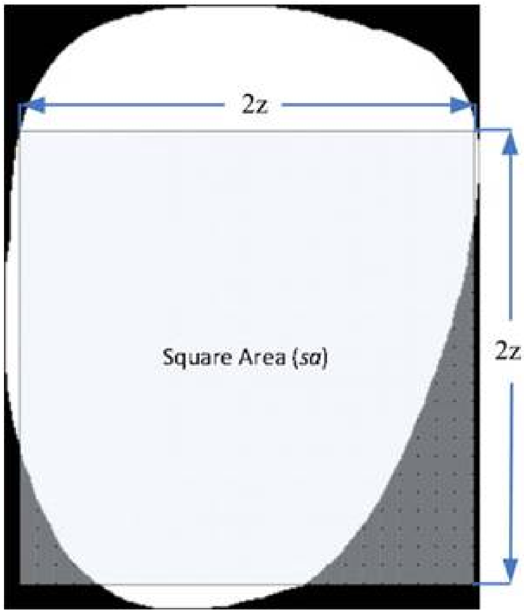

Fig 6 Illustration of feature 10

9) Circle area ratio: Circle area ratio (car) is the ratio of ca to a

$$car = ca/a \ (13)$$

10) Square area: Square area (sa) is the area of a square defined within the tongue foreground using smaller half-distancez (refer to Fig. 6):

$$sa = 4z^2 \qquad (14)$$

11) Square area ratio: Square area ratio (sar) is the ratio of $sa$to a

$$sar = sa/a \ (15)$$

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IV. PROPOSED METHODOLOGY

The flow of proposed algorithm is as follows.

1. Input image is selected from tongue image database.
2. Pre-process (resize the image)
3. For colour features,
    1. 12 colours are extracted & converted to corresponding LAB values.
    2. The Euclidian distance between standard value and calculated value is determined
    3. Mean standard deviation is calculated.
4. For texture features,
    1. The tongue surface is divided in 8 blocks.
    2. Gabor filter is used for texture feature extraction of each block
    3. Mean value is calculated for each block
5. For geometry features, extract various shape features and their ratios using mathematical formulae.
6. For matching,
    1. Divide the database into training and testing set.
    2. KNN is used for training and classification
    3. Determine whether the input image is DM/NPDR/Healthy.

7. Display Result

V. EXPERIMENTAL RESULTS

Stepwise result is shown as below. First we select an input image from the database. The image is resized to obtain a standard data set. To remove any noises from the image the image is filtered.

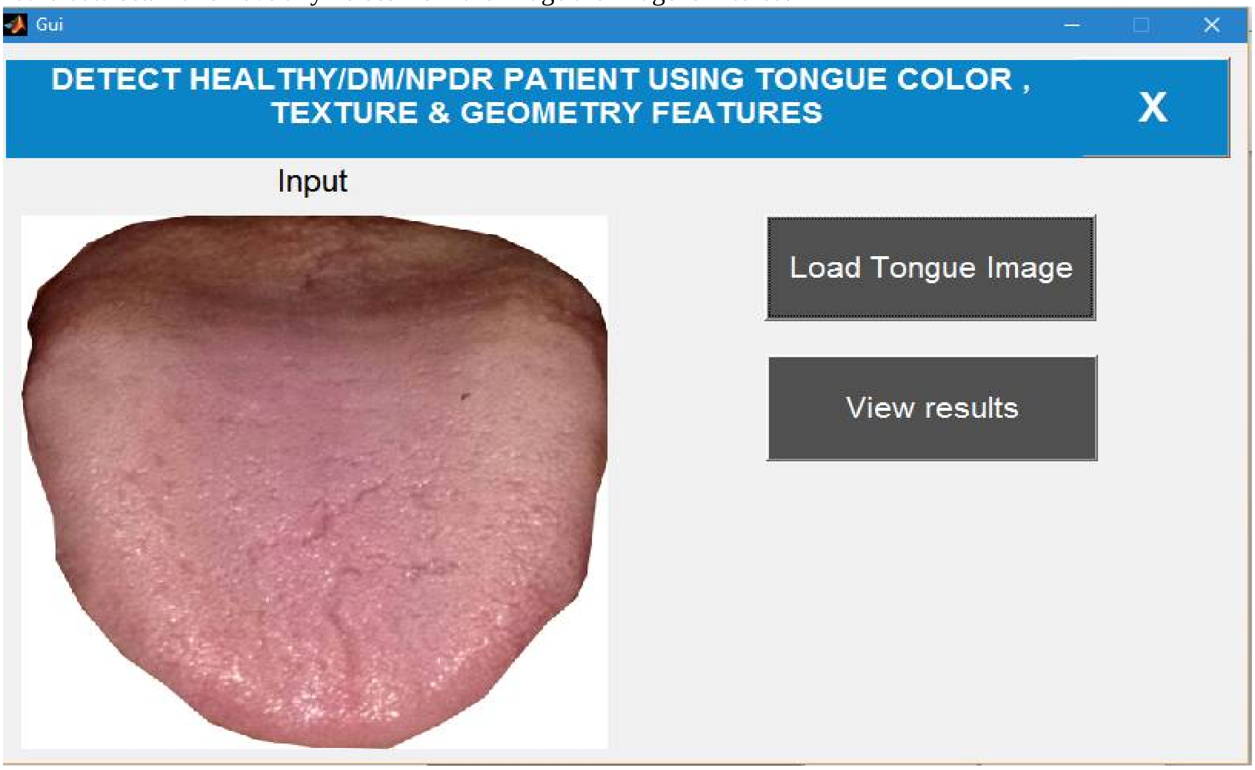

Fig 8 Load Input Image

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Fig 8 shows the GUI of the program. User has to load a test image first. On clicking “View Result”, all the features are extracted & result is displayed.

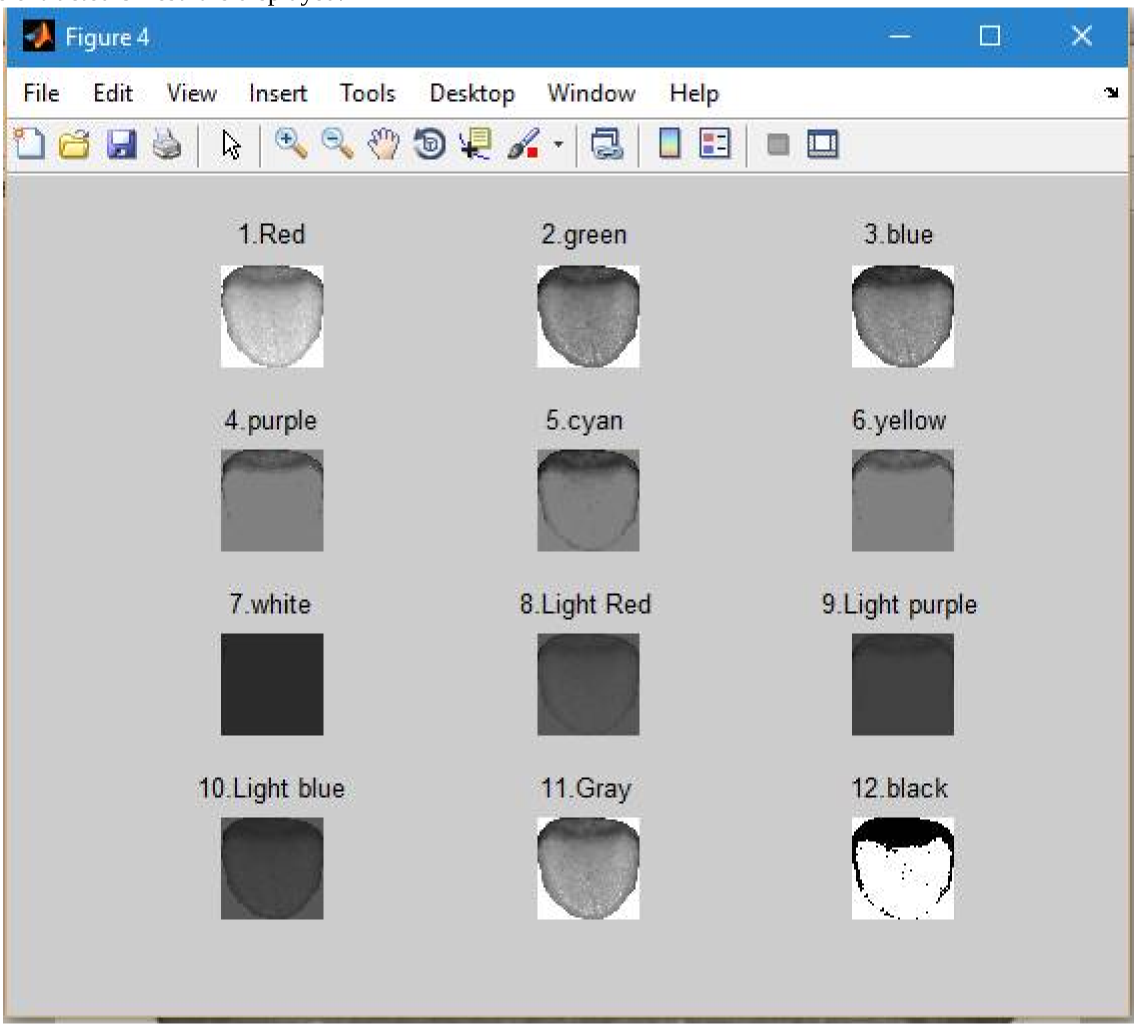

Fig- 12 colour features

For texture feature extraction, first the image is divided into 8 blocks. Each block is then convolved with 2D Gabor filter. This will give us the texture features of the input tongue image. Fig10 shows the block separation of input tongue image. We obtain different values for texture for tongue images from Healthy, DM & NPDR dataset.

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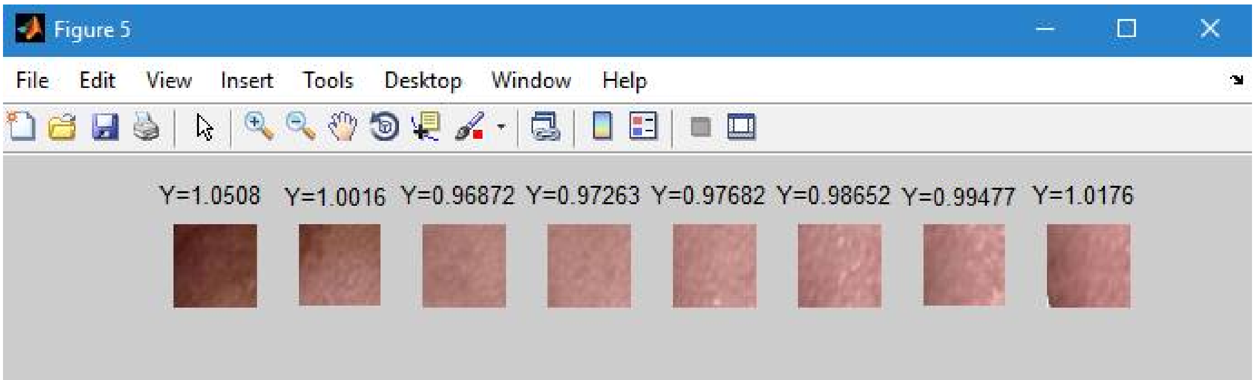

Fig 10 Block separation& texture value of each block

When user clicks on the “Geometry Feature” on the GUI, geometry features are displayed. Using mathematical formulas the values of 11geometric features is calculated. All the geometric features are described in section III. Fig 11 shows the extraction of geometric features of the input image. All the geometric values are displayed in the command window.

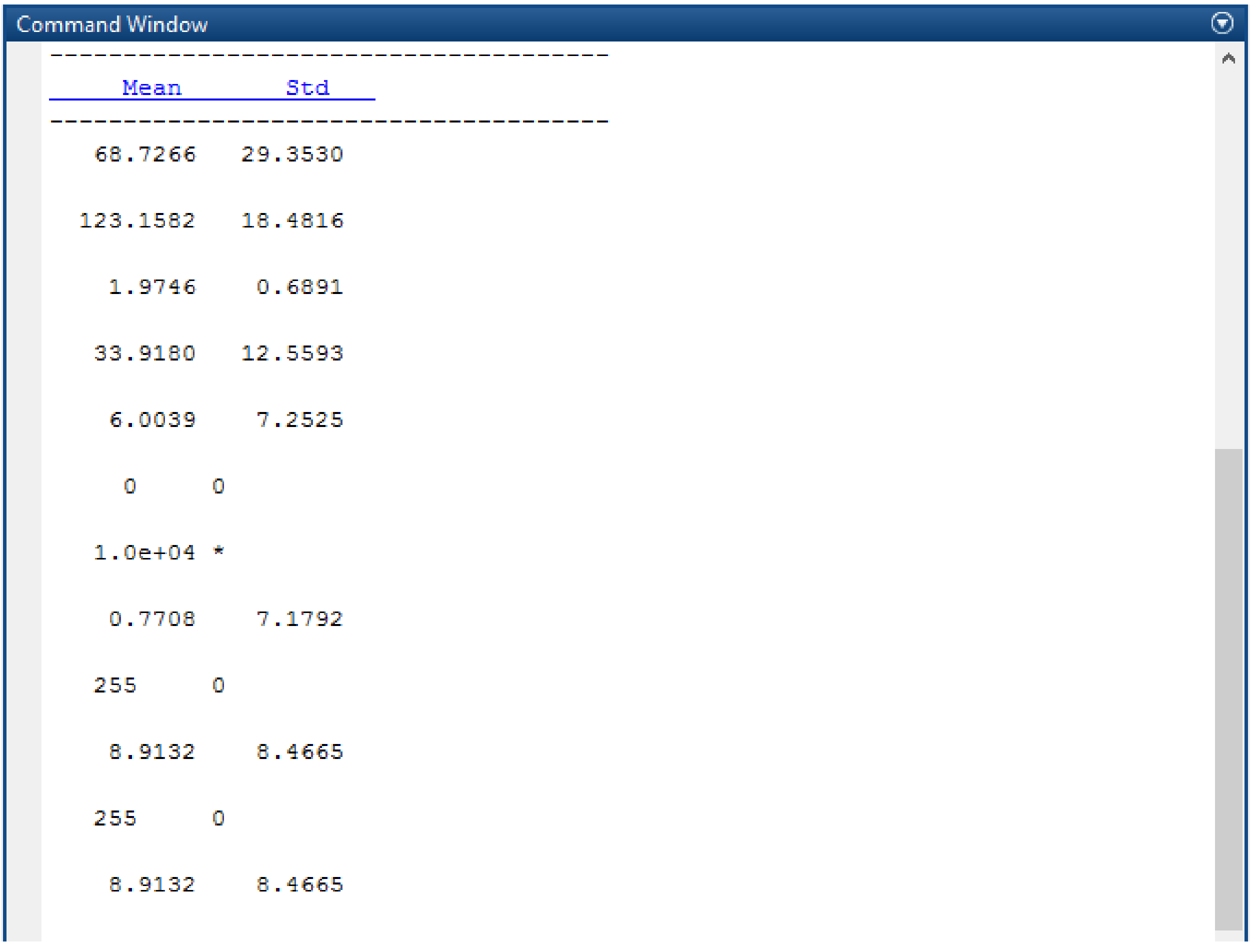

Fig 11 Geometry features

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After all the colour, texture & geometry features are extracted, they are analysed. KNN is used for classification. After training, the classifier is able to distinguish between healthy, diabetic& NPDR patients with the help of the extracted features. The final result is displayed as shown in Fig. 12.

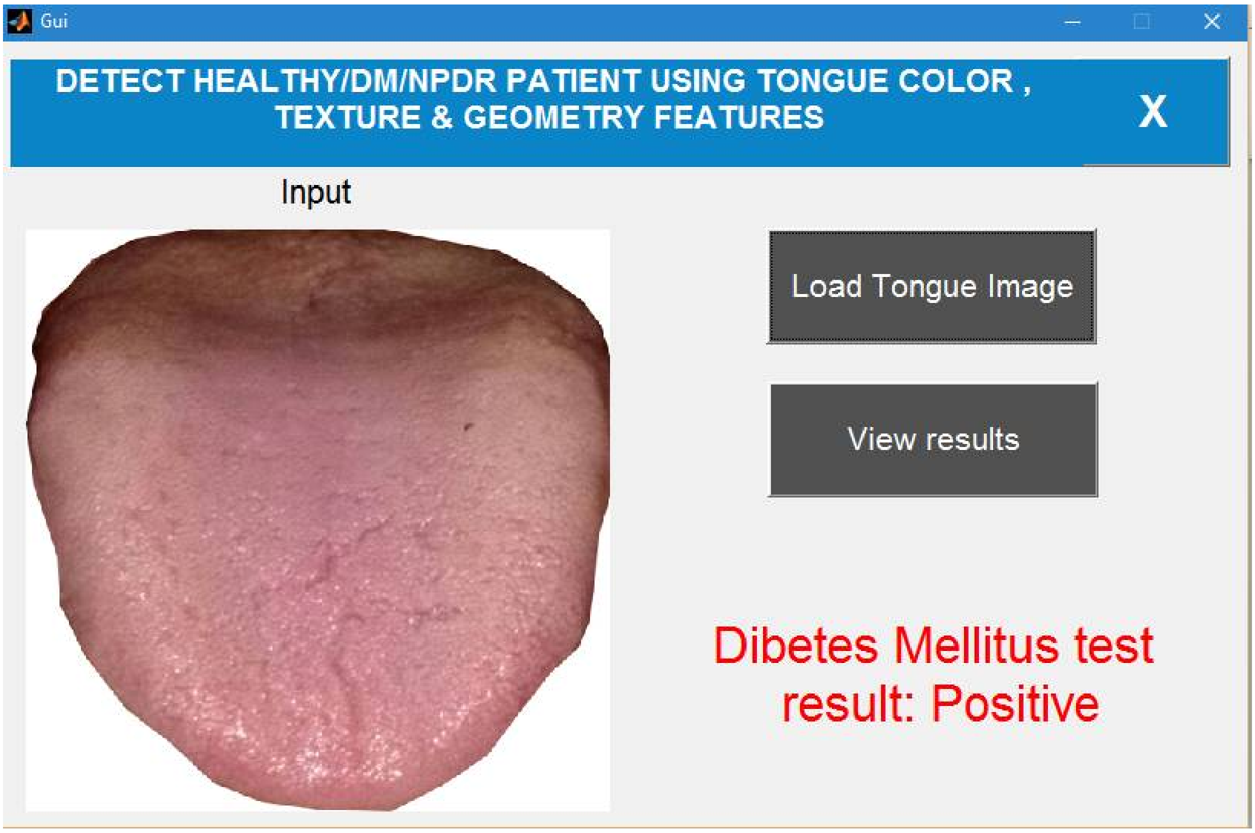

Fig 12 Classification result

VI. CONCLUSION

We have implemented a non-invasive technique to use tongue images and detect diabetes mellitus & non proliferative diabetic retinopathy using colour, texture & geometry features together. This method requires minimum human intervention & can be used at the diabetes screening laboratories. Further, we can include algorithms to determine the age group of the patients or to detect the stages of retinopathy.

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