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Review of Detecting Diabetes Mellitus and Diabetic Retinopathy using Tongue Images and Its Features.

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ABSTRACT

Diabetes mellitus, normally called Diabetes, is resulting because of the pancreatic failure which affected approximately 336 million people across the world according to the report of 2011. This disorder is characterized by a high level of blood sugar which when untreated properly could lead to Diabetic Retinopathy and visual impairment. Commonly the detection of this disease is with a needle injection and measuring the amount of glucose in the blood which is painful. This paper reviews the approach of using the tongue features like geometry, color and shape to detect diabetes as well as Diabetic Retinopathy. With these features Diabetic mellitus and diabetic retinopathy can be distinguished with an accuracy of up to 80.52%.

Keywords: Diabetes mellitus, Diabetes Retinopathy, Image acquisition, Color gamut, Geometrical feature, Texture values.

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INTRODUCTION

Diabetes mellitus (DM) commonly referred to as diabetes, is a group of metabolic diseases in which the blood sugar levels are relatively high for a protracted period of time. The prognosis of high blood sugar comprises of frequent urination, increased thirst and increased hunger. If abstained from treatment could lead to many complications like Diabetic retinopathy (DR) and non-proliferative diabetic retinopathy (NPDR). About one third of the people with diabetes do not know that they have the disease. There are two type of diabetes, type 1 DM where the pancreatic cells fail to produce insulin and type 2 DM where the body can't properly use the insulin that is released (called insulin insensitivity or insulin resistance) or does not make enough insulin. Type 1 is always treated with the injection of insulin and there is currently no cure for it. If a person is suffering with type 2 DM, it can be treated with moderate weight loss (10–15 pounds) and 30 minutes of moderate physical activity (such as brisk walking) each day.

According to the World Health Organization, in 2002 diabetic retinopathy was responsible for 4.8% of the cases of visual impairment in the world. There is no cure for DR but the initial stages of DR called, non-proliferative DR could be treated to prevent visual impairment if treatment is done before the retina has been severely damaged. Surgical removal of the vitreous gel (vitrectomy) may also help to improve vision if the retina has not been severely damaged [1]. Sometimes injections of an anti-VEGF (vascular endothelial growth factor) medicine or an anti-inflammatory medicine help to shrink new blood vessels in proliferative diabetic retinopathy. Other methods like angiography and color [2]–[10] fundus imaging [11]-[14] are used to examine the human retina in order to detect DR and subsequently NPDR. In angiography the fluorescein (a radio opaque contrast agent) is injected into the vein and imaging is done using x-rays to obtain real time moving images of an interior of an object. In case of color fundus technique, the back of the eye is captured using specialized flash enabled fundus cameras that are connected to an intricate microscope and imaging is done by exposing the eye to bright flashes. Therefore a non-invasive is to be developed.

The diagnostic testing for detection of diabetes [19] is either by an A1C test, also called the hemoglobin A1c, HbA1c, or glycohemoglobin test, a fasting plasma glucose test (FPG) or an oral glucose tolerance test (OGTT). These are the standard methods used for detecting diabetes. Although they are almost always accurate, all the tests can't be used to find out all the types of diabetes. The FPG is the most commonly used test as it is not only faster, it is also less expensive. The FPG test measures blood glucose in a person who has fasted for at least 8 hours and is most reliable when given in the morning. People with a fasting glucose level of 100 to 125 mg/dL have impaired fasting glucose (IFG), or prediabetes. A level of 126 mg/dL or above, confirmed by repeating the test on another day, means a person has diabetes. In order to analyze the blood glucose levels, the person needs to be injected with a syringe to collect blood samples.

Although the above mentioned process is the most widely used these days, it could be considered as invasive and physically painful. To make this procedure easier, a non-invasive computerized approach has been put forth in this paper. This approach is used to detect DM and NPDR by differentiating healthy samples, DM samples and DM with NPDR samples using a pattern of tongue features consisting of color, texture and geometry. Generally, traditional medical practitioners have been able to identify healthy tongues versus diabetic tongues but this ability comes from years of experience. Therefore a computerized method with accuracies up to 80.52 percentages can be obtained.

The non-invasive method proposed, uses an imaging instrument which captures a picture of the tongue under consideration and this image is segmented [15][23]. Experimental results were conducted on a set of data consisting of 130 healthy samples, 267 DM samples (void of NPDR) and 29 NPDR samples [18]. The captured images are image wrapped, and the color and texture observed is compared with the spectrum established according to the predicted values. The color spectrum is fixed with twelve color [16] [17] and the texture values, if represented by eight blocks in which they are characterized [20]-[21]. The geometric details, i.e., the shape, is estimated based on 13 features that are derived from the tongue images based on many factors like measurement, length, area and ratio [22]. Initially the three features are used to diagnose the condition of the patient and then categorization is done accordingly. Optimal combined usage of the color, texture and geometry of the tongue can also be done for a better understanding of the patient and his/her medical condition.

In this paper, a computerized tongue image processing based on the quantitative and qualitative features is analyzed. This method is focused on identifying and categorizing the diagnosis rather than identifying the syndromes. The quantitative features, namely, chromatic and textural features, are majorly focused here.

Rest of the paper divided into four sections which begins with image acquisition in section I. Remaining content of this article are organized as color reproduction and chromaticity, features and texture and geometrical characteristics in section II, section III and section IV respectively, followed by conclusion and references.

IMAGE ACQUISITION

Traditional Chinese medicine has proved that the human body can be analyzed using the tongue features like the shape, color, texture etc., and with imaging devices shown in the Fig.1 [10]

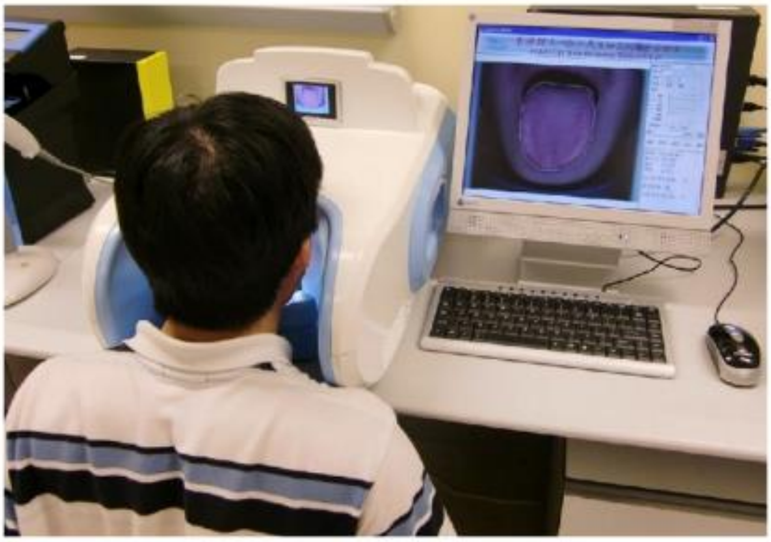


Fig. 1. Tongue image capturing device

The image capture deviceis made up of a 3-chip CCD camera with 8 bit resolution and two D65 fluorescent tubes placed symmetrically around the camera in order to produce a uniform illumination. To remove any noise and to avoid different illuminations, the images are color corrected [27]. The images are captured in JPEG format ranged from 257×189 pixels to 443×355 pixels and therefore the images are consistent and can be classified easily. The concept discussed in [27] is, in order to improve the correction accuracy on tongue colors by use of a Munsell colorchecker, a new colorchecker by aid of tongue color space is designed. Hence, this method is proven to be non-invasive when compared with the other approaches to detection of DM.

After the image has been captured, it needs to be segmented. The segmentation process is done chiefly to separate the foreground pixels with its background. Segmentation is done according to [23] which is fully automatic without any need of adjusting parameters for different images and do not need any initialization.

COLOR REPRODUCTION AND CHROMATICITY

The tongue color gamut contains a certain subset of complete colors that are present on the surface of the tongue and according to the CIE 1931 color space, it is defined as quantitative links between physical pure colors. The tongue color gamut exists within the red boundary shown in the Fig. 2 and Fig. 3. The black boundary shown in the figure below is where 98% of the tongue colors fall in the spectrum.

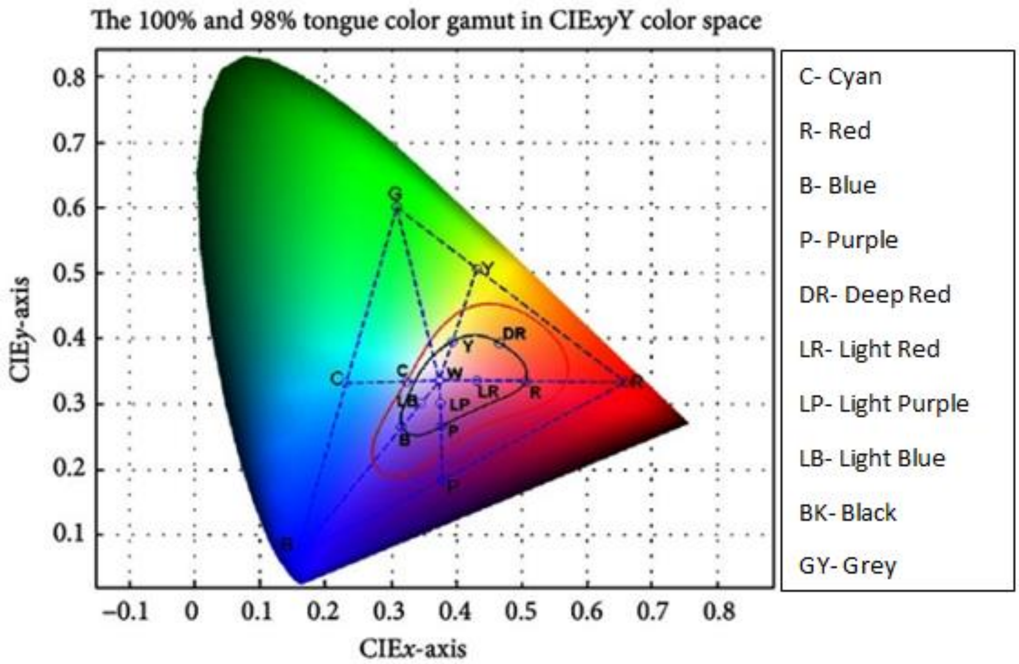


Fig. 2. The colored triangle is the gamut available to a typical tongue.

Fig. 3. Colors of the tongue gamut.

To better explain the color gamut 12 colors are predefined using which the colors can be classified as tongue related colors and tongue unrelated colors.

The RGB values are first extracted for every foreground pixel and are converted to CIELAB by transferring to CIEXYZ by

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Followed by CIEXYZ to CIELAB through

$$\begin{cases} \mathrm{L} *= 1.66. f\left({}^{Y}/_{B}\right) - 16 \\ a *= 500. \left[f\left({}^{X}/_{A}\right) - f\left({}^{Y}/_{B}\right)\right] \\ b *= 200. \left[f\left({}^{Y}/_{B}\right) - f\left({}^{Z}/_{C}\right)\right] \end{cases}$$

Where $f\ (x)\ = x^{1/3}$ if $x\ >\ 0.008856$ or $f\ (x)\ =\ 7.787x\ +\ 16/116$ if $x\ \leq\ 0.008856$.

A, B, C in the above equations are the CIEXYZ tristimulus values of the reference white point. The CIELAB values are then compared to the 12 colors from the tongue color gamut and after which the colors are matched by averaging in Euclidean distance it is assigned the color which is close to it. After evaluating all tongue foreground pixels, the cumulative value of every individual color is calculated and is divided by the total number of pixels. This ratio of the 12 colors forms the tongue color feature vector ϑ where

$$\vartheta = [c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, c_9, c_{10}, c_{11}, c_{12}]$$

c_j represents the sequence of color; $j = 1,2,3 \ldots$

FEATURES AND TEXTURE

The tongue texture and features are covered in this section, to understand the texture well, eight points in the tongue are selected and these eight points or bars is of size $64x64$. This is the most suitable size as all the areas of the eight bars are covered equally at this size. Three bars are smaller than the rest of the five bars, the smaller bars cover the inner part of the tongue and there is minimum overlapping whereas the outer portion of the tongue is enveloped by the larger bars where the overlapping takes place with the other bars. By using the foreground image of the segmented tongue, the center of the image is found out and then the bars are calculated accordingly. The positioning of these bars are then done but locating the edges of the tongue and measuring equal parts of the tongue from its center to the eight bars. The positions of the bars are as follows. Bar 1 is at the tip of the tongue and 2 and 3 are on its either sides. Bars 4 and 5 are on the either side of 2 and 3. Bars 6 and 7 and at the root and the 8th bar is placed at the center of the tongue. The Gabor filter is a liner filter which is used in image processing for texture processing. To compute the texture value of each block, the 2-D Gabor filter is applied and defined as

$$G_k(x,y) = exp(\frac{x'2 + \gamma 2 \cdot y2}{-2\sigma 2}) cos(\frac{2\pi x'}{\lambda})$$

where $x \geq x \cdot cos\theta + y \cdot sin\theta$, $y \geq -x \cdot sin\theta + y \cdot cos\theta$, σ is the variance, λ is the wavelength, γ is the aspect ratio of the sinusoidal function, and θ is the orientation. Three separate choices for σ and θ were inspected to get a perfect outcome. A texture block is convoluted with each of the filter which produces a response

$$R_k(x,y): R_k(x,y) = G_k(x,y) * H(x,y)$$

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

$$FR_i(x,y) = max(R_1(x,y), R_2(x,y), \ldots, R_n(x,y))$$

The equation above is used to select the maximum pixel intensities and represent the texture of a block by averaging the pixel values of FR_i. Finally the choices for σ with three orientations was chosen.

GEOMETRICAL CHARACTERISTICS

As seen earlier, there are 13 geometrical feature that is obtained from the tongue images based on dimension, size and scope of surface. The features are measured as listed below.

A. WIDTH: This is measured as a horizontal distance along the $x - axis$ from side to side with the left furthest distance as x_{min} and the right furthest is the . x_{max}

$$width = x_{max} - x_{min}$$

B. LENGTH: This is measured as the vertical distance along the $y - axis$ from top to bottom with the top most distance as y_{min} and the bottom most distance as y_{max}.

$$length = y_{max} - y_{min}$$

C. LENGTH TO WIDTH RATIO: The length of the tongue is divided by the width to obtain the length to width ratio.

D. SMALLER HALF DISTANCE (z): This is measured by comparing the length and the width to find the shorter distance and the half of this is calculated as shown in Fig.4.

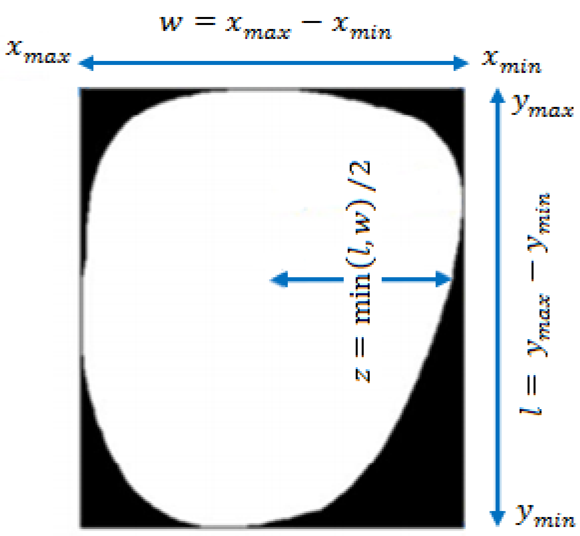


Fig. 4. Diagrammatic representation of characters A, B and D.

$Z = min(length, width)/2$

E. CENTER DISTANCE (cd): This is measured by noting the center point of the width $([\max(y_{xmax}) + \max(y_{xmin})]/2)$ and the center point of the length (y_{cp}) and measuring the distance between these two points, depicted in Fig.5.

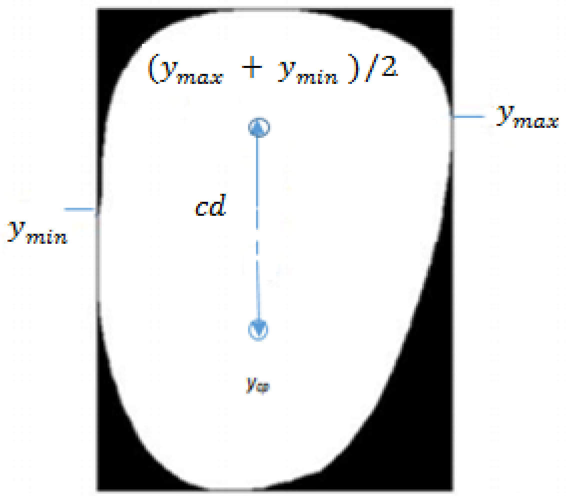


Fig. 5. Diagrammatic representation of character E.

$$cd = \left(\frac{[\max(y_{xmax}) + \max(y_{xmin})]}{2}\right) - y_{cp}$$

where $y_{cp} = (y_{max} + y_{min})/2$.

F. CENTER DISTANCE RATIO (cdr): It is defined as the ratio of the center distance to the length.

$cdr = cd/length$

G. AREA (a): The area is the measured from the image of the tongue by calculating the total number of pixels in the image.

H. CIRCULAR AREA (ca): This is defined as the area of the circular region on the tongue pixels using the smaller half distance (z), shown in Fig. 6.

$$ca = \pi r^2$$

where r is the radius of the circular region on the tongue.

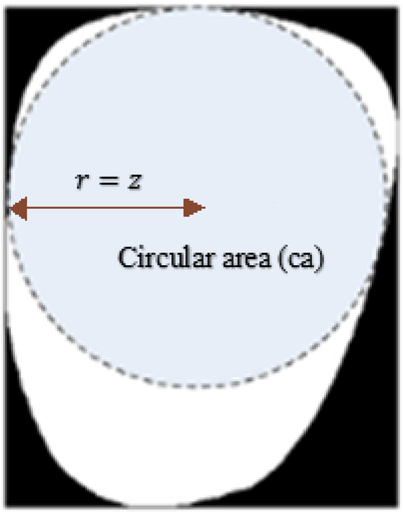


Fig. 6. Diagrammatic representation of character H.

I. CIRCULAR AREA RATIO (car): This is the ratio of the Circle area to the area.

$$car = ca/a$$

J. SQUARE SURFACE AREA (sa): This is the area of the square surface in the tongue pixels using the length and the width, as shown in Fig.7.

$$sa = wl$$

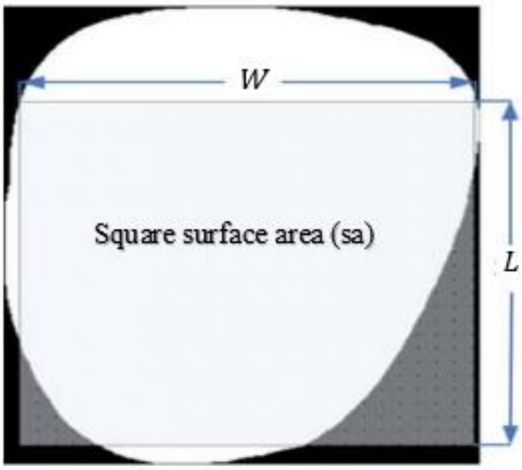
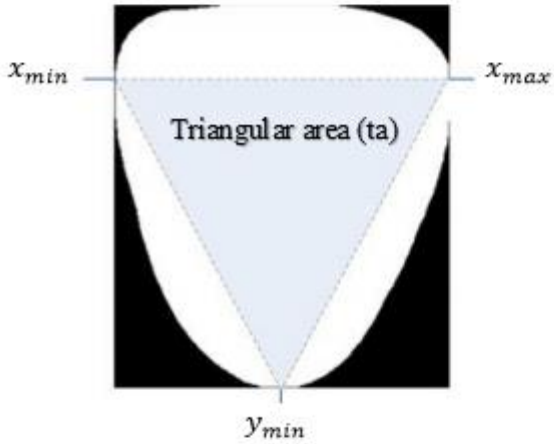


Fig. 7. Diagrammatic representation of character J.

K. SQUARE AREA RATIO (sar): It is the ratio of the square aurface area to the area.

$$sar = sa/a$$

L. TRIANGULAR AREA: This is the area of the triangular region on the tongue center. The left most point of the triangle is the x_{min} and the right most point is the x_{max} and the bottom point is the y_{max}, as shown in Fig.8.



M.

Fig.8 Diagrammatic representation of character L.

N. TRIANGULAR AREA RATIO (tar): It is the ratio of the triangular area to the area.

$$tar = ta/a$$

CONCLUSION

The study of tongue features such as the tongue shape, color and texture have been proved to be non-invasive and has been very effective way to diagnose diabetes and its associated disease diabetes retinopathy. Based on the shape, color and texture of the tongue, a noninvasive approach is categorized into healthy, DM and NPDR tongues with accuracies up to 80.52%. Further the age group of the patients can be determined by relevant algorithms.

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