ISSN 2278-3091
Volume 8, No.3, May - June 2019
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse19832019.pdf
https://doi.org/10.30534/ijatcse/2019/19832019

Health Evaluation Device Using Tongue Analysis Based on Sequential Image Analysis

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ABSTRACT

This study employs digital image processing as a tool to reduce the complexity in tongue analysis. Through visual inspection, classification of tongue coat and body color is entirely based on the verdict of the medical personnel thus not providing an absolute truth towards chronic and acute irregularities the patient is suffering from. A firmware which can extract the natural color of the tongue and yield an accurate list of symptoms that might lead to a conclusion of anomalous working on an individual's internal organ was developed. Its system framework comprises of: (1) image acquisition (2) image segmentation; (3) body and coat segmentation; (4) color classification and; (5) neural network. Moreover, the proposed device is an open source technology developed using Python programming language and Linux operating system on a Raspberry Pi 2 B+. The experiment revealed that the proposed method produced significant results with an accuracy of 93.33%.

Key words : biomedical engineering, image processing, Python, Raspberry Pi, tongue analysis

1. INTRODUCTION

People nowadays spend most of their time in work or school hence, giving less priority on their health status. In a study conducted by AIA [1], it was found that 75% of the Filipino population are not living a healthy lifestyle. Also, 53% of the population undergone medical check-up only once for twelve months. Thus, daily monitoring of health condition is a good practice to help maintain a vigorous lifestyle and prevent irregularities.

Based on a study from Philippine Statistics Association (PSA) [2], 250,000 practitioners in the Philippines have been using traditional medicine as a practice. One type of traditional medicine is Traditional Chinese Medicine (TCM). Typical diagnosis used in TCM [3] includes diagnosis using the eyes, nose, face, mouth/lip, ears, throat, breasts, hands, nails, chest, genitals, legs, skin, and the most popular which is the tongue. Non-invasive TCM diagnostic tools for mouth/lip [4], face [5], fingernails [6], [7], voice [8], and hands (pulse) [8] were developed as an aid for both the doctor and the patient. On the other hand, image processing was applied in non-TCM diagnostics such as tongue [9], iris [9], [10], retina for diabetic retinopathy [9], [11], skin [12], and face [13].

Tongue Analysis is part of Traditional Chinese Medicine which is considered as one of the primary processes in assessing patient's condition. It is part of a common routine in a physical examination to use the tongue as a gauge for observing the improvement or weakening of the patient's situation since the tongue body and coating colors are not affected by short-term incidents or current variations. For this purpose, the tongue body color is more suitable in chronic situations, while the tongue coating is generally useful in acute conditions. [14]

In [15], a system was developed wherein ailments are traced through tongue image processing. It deals with the threshold of tongue signs for disease identification. A collection of tongue images was gathered as an input on the computer to analyze using MATLAB. Neural network was preferred as a classifier since it performs precisely similar to how the human brain performs.

Meanwhile, the study in [16] focused on evaluating the tongue features including shape, color, coating, pimples, and cracks. The algorithm utilizes image averaging and gradient technique for extracting the true color and coating of the tongue. Median filter, local contrast enhancement and image

sharpening technique were used for shape, pimple and cracks on the tongue surface. This method yields an enhanced input image to aid medical practitioners in tongue inspection.
Lastly, in [17], their developed system quantitively analyzed the outline of a human tongue using its geometrical features. Thirteen geometrical characteristics based on measurements, distances, areas, and their ratios are derived from tongue images taken by a developed tool that corrects color. Furthermore, the tongue image capture device guarantees the correct alignment of the images. After this the resulting image will be compared to the database then there will be an output.

This research aims to utilize tongue analysis as a tool to raise awareness on an individual's health condition through developing an open source health assessment device through tongue image analysis. This proposed device used digital image processing techniques and HSV color space in color classification for an accurate diagnosis of the tongue image.

2. RESEARCH METHOD

2.1 Image Acquisition

Image acquisition plays a vital role in processing images specifically tongue images. The output relies both in the algorithm used and the quality of the input image. Lighting is a crucial part in image acquisition since both excess lighting and shadow acts as a noise in the tongue image that can modify the natural color of the tongue image, hence light diffusion is necessary. For proper illumination, two strips of daylight colored LEDs are fixed in the scanning compartment with an angle of inclination of 45^0 to scatter light equally to the surface of the tongue. The luminosity is moderated by limiting the current flow and diffusing the LEDs. Images below are taken by the employed lighting system.

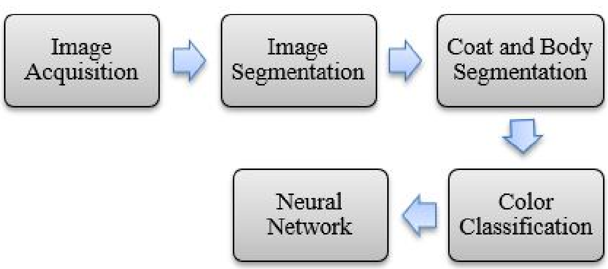


Figure 1: Block Diagram of the Proposed System

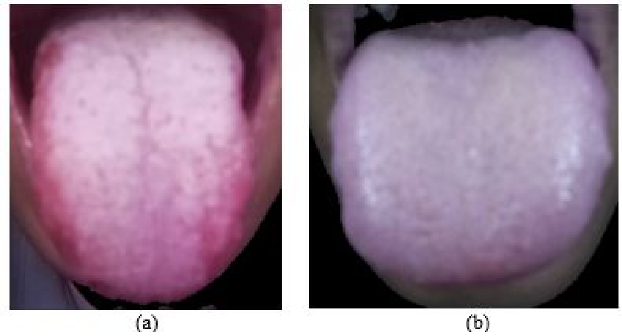


Figure 2: (a) Red tongue (b) Purple tongue

2.2 Image Segmentation

One major concern in an automated tongue analysis is when the tongue body is automatically segmented from its background. The software introduces a new approach with aid of the Sobel transform [18] and Watershed algorithm [19]. The task of segmenting the tongue is acquired by converting the input image into 2-D array to find the edge magnitude using Sobel transform. The equation for the edge magnitude is shown below in equation (1).

$$M = \sqrt{\sum S_H - S_V} \tag{1}$$

The contour of the tongue is fed to the Watershed Algorithm to separate overlapping objects. The algorithm is done by labelling the image, marking regions of the image by an integer value, where any non-zero values in input are counted as features or objects and zero values are least priority. Labelled pixels with low values represent the background, and the mode of the remaining labelled pixels represent the tongue surface. After separating the tongue from its background in grayscale, the converted image is modified to a binary-level image through thresholding. The binary image of the tongue is shown in Figure 3.

Completing the segmentation process requires the product between the matrix of the input image and the binary image thus, extracting the segmented image shown in Figure 4.

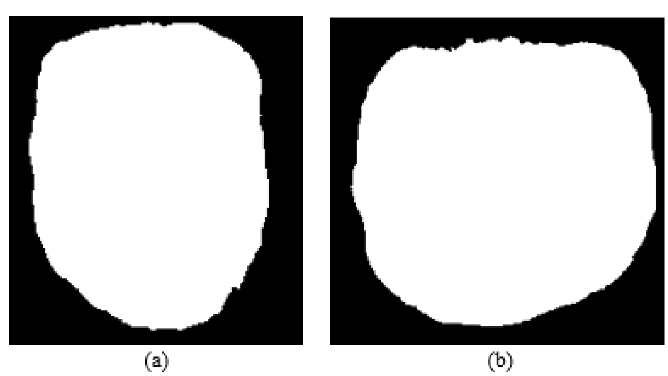


Figure 3: (a) Binary-level image of red tongue (b) Binary-level image of purple tongue

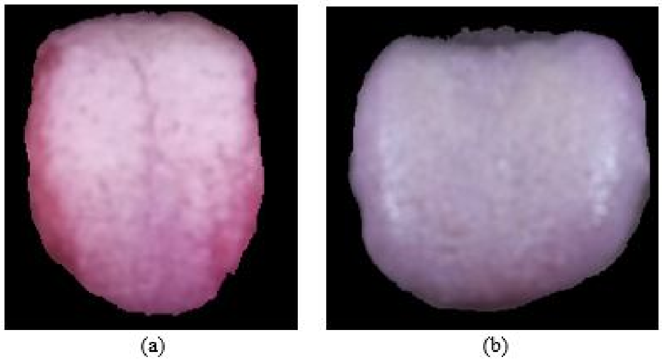


Figure 4: (a) Segmented image of red tongue (b) Segmented image of purple tongue

2.3 Coat and Body Segmentation

To completely identify the color of the tongue body and tongue coating, another segmentation arises. The segmentation of the tongue coating from the tongue body justifies the region where coating is situated. This is done to separately classify the coat and body color using thresholding. Figure 5 illustrates the binary image of a tongue body and coat segment.

2.4 Color Classification

This method requires conversion from RGB (Red – Green – Blue) color space component to HSV (Hue – Saturation – Value) color space. The objective is to facilitate the program to recognize the image like the way the human eye does. The conversion is for the image to be more intuitive and perceptually appropriate than Cartesian (cube) representation.

The HSV color model circumscribes a color space in terms of three essential components, the Hue, Saturation and Value. The Hue describes the color itself, Saturation depicts the intensity of the color and the Value measures the brightness.

The segmented tongue color and coating are classified through an iterative process on the entire segmented image, examined pixel-by-pixel, and determining the equivalent HSV component of majority of the pixels. A neural network concludes all findings through sorting the concluded tongue color to its corresponding analysis. Based from HSV graph in Figure 6, the color classification ranges only in the red and violet hue region for the tongue color, and in the yellow hue region for the tongue coating.

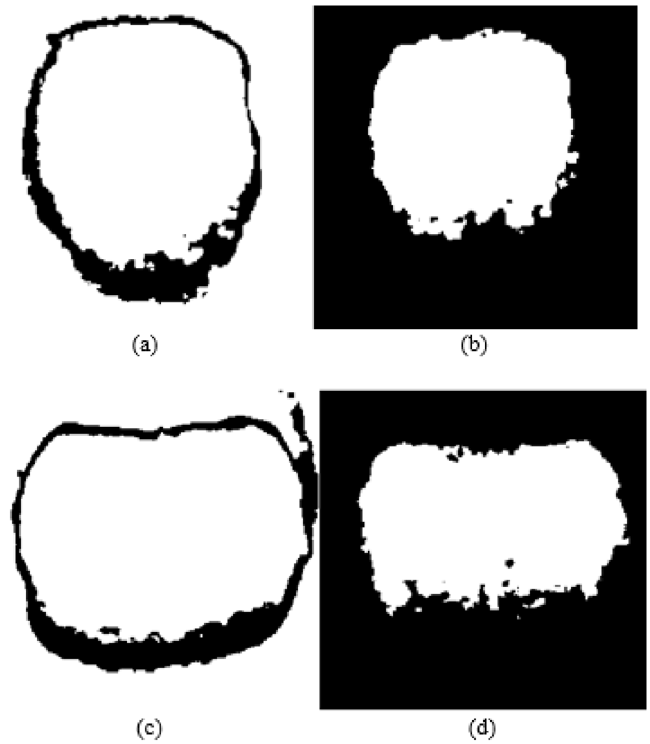


Figure 5: (a) Red tongue body segment (b) Red tongue coat segment (c) Purple tongue body segment (d) Purple tongue coat segment

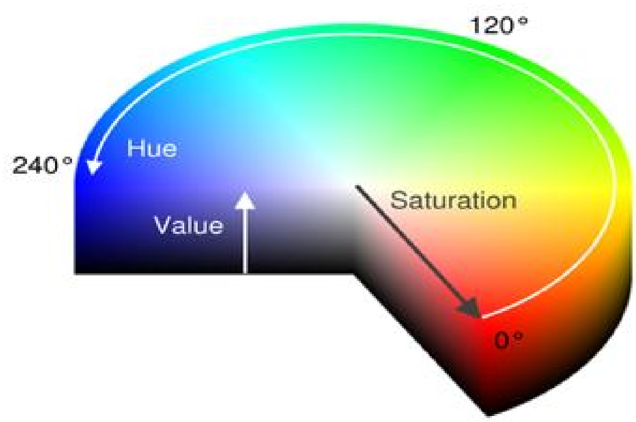


Figure 6: HSV solid cylinder

2.5 Artificial Neural Network

The ANN (Artificial Neural Network), administered using Python programming language and SciPy library in conjunction with Sci-kit imaging library, consists of various iterations of conditions in a feed-forward manner; especially designed for the pixel analysis and used for the image segmentation and color classification.

The neural network decides for the conclusion being directed from the basis of corresponding symptoms regarding the resulted tongue color and coating. This study covers 4 tongue body colors: Red, White, Pink and Pale; and 4 tongue coating colors: Thin White, Thick White, Thin Yellow and Thick Yellow. Based on research and data gathered by the authors, the database for the results are listed below [14], [20], [21].

Table 1: Organs Affected

Tongue Body Color	Tongue Coating Color	Organ Affected
Red	Thick Yellow	Stomach and Large Intestine
Red	Thin Yellow	Lungs
Red	Thin/ Thick White	Kidney
Pale	Thin/ Thick Yellow	Liver
Pale	Thin White	Spleen
Pale	Thick White	Heart and Kidney
Purple		Liver, Blood Stasis
Pink		None

Table 2: Traditional Chinese Diagnosis

Tongue Body Color	Tongue Coating Color	Diagnosis
Red	Thick Yellow	Interior Heat
Red	Thin Yellow	Defensive Qi-level in the Lungs
Red	Thin/ Thick White	Lesser Yin (Heat)
Pale	Thin/ Thick Yellow	Excess Heat
Pale	Thin White	Deficiency of flow of food in the body
Pale	Thick White	Lesser Yin (Cold)
Purple		Yin Deficiency
Pink		None

Table 3: Symptoms

Tongue Body Color	Tongue Coating Color	Diagnosis
Red	Thick Yellow	Feel Hot, Sweat Easily, Thirsty, Constipated, Irritable, Pain in the Abdomen
Red	Thin Yellow	Coughing, Feverishness, Thirsty, Stressed, Pre-Menstrual Problem
Red	Thin/ Thick White	Dryness of the Mouth and Throat, Hot Flushes, Sweat at Night, Fever, Insomnia, Irritability
Pale	Thin/ Thick Yellow	Dizziness, Fatigue, Insomnia, Palpitation, Pain in the Chest
Pale	Thin White	Fatigue, Absence of desire to eat, Diarrhea, Absence of Thirst, Chills, Overthinking
Pale	Thick White	Cold Feeling, Pale Skin, Backache, Tendency to Lose Control, Feels Down
Purple		Headaches, Dry Lips, Cold Limbs, Painful Legs, Liver Spots, Lack of Skin Luster
Pink		None

3. DESIGN IMPLEMENTATION

The proposed system has a Raspberry Pi camera module responsible for acquiring tongue images and a Raspberry Pi 2 model B+ to perform sequential image processing. During image acquisition, a daylight colored diffused LEDs provides a proper lighting to reveal the natural color of the tongue and reduce noise in the input image. A 5” Waveshare touchscreen LCD is used as a medium for user interfaces.

The main input of this device is the tongue image and the output will be a list of assessed symptoms of the patient through tongue analysis. The bodywork is fabricated using vacuum forming to create a trapezoid-like shape with smooth edges projecting a sleek design. The base of the device is made of plywood and the interior is designed in a structured manner where it is composed of three divisions: (1) Source Compartment (2) Scanning Compartment and (3) Core Compartment.

Figure 7: The proposed health evaluation device using tongue analysis

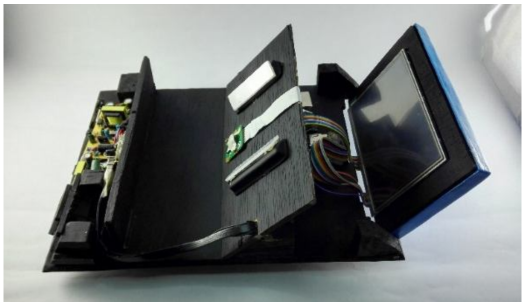


Figure 8: Internal view of the proposed health evaluation device

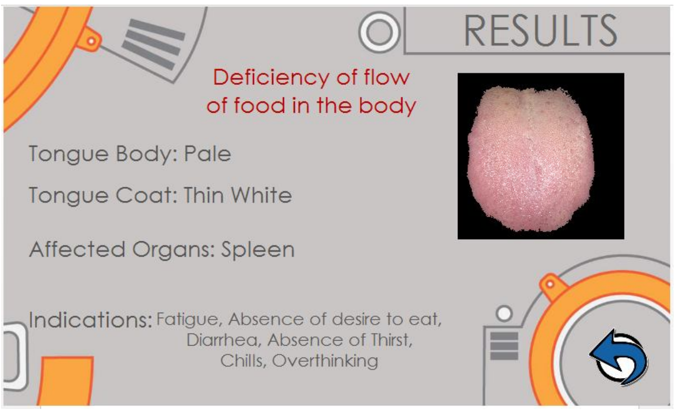


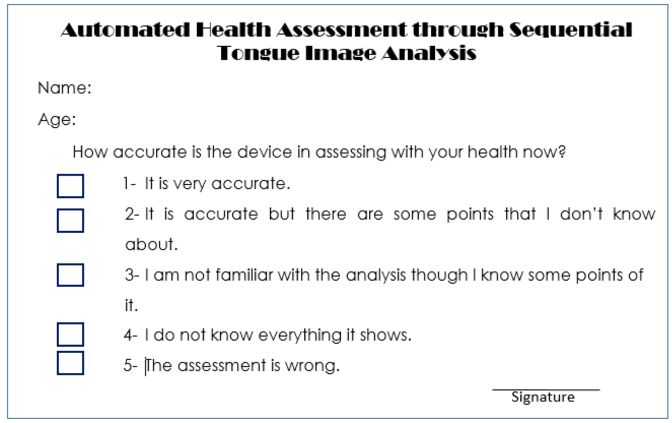
Figure 9: Sample output of the proposed health evaluation device

4. RESULTS AND DISCUSSION

Three (3) trials each for 30 subjects were conducted to test the consistency of the results. The statistical analysis is done by averaging the accepted values over its sample size (n=30) and the outcome is 92.222%. The proponents conducted a survey (shown in Figure 10) after each patient for the evaluation whether the results of the proposed health evaluation device correspond to the user's health condition.

Null hypothesis: The proposed health evaluation device based on tongue analysis could identify the natural color of the tongue thus providing reliable results.

Alternative hypothesis: The proposed health evaluation device based on tongue analysis could not identify the natural color of the tongue thus not providing reliable results.



Automated Health Assessment through Sequential Tongue Image Analysis

Name:

Age:

How accurate is the device in assessing with your health now?

- ☐ 1- It is very accurate.
- ☐ 2- It is accurate but there are some points that I don't know about.
- ☐ 3- I am not familiar with the analysis though I know some points of it.
- ☐ 4- I do not know everything it shows.
- ☐ 5- The assessment is wrong.

Signature

Figure 10: Survey Form

Table 4: Kolmogorov-Smirnov Test

X	F	Cumulative Freq	Sn(x)	Z-Score	Fo(x)	Fo(x)-Sn(x)
1	16	16	0.5333	-0.8346	0.2019	0.3313
2	11	27	0.9	0.6382	0.7383	0.1616
3	3	30	1	2.1112	0.9826	0.0173
4	0	30	1	3.5841	0.9998	0.0001
5	0	30	1	5.0571	0.9999	0

Substituting for n in the left side expression:

$$D_n = \frac{1.36}{\sqrt{n}} = \frac{1.36}{\sqrt{30}} = 0.2813 \quad (2)$$

$$D_{max} = 0.3313 \quad (3)$$

Since the calculated deviation D(0.2483) is lower than the maximum deviation D(0.3313) from Table 4 therefore null hypothesis is accepted.

Kolmogorov-Smirnov Test is a nonparametric test that is used for univariate case when ordinal data is to be measured. It is more appropriate to be used than the chi-square test when ordinal data are met in every situation. The null distribution of this statistical test is calculated under the null hypothesis that the sample is drawn from the reference distribution.

Figure 8 illustrates the accuracy of the device by comparing the color analysis from APHI-Tech to the visual inspection done by a medical specialist from a hospital. The number of matched images over 30 patients is 93.33%.

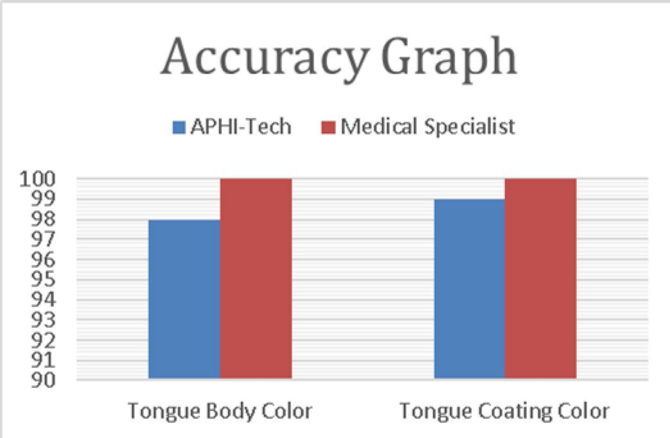


Figure 11: Accuracy Graph. APHI-Tech is the name of the health evaluation device based on tongue analysis.

5. CONCLUSION

In this study, the images of the tongue were processed using sequential image analysis. The color characteristic of the coating and body of the tongue were enhanced to extract the natural color and fed into a neural network to yield an accurate list of indications that might lead to a conclusion of anomalous working on an individual's internal organs.

The experiment was conducted on 30 patients at Paltok Health Clinic and images gathered were checked by a medical specialist. The system was able to overcome the bias of color perception thus, setting the standard for tongue color analysis. The statistical results proved the accuracy of the proposed health evaluation device to be 93.33%.

ACKNOWLEDGEMENT

This study is supported by the University Research and Development Services Office and the University Research and Extension Council of the Technological University of the Philippines. The University is highly acknowledged for the financial support. The authors would like to thank Dr. Philip Niño Tan-Gatue of the Philippine General Hospital and all the staffs of the Paltok Health Clinic for their support and cooperation in doing this project, to the Python community especially to the core developers of SciPy contributed by Travis Oliphant, Pearu Peterson, and Eric Jones, and to our colleagues and professors from the Electronics Engineering Department for the encouragement.

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