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Article in Journal of Techniques · April 2023

DOI: 10.51173/jt.v5i1.868

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Journal of Techniques, ISSN: 2708-8383, Vol. 5, No. 1, 2023, Pages 22-37
DOI: https://doi.org/10.51173/jt.v5i1.868

JOURNAL OF TECHNIQUES

Journal homepage: *http://journal.mtu.edu.iq*

RESEARCH ARTICLE - ENGINEERING

Tongue Color Analysis and Diseases Detection Based on a Computer Vision System

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Article Info.

Article history:

Received
18 August 2022

Accepted
04 December 2022

Publishing
31 March 2023

Abstract

The tongue reflects the abnormal condition and behavior of the internal organs of the body, such as problems of the heart, liver, pancreas, stomach, intestines, blood diseases and others, which lead to changes in some of the features and characteristics of the tongue. The most important of these is tongue color, which can be adopted as a biometric that can be used in Computerized Tongue Diagnostic Systems (CTDS). Quantitative diagnosis of the tongue requires some devices, including image acquisition devices such as cameras, light sources, filters, color checkers, image analysis and processing devices through the application of some algorithms or image processing and color correction software, as well as a computer. This study proposes a real-time imaging system to analyze tongue color and diagnose diseases using a webcam under specific conditions. The proposed system was designed in a Matlab GUI environment. After testing the system on a data set of more than 100 images, the preliminary results showed that the proposed system gives a disease diagnosis with an accuracy rate of no less than 86.667%. The proposed system contributed to the diagnosis of several diseases in real time, with an accuracy of 95.45%, with ease of use, implementation and low cost. This gives impetus to further studies to apply computerized diagnosis in medical applications, to enhance the medical reality, monitor patient health, and make an accurate diagnosis.

Publisher : Middle Technical University

Keywords: Color Analysis; Computer Vision System; Tongue Diagnosis.

1. Introduction

Traditional Chinese Medicine (TCM) generally relies on diagnosing diseases through four processes through which information is obtained: examination, smell, hearing, inquiry, and palpation. The diagnosis of the tongue over the rest of the body by practitioners of traditional Chinese medicine has been leading for about 2,000 years or more [1]. The human tongue has advantages and characteristics related to the internal organs of the body and plays an important role in diagnosing diseases and stages of disease development [2–4], including tongue color, coating color, tongue shape, coating thickness, saliva, and tongue fissures, Bruises, red dots, and teeth marks [5]. The most important of these features is the color of the tongue and the color of the coating [4], where the color of the normal tongue is pink with a thin white layer [6]. Some diseases directly affect the color of the tongue and the color of the coating, for example, diabetes mellitus (DM)) is a common and dangerous disease that causes oral complications. It gives the yellow color to the tongue coating [7] and gives the blue color to the tongue with a yellow coating to people with a type (DM2) [5]. Cancer gives the tongue a purple color with a thick greasy coating [6], and the color of the tongue is red with a crooked shape for patients with acute stroke [8], and the color of the white tongue indicates a cold syndrome or anemia. And the yellow color indicates heat syndrome, liver and gallbladder diseases [1], [9], circulatory and digestive problems that give the tongue a blue or purple color [9], and appendicitis causes some changes on the surface of the tongue [10], and it reflects the severity of infection with the COVID-19. Its effect on the tongue, where the color of the tongue is pale pink in light infection, red in moderate infection, and dark red (burgundy) in severe infection, as well as inflammation of the tongue and its ulceration, gives a dark red color to the tongue [9], [11]. As for patients with resistant pylori infection, the color of the tongue is red with white paint [8]. Tongue Diagnostic Systems (TDSs) are considered one of the most effective and important non-invasive systems for diagnosing diseases remotely at any time and place without contacting the patient. What helps support the global need for primary health care systems, especially in light of the Corona pandemic and the outbreak of some infectious diseases, which made it necessary to rely on TDSs to assist in clinical decisions and prevention of human error. Many studies have been conducted in the field of tongue analysis and diagnosis, depending on its features, some of those research studied the effect of changing lighting on analyzing tongue colors and how to reduce them, and other works research in diagnosing diseases. A new implicit correlation was investigated by Zhang et al. [12] to propose a new method for diagnosing some diseases (mention some diseases here) based on objectively analyzing tongue color through its color features. The tongue image data were captured by a CCD with two D65 bulbs, and 11 diseases could be successfully classified with an average accuracy of 91.99%. A study by Jung et al. [13] suggested tongue diagnostic systems (TDS) based on light sources, cameras, color checkers, tongue classification, tongue segmentation and color correction software to assist in obtaining information with visible light waves

Nomenclature

CCD	Charge-Coupled Device	B	Blue
TCM	Traditional Chinese Medicine	Y	Yellow
GUI	Graphical User Interface	LR	Light Red
ROI	Region of Interest	2D	Two-Dimensional
TDS	Tongue Diagnostic System	USB	Universal Serial Bus
SVM	Support Vector Machine	W	White
CTDS	Computerized Tongue Diagnostic Systems	Cb	Chromatic Blue
Cr	Chromatic Red	R	Red
PI	Pink	G	Green
LP	Light Purple	LB	Light Blue
DR	Dark Red	C	Cyan
OR	Orange	P	Purple
BK	Black		

from a two-dimensional (2D) image, allowing data to be collected from multiple ranges under different conditions. The proposed TDS provided accurate, fast and convenient information that helps in health assessment. Wang et al. [14] proposed an imaging system based on SVM that mathematically analyzed the statistical distribution of human tongue colors in depth to obtain diagnostic features. The color distributions of many tongue features, such as red dots and point dots, were used to obtain a ratio between the tongue color space and the color distributions. As reported in a study by Cheng et al. [15] a new model was proposed for detecting different lighting conditions using a smartphone and noticed the color difference in the image taken with and without flash in different lighting conditions to correct colors in different lighting conditions. The brightness was upgraded, and the interference rate was observed in colors in the tongue image, and white fur was determined when the overlap exceeded 60%. The detection proposed model was trained by SVM on the corrected image to detect the white fur region. A study by Chen et al. [16] suggested a computational method of tongue diagnosis for color determination with six colors based on calorimetry and computational simulation of tongue diagnosis in traditional Chinese medicine (TCM). With the help of experienced clinicians using the Munsell Color Book, a comparison between tongue colors and common colors was analyzed based on the elements of color, texture, and moisture. A study by Pang et al. [10] described a tongue calculation model for diagnosing appendicitis by analyzing the number of changes occurring on the surface of the tongue as a result of diseases. Maps were created from the image of the tongue for the corresponding diseases in a statistical way based on the chromatic and structural features. Experiments have been conducted on a large database containing more than 12,000 images captured by a digital camera showing encouraging results and have promoted the modernization of the traditional diagnostic process for the tongue, the ratio of the correct classification is up to 92.98%. A new implicit correlation was investigated by Umadevi et al. [17] to get a new method to diagnose diabetes based on tongue images using a Versatile Tooth-Marked Region (VTMR) method. The performance of the proposed VTMR method was evaluated on 96 tongue images collected from a medical college hospital and research institute and 97 UV-scanned tongue images captured from an iPhone with an HD camera, and achieved classification accuracy rate of 90.23%. Naveed et al. [18] suggested a developed algorithm called fractional order Darwinian particle swarm optimization (FODPSO) algorithm to diagnose diabetes from 700 images of the tongue captured by a digital camera and a smartphone, and achieved diagnosis accuracy rate of 95.2%. An Infrared tongue thermal imaging system was proposed by Thirunavukkarasu et al. [19] to measure tongue temperature for the diagnosis of diabetes, where the proposed system classified diabetes depending on the temperature difference of the tongue using Convolutional Neural Networks (CNN). Tongue thermogram data were collected using an infrared camera from 140 subjects, the proposed method has 94.28% accuracy rate of diagnosis. To provide a more accurate diagnosis of the tongue, several researchers used spectroscopy based on electromagnetic theory to access the individual pixel spectrum of the tongue image. According to the electromagnetic theory, living organisms emit certain frequency bands of light. These frequencies extracted from hyperspectral data correspond directly to the amount of energy from the surface of the tongue. For example, Qingli and Zhi [20] suggested a method for tongue color analysis based on spectra-angle spectra. The proposed work provided spectral properties in different wavelength regions based on hyperspectral images and the spectral angle mapper (SAM) algorithm to know the color of the tongue surface using 200 hyperspectral tongue images. The results indicated that the method overcame some limitations of the traditional method for identifying tongue color with better classification performance and accuracy of 88%. The method used a color ultra-spectrum camera to capture images of the tongue. For each work mentioned above, there were advantages and disadvantages regarding the different operating conditions and the methods used. Determining the ROI and the location of the tongue was among the most important problems that faced the research. In addition, most studies in the field of tongue diagnosis relied on the tongue color analysis of an image previously captured with different cameras using different methods and algorithms to diagnose mostly one disease, and they depend on color calibration cards that are uncomfortable, do not give a voice message of the patient's condition after the examination. This study will address the above limitation by proposing an imaging system to process the image captured directly by the Webcam, analyze tongue color and diagnose more than one disease in real-time, and gives more accuracy.

How does a computer aid in medical applications to provide accurate diagnosis and reduce human error? This study aims to implement and test a computerized disease diagnosis system by analyzing tongue color in terms of effectiveness, safety, cost and reliability, by building a computerized disease detection system that is easy to use and low in cost, and gives results in real-time without touching the patient, using a graphical user interface (GUI) to operate and control the proposed system and display the diagnostic outcome.

In light of the COVID-19 pandemic and the outbreak of infectious diseases, there is an urgent need for systems for diagnosing diseases and treating them remotely without touching the patient to avoid infection. The current study contributed to the use of the computer to diagnose diseases by analyzing the color of the tongue and suggesting an easy-to-use and inexpensive system that can be provided everywhere to diagnose diseases simultaneously and give advice without any physical contact with the patient.

The proposed system can greatly and effectively help in primary health care systems and early detection of diseases, especially in poor, middle- and low-income countries that lack advanced medical and laboratory devices and equipment because of the high cost.

The proposed system can help in the clinical decision and reduce human error, especially in remote areas that lack the professional medical staff and advanced laboratories.

The proposed system can also effectively help reduce the spread of diseases and mortality through the use of a computer, a high-resolution camera, and image processing programs to analyze the color of the tongue, diagnose the patient's condition, and send a text message with the diagnosis result to the caregiver.

2. Materials and Methods

2.1. Data Collection

A set of more than 100 images was collected in Mosul General Hospital in Mosul, Iraq, for patients of both sexes at different ages with diabetes, renal insufficiency, anemia, blood pressure, heart failure, asthma, and others in good health who were of different ages. In addition, images of patients with different diseases that caused visible changes in the color of the tongue were downloaded from the Internet. This study follows the guidelines of the Declaration of Helsinki (Finland 1964) under human ethical protocol number (201/21) Human Research Ethics Committee at the Ministry of Health and Environment, Training and Human Development Centre, Iraq, where written informed consent from all subjects was obtained with a full explanation of the experimental procedures.

2.2. Experimental Setup

In this study, a tongue image capture device was designed, which is a black box equipped with three groups of white light LEDs that were uniformly distributed to prevent shadows on the tongue. The box was equipped with a USB webcam (Logitech brio) with a resolution of 1920 x 1080. The box has a window through which it captures tongue pictures. In addition to the design of the Matlab program graphical user interfaces GUI to process the captured image of the tongue, after defining the region of interest ROI, analyze the colors in it into (RGB) and (YCbCr) color spaces, and determine the color of the tongue through the conditional IF algorithm, compared to the set of conditions and the ranges of color values installed in the program for each color, then the results of the analysis for the colors of the tongue, colors histogram, and the tongue color are displayed on the graphical user interface with a voice message with the color of the tongue. Figs. 1 and 2 show the external view of the proposed system and the GUI operator panel, respectively.

2.3. ROI Selection on the Tongue

The tongue image capture device fixed the camera to the mouth area so that the tongue is in the center of the image. After capturing the image and selecting the region required, four matrixes of the ROI are determined. For center ROI, the matrix of the ROI is 350 × 200 pixels around the center of the tongue. The second matrix of the ROI is 350 × 100 pixels on the root of the tongue. The third matrix of the ROI is 250 × 150 pixels on the tip of the tongue. The fourth matrix of the ROI is 100 × 300 pixels on the right edge of the tongue as shown in Fig 3 (a), (b), (c), and (d), respectively. The ROI is then cropped from the original image to undergo a color analysis process.

2.4. Tongue Colors Classifications

In a previous study, a statistical process was conducted for more than 9000 tongue samples, where the tongue colors were distributed on the CIE X-y chromatogram, which provides a description of all visible colors. As shown in Fig. 4 [14], the color gamut of the tongue was represented by a red border, as shown in Figure 5(a). We proposed dividing the color gamut of the tongue in the study into 14 color centers which are white (W) in the middle, followed by the near colors, pink (PI), light purple (LP), light Blue (LB), cyan (C), green (G), light red (LR), purple (P), blue (B), yellow (Y), orange (OR), red (R) and dark red (DR). As shown in Figure 5(b), the black color (BK) is outside the gradient. The color centers were analyzed into (RGB) and (YCbCr) color spaces, and the range of color values (R, G, B, Cb, Cr) was determined for each color center. For example, Table 1 shows the color values (R, G, B, Cb, Cr) for six points within the yellow color area.

Fig. 1. Tongue image capture device and experimental setup of the proposed imaging system

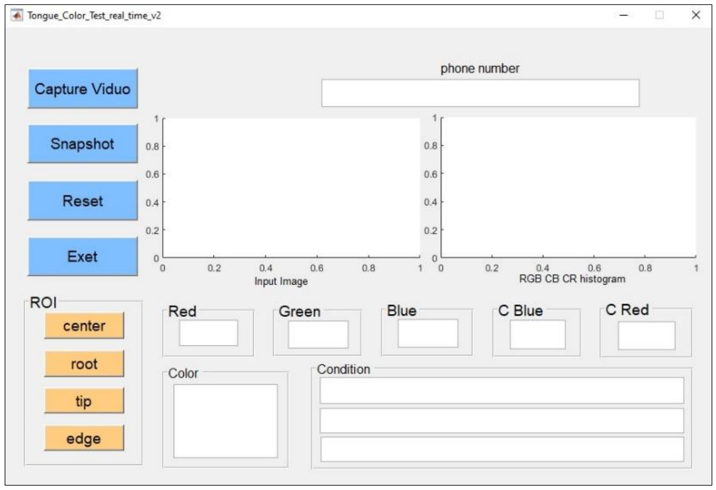
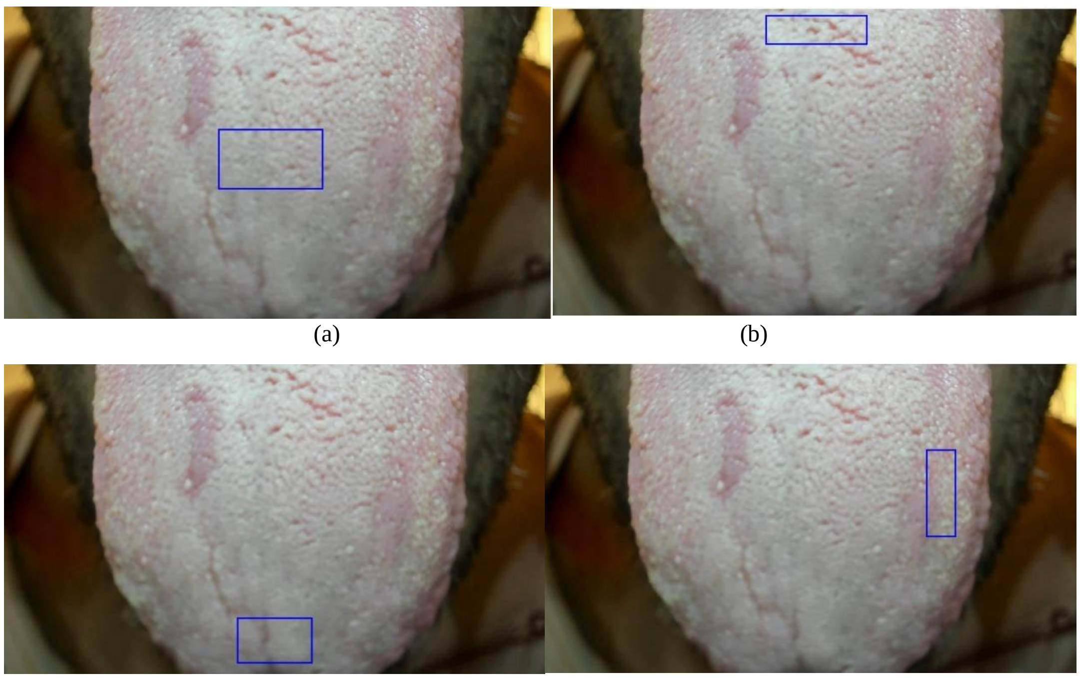


Fig. 2. The GUI operator panel of the proposed system



(a) (b)

(c) (d)

Fig. 3. (a) The selected center ROIs, (b) The selected root ROIs, (c) The selected tip ROIs, (d) The selected edge ROIs

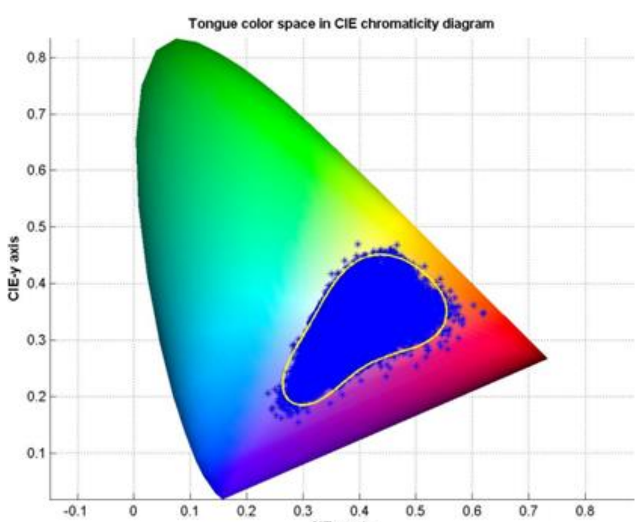
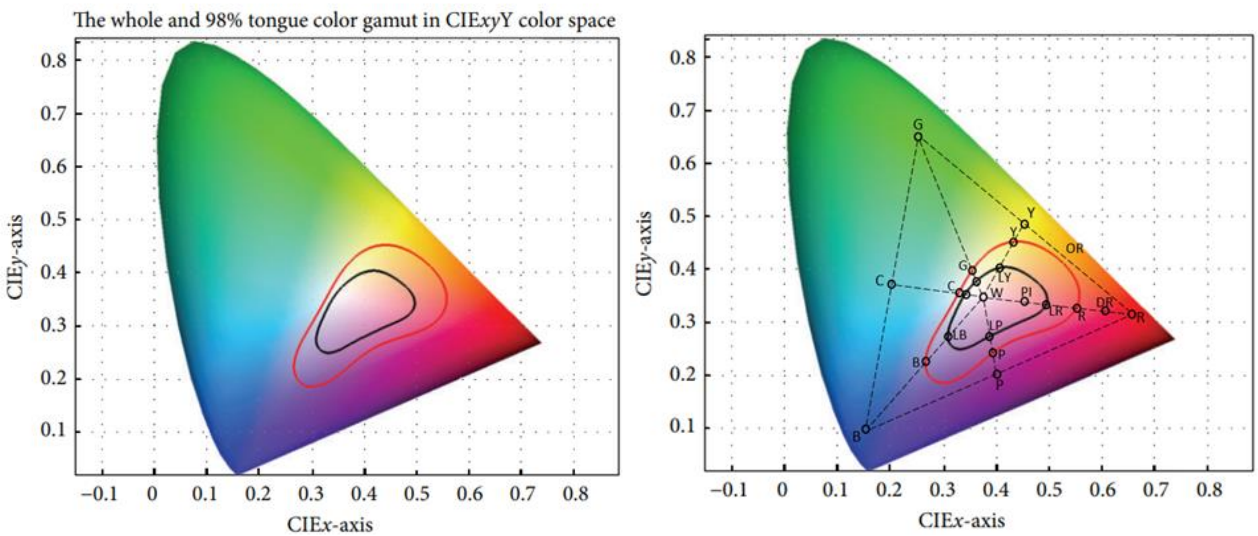


Fig 4. Statistical distribution of tongue colors



(a) (b)

Fig. 5. (a) Tongue color gamut in the CIExy color space. (b) Colors that obtain on color gamut.

Table 1. Yellow area (Y)

Point	R	G	B	Cb	Cr
1	218	184	179	121	143
2	195	191	182	123	131
3	180	182	153	116	129
4	172	171	168	126	128
5	167	172	161	124	126
6	155	158	150	125	127

In the yellow area, the value of green is higher than the value of blue, and the value of green can be higher or lower than the value of red, and the value of red is always greater than 140, and the difference between the values of green, and the value of red is small, and the value of (Cb) is (105 - 135), and the value of (Cr) be (120 - 180). Figs. 6 and 7 show the yellow color diagram and color values for six points.

For the white color area, the values of the colors are close so that the difference between them is less than 10, the blue value is higher than the green value, the green color value can be higher or lower than the red color values, and the color values are always greater than 100, and the value of (Cb) is (125 - 135), and the value of (Cr) is (120 - 135). In the Pink area, the value of red is greater than the value of blue, the value of blue is greater than the value of green, the value of red is greater than 150, the value of green is greater than 120, and the value of (Cb) is (110 - 140), and the value of (Cr) is (130 - 175). For the light red area, the value of the red color is greater than the value of the blue color, the value of the blue color is greater than the value of the green color, the value of the red color is greater than 140, the value of the green color is greater than 110 and less than 120, and the value of (Cb) is (110 - 140), and the value of (Cr) is (135 - 190). In the red area, the value of the red color is greater than the value of the blue color, the value of the blue color is greater than the value of the green color, the value of the red color is greater than 150, and the value of the green color is greater than 90 and less than 110, and the value of (Cb) is (110 - 140), and the value of (Cr) be (145 - 200). For the dark Red area, the value of the red color is greater than the value of the blue color, the value of the blue color is greater than the value of the green color, the value of the red color is greater than 100, the value of the green color is less than 90, and the difference between the values of red and blue is greater than 30, and the value of (Cb) is (110 - 145), and the value of (Cr) be (150 - 200). In the Light Purple color area, the value of the blue color is higher than the value of the green color, the value of the red color can be higher or less than the value of the blue color, and the value of the red color is less than 225, and the difference in the value of the blue and green color is less than 35 and greater than 15, and the value of (Cb) is (120 - 140), and the value of (Cr) be (130 - 170). For the violet color area, the value of the blue color is higher than the value of the green color, the value of the red color can be higher or less than the value of the blue color, and the value of the red color is less than 210, and the difference in the value of the blue and green color is greater than 35, and the value of (Cb) is (125 - 155), and the value of (Cr) be (130 - 180). In the Light Blue color area, the value of blue is higher than the value of green, the value of green is higher than the value of red, the value of blue is greater than 140, and the difference between the value of green and red is less than 20, and the value of (Cb) is (130 - 170), and the value of (Cr) be (110 - 145). In the Light Blue color area, the value of blue is higher than the value of green, the value of green is higher than the value of red, the value of blue is greater than 140, and the difference between the value of green and red is less than 20, and the value of (Cb) is (130 - 170), and the value of (Cr) be (110 - 145). For the blue color area, the value of blue is higher than the value of green, the value of green is higher than the value of red, the value of blue is greater than 140, and the difference between the value of green and red is greater than 20, and the value of (Cb) is (140 - 170), and the value of (Cr) be (105 - 145). In the cyan color area, the value of green is higher than the value of blue, the value of blue is higher than the value of red, the value of blue is greater than 140, and the difference between the value of blue and red is greater than 10, and the value of (Cb) is (115 - 145), and the value of (Cr) is (100 - 135). For the green color area, the value of green is higher than the value of red, the value of red is higher than the value of blue, the value of green is greater than 140, and the difference between the value of green and blue is greater than 25, and the value of (Cb) is (90 - 135), and the value of (Cr) be (100 - 145). In the orange color area, the value of red is higher than the value of green, the value of green is higher than the value of blue, the value of red is greater than 140, and the difference between the value of red and green is greater than 15, and the value of (Cb) is (90 - 135), and the value of (Cr) is (130 - 180). In the black area, the color values are close to each other, the difference between them is less than 15, and they are all less than 100, the value of (Cb) is (110 - 140), and the value of (Cr) is (115 - 145).

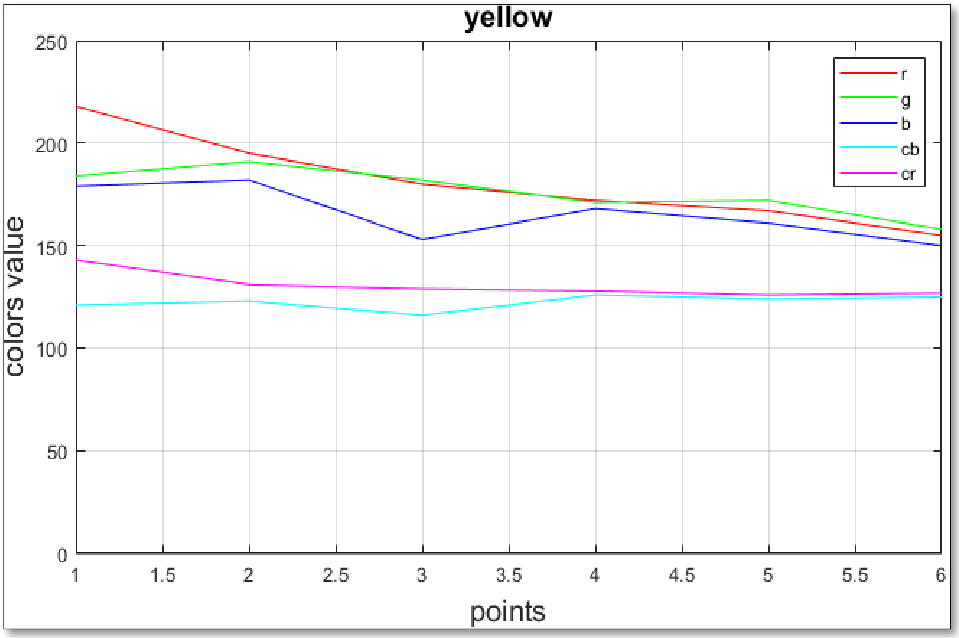


Fig. 6. Yellow color diagram for six points

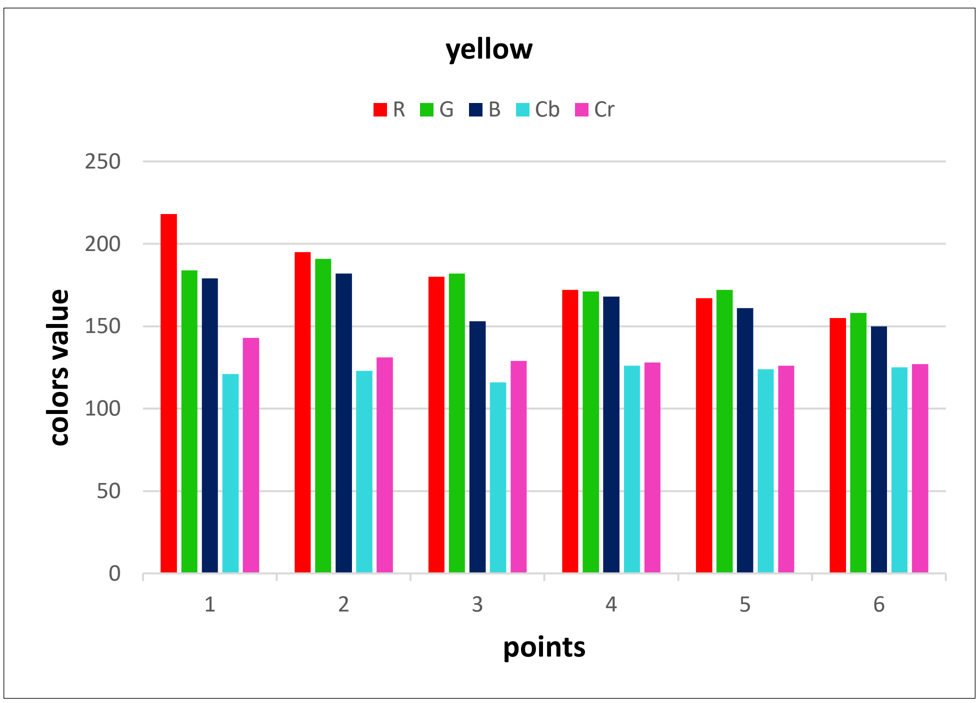


Fig 7. Yellow colors values for six points

2.5. Tongue Color Detection and Decision Making

As explained in the previous section, the expected colors of the healthy and sick tongues were determined using channels (RGB) and (Cb Cr) as the main components to determine the color of the tongue. The threshold boundaries between one color and another and multiple ranges of channel values (R G B Cb Cr) were determined for each color. When examining the tongue in real-time, the tongue color was analyzed after being photographed, and the average channel values of (R G B Cb Cr) were calculated. After analyzing the colors for each pixel in the image matrix, the mean is calculated for all the pixels in the matrix to be converted into numerical values indicating the color of the tongue. Using 'if and elsif', the proposed imaging system could decide about the tongue color and the patient's condition and possible diseases and give a voice message for the possible disease.

3. Results and Discussion

The proposed imaging system used two types of input data. The first type is for actual patients. The second type is simulated patient images downloaded from the Internet to cover some diseases for which no actual infections were obtained. In the first type, patients with diabetes, anemia, kidney failure, asthma, and heart diseases were examined as well as healthy people, while the second type was colored in a normal tongue with the same color that caused by diseases that were not obtained from real patients with these diseases such as cancer, infection of the enlarged papillae and inflammation tongue and COVD-19 infection. Each time the values of the color channels (R G B Cb Cr) are compared with the values installed in the program of the system and give a decision about the color of the tongue and the diseases causing it.

3.1. Test areal tongue

The proposed system was tested in Mosul General Hospital on healthy people and for patients with diabetes, others suffering from anemia, others suffering from respiratory problems such as asthma, patients with renal insufficiency, and patients with heart problems. The color of the tongue for healthy people was pink, as shown in Fig. 8, where the ROI was located in the center of the tongue. The color histogram for the normal case is shown in Fig. 9.

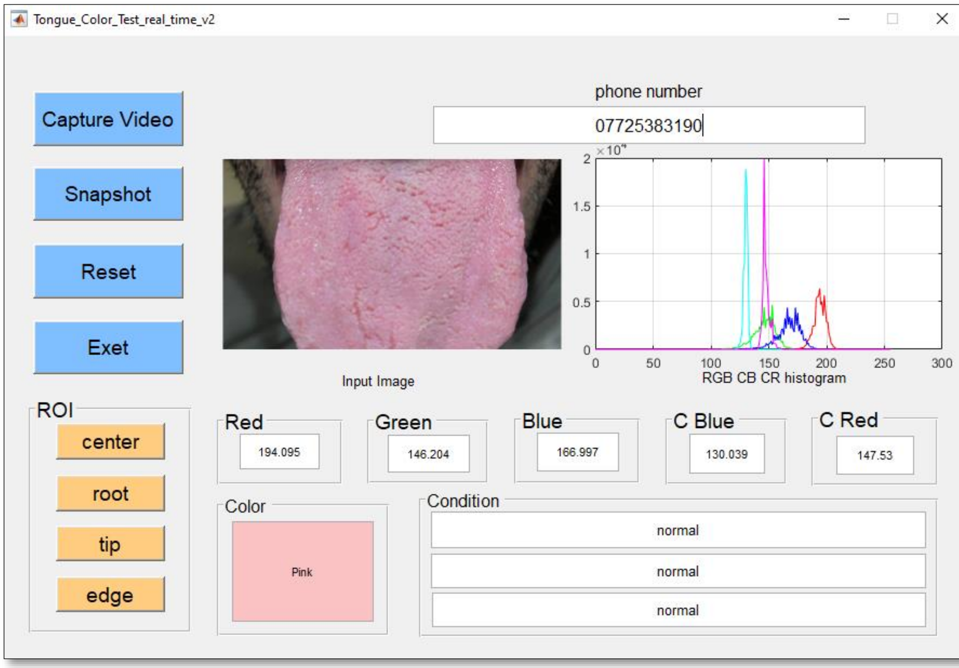


Fig 8. Test a normal case in real-time

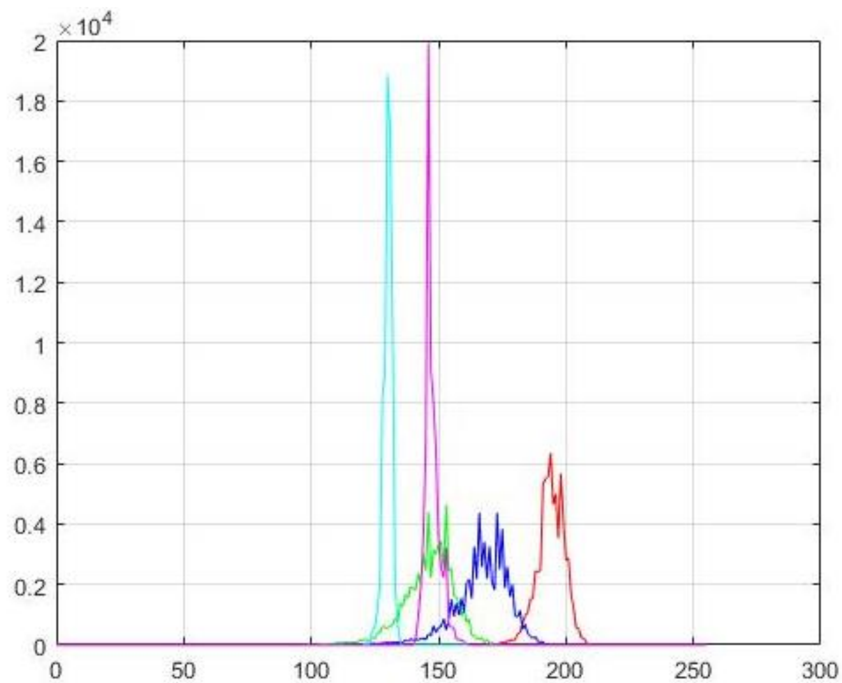


Fig 9. The colors histogram of the normal case

The proposed imaging system corresponded to the pink color when the value of red was higher than the value of blue by a difference of more than 25, the value of blue was greater than the value of green, and the value of red was greater than 150. The proposed imaging system corresponded to other tongue colors related to their diseases as follows:

3.1.1 Diabetes

With regard to diabetes that causes yellowing of the tongue, the system was tested on 35 patients who were confirmed to have diabetes. The ROI was identified around the center of the tongue, which reflects the state of the digestive system and stomach. The proposed imaging system succeeded in correctly diagnosing 33 patients, and the tongue's color was yellow, as shown in Fig. 10. The color histogram of the above state is shown in Fig. 11.

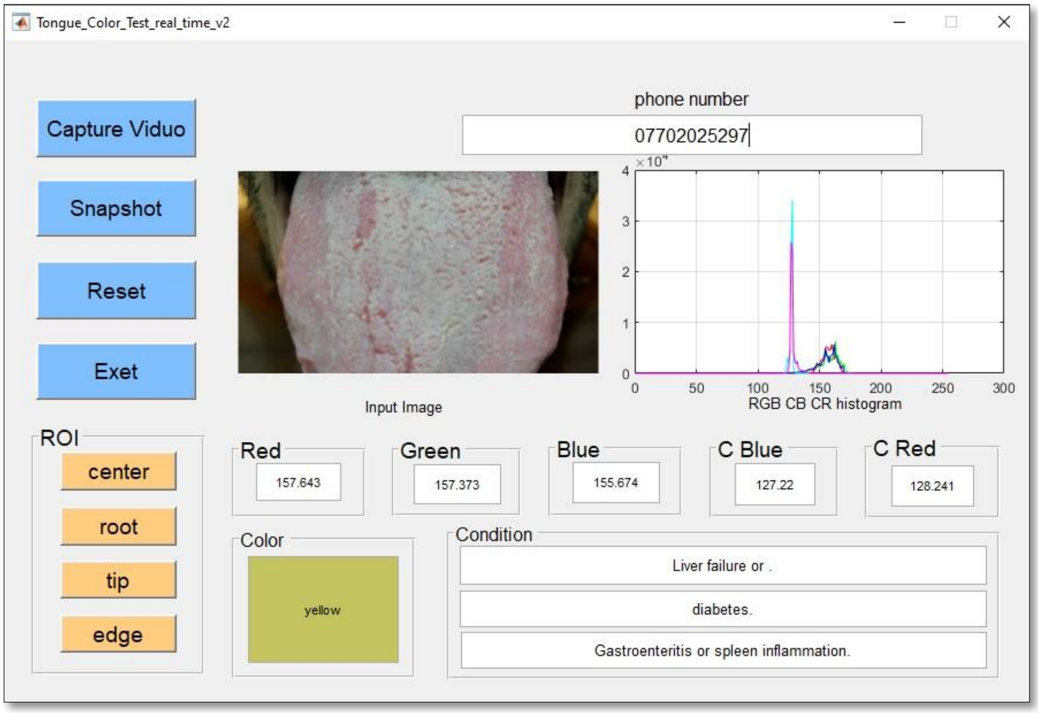


Fig. 10. Test diabetes case in real-time

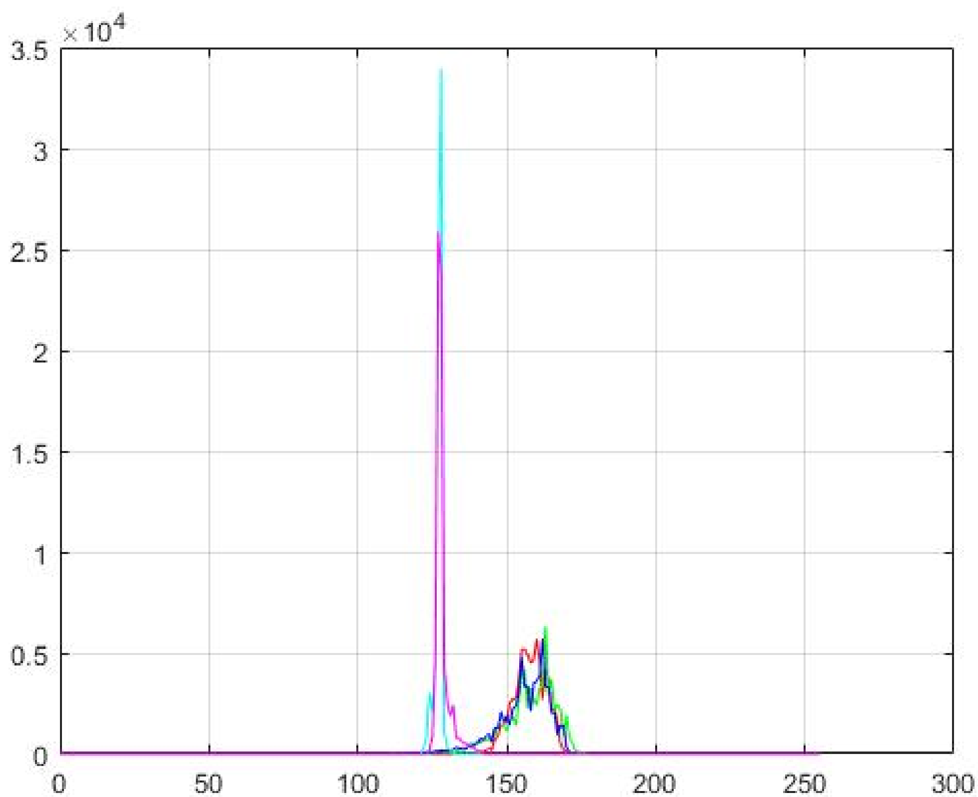
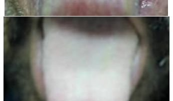


Fig. 11. The colors histogram of the diabetes case

The results obtained from all subjects using the proposed imaging system for diagnosing diabetes is shown in Table 2.

Table 2. The obtained results from 35 subjects with diabetes

Picture	ROI	R	G	B	Cb	Cr	Color	Diagnosis
	center	175.58	182.82	166.43	121.9	125.9	yellow	diabetes
	center	177.52	178.79	168.78	123.8	128.14	yellow	diabetes
	center	151.31	154.05	145.2	124.52	127.35	yellow	diabetes
	center	166.99	159.68	152.71	123.88	131.73	yellow	diabetes
	center	155.97	156.57	145.41	123.19	128.54	yellow	diabetes
	center	168.4	160.57	154.27	124.09	131.9	yellow	diabetes
	center	167.96	158.94	153.82	124.43	132.32	yellow	diabetes
	center	186.78	187.49	165.11	118.33	129.3	yellow	diabetes
	center	164.37	161.3	156.03	125.24	129.83	yellow	diabetes
	center	161.46	150.85	132.76	118.54	133.94	yellow	diabetes
	center	177.54	170.77	163.95	124.02	131.84	yellow	diabetes
	center	162.85	155.82	153.73	126.01	131.26	yellow	diabetes
	center	177.13	179	178.7	128.14	127.17	yellow	diabetes
	center	183.89	190.84	188.82	128.18	125.03	yellow	diabetes
	center	169.49	122.1	170.4	127.65	126.94	yellow	diabetes
	center	143.25	141.04	135.03	125.02	129.44	yellow	diabetes
	center	163.59	152.7	149.86	125.11	132.98	yellow	diabetes
	center	182.96	183.47	176.64	125.14	128.23	yellow	diabetes
	center	179.76	180.87	179.37	127.5	127.6	yellow	diabetes

	center	207.45	201.55	196.95	125.09	130.93	yellow	diabetes
	center	141.76	145.23	131.98	122.71	127.36	yellow	diabetes
	center	166.81	162.98	156.93	124.78	130.08	yellow	diabetes
	center	160.03	159.8	155.51	126.08	128.37	yellow	diabetes
	center	136.19	128.82	110.49	118.93	132.52	yellow	diabetes
	center	161.02	162.91	159.02	126.58	127.36	yellow	diabetes
	center	165.32	157.1	153.6	125.25	131.88	yellow	diabetes
	center	145.87	149.5	129.63	119.85	127.79	yellow	diabetes
	center	161.5	154.3	147.31	123.87	131.68	yellow	diabetes
	center	175.64	179.4	176.3	127.2	126.42	yellow	diabetes
	center	180.3	176.84	149.85	115.71	131.43	yellow	diabetes
	center	167.76	167.11	160.52	125.01	128.73	yellow	diabetes
	center	187.76	182.99	182.51	127.09	130.11	yellow	diabetes
	center	157.64	157.37	155.67	127.22	128.24	yellow	diabetes
	center	168.02	168.68	169.54	128.5	127.58	white	anemia
	center	195.2	182.38	196.53	132.3	132.68	pink	Normal

It is clear from Table 2 that the results show the value of green was higher than blue, and the difference between red and green was small, less than 10. This is because of the yellowness of the tongue. Based on the results obtained in diagnosing diabetes using the proposed imaging system, the accuracy rate was 94.286%. The misdiagnosed cases were only for two subjects where the diagnosis of one of them was normal and gave the color of the tongue pink, and the other was diagnosed with anemia and gave the color of the tongue white

3.1.2. Anemia

Usually, the tongue is white in patients with anemia. Twenty-one patients with anemia were examined using the proposed imaging system. The ROI was around the center of the tongue. The diagnosis of the system was correct for 20 cases where the color of the tongue was white, as shown in Fig. 12. The color histogram of the above state is shown in Fig. 13.

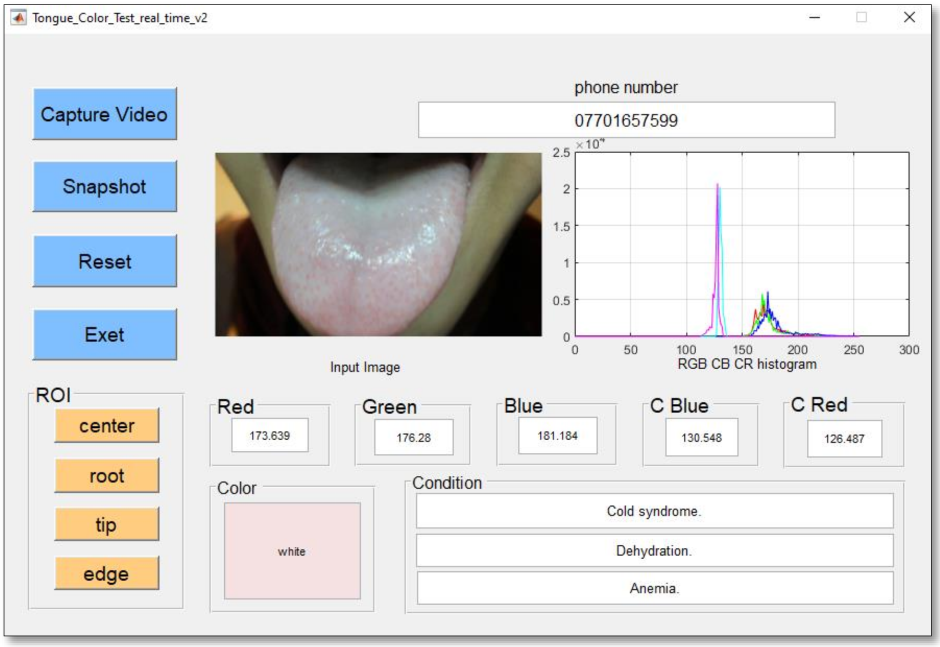


Fig. 12. Test anemia case in real time

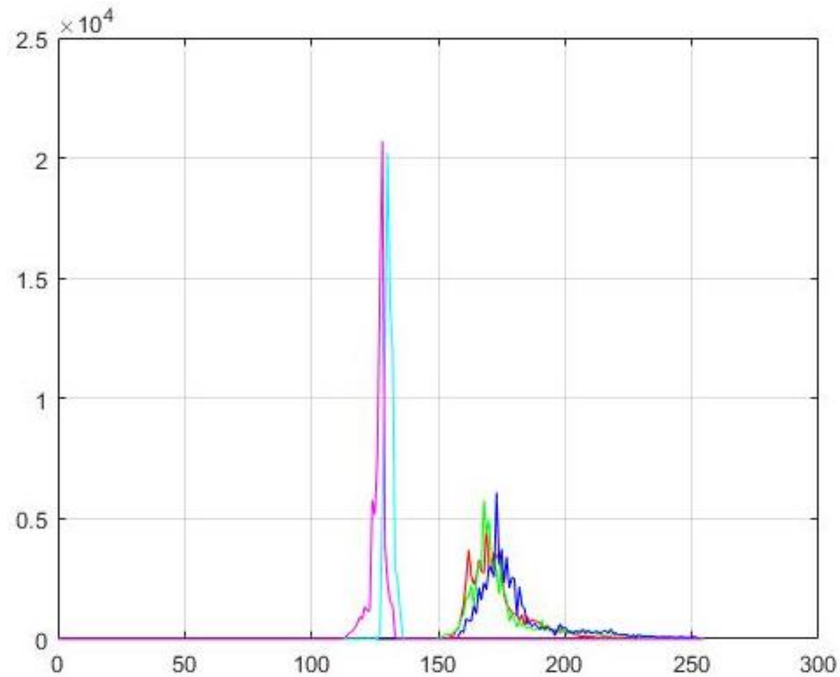
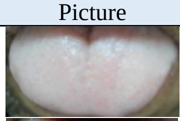


Fig. 13. The colors histogram of anemia case

The results obtained from all subjects using the proposed imaging system for diagnosing anemia is shown in Table 3.

Table 3. The obtained results for 20 patients with anemia

Picture	ROI	R	G	B	Cb	Cr	Color	Diagnosis
	center	199.87	200.26	204.39	129.76	127.39	white	anemia
	center	178.74	177.61	178.98	128.43	128.39	white	anemia
	center	174.21	172.22	174.33	128.64	128.77	white	anemia

	center	132.54	130.29	133.89	129.27	128.82	white	anemia
	center	164.74	165.61	167.86	128.79	127.17	white	anemia
	center	187.37	179.64	185.01	129.21	131.09	white	anemia
	center	167.02	163.64	170.5	130.5	129.04	white	anemia
	center	157.2	153.67	155.11	128.12	129.47	white	anemia
	center	178.75	184.02	184.43	128.97	125.68	white	anemia
	center	162.6	160.33	164.3	129.42	128.75	white	anemia
	center	201.28	204.3	211.74	131.71	126.18	white	anemia
	center	131.76	134.14	134.48	128.51	126.89	white	anemia
	center	193.65	189.99	199.83	131.77	129	white	anemia
	center	203.84	201.34	203.72	128.67	128.93	white	anemia
	center	168.21	163.72	168.99	129.64	129.63	white	anemia
	center	198.14	189.37	197.82	130.39	131.32	white	anemia
	center	156.89	163.44	166.99	130.61	124.8	white	anemia
	center	165.27	166.78	176.44	132.47	125.6	white	anemia
	center	166.6	155.37	164.73	130.42	132.3	white	anemia
	center	174.68	146.99	147.11	124	140.17	pink	Normal
	center	183.52	172.44	179.73	129.57	132.35	white	Anemia
	center	173.64	176.28	181.18	130.55	126.49	white	Anemia

The convergence between the values of the colors in Table 3. was clear, with the value of the blue color being higher than the value of the green color. The reason for these readings is the white color on the tongue. The accuracy of the system in diagnosing anemia was 95.45%. Only one case was misdiagnosed due to the color of the tongue being pink.

3.1.3. Asthma

Respiratory diseases such as (asthma) cause a lack of oxygen in the blood, which gives the tongue blue or purple. To test the proposed imaging system in diagnosing diseases that cause blue tongue, fifteen patients with asthma were examined. The ROI around the center of the tongue was identified. The proposed system provided a correct diagnosis for 13 cases, and the color of the tongue was either light purple or light blue, as shown in Fig. 14, and its color histogram as shown in Fig. 15.

Fig. 14. Test asthma case in real time

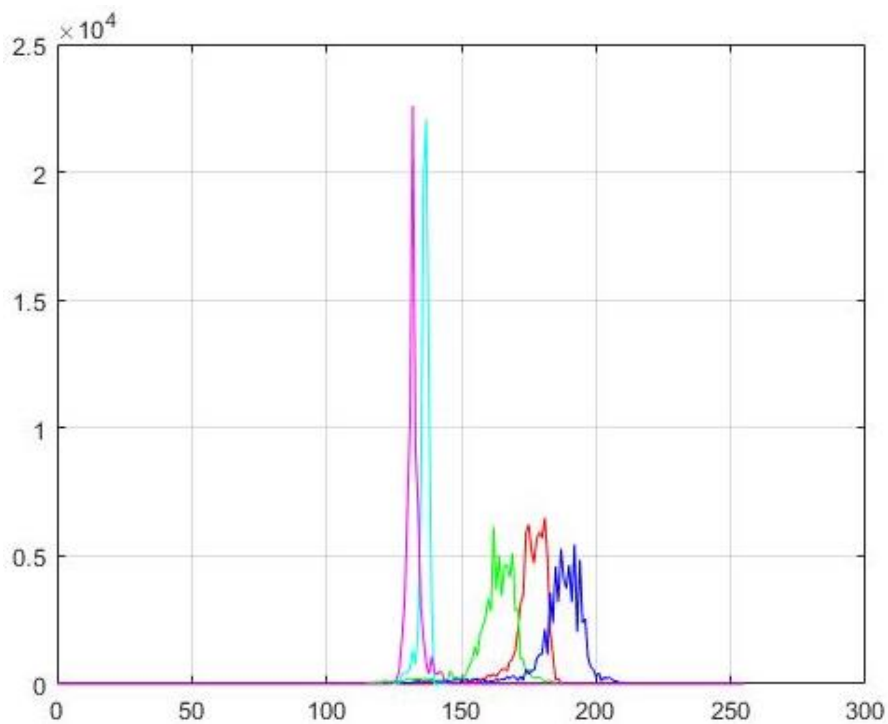
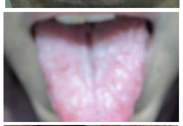


Fig. 15. The colors histogram of asthma case

The results obtained from all subjects using the proposed imaging system for diagnosing asthma is shown in Table 4.

Table 4**.** The obtained results from 15 subjects with asthma

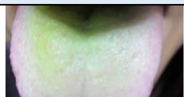
Picture	ROI	R	G	B	Cb	Cr	Color	Diagnosis
	center	200.05	188.5	208.34	135.03	131.72	Light purple	asthma
	center	163.16	165.81	176.22	132.89	125	Light blue	asthma
	center	182.98	173.35	196.5	136.74	130.76	Light purple	asthma
	center	194.38	174.47	205.49	138.54	134.54	Light purple	asthma
	center	197.56	167.51	194.7	135.48	139.23	Light purple	asthma
	center	173.99	182.13	196.71	135.66	123.42	Light blue	asthma
	center	192.31	157.63	173.73	129.91	142.11	Light purple	asthma
	center	198.17	187.84	212.71	137.31	130.79	Light purple	asthma
	center	190.83	140.94	170.16	133.39	147.81	Light purple	asthma
	center	154.58	167.41	188.78	139.23	120.85	Light blue	asthma
	center	187.15	163.32	186.15	134.52	136.83	Light purple	asthma
	center	175.79	132.66	154.82	131.35	145.36	Light purple	asthma
	center	153.61	125.06	138.82	129.78	139.58	pink	normal
	center	213.37	198.01	202.76	127.8	134.43	white	Anemia
	center	176.16	162.38	186.01	136.34	132.36	Light purple	asthma

From Table 4, it is clear that the value of the blue color increased over the value of the green color by a medium difference, causing a light purple color on the tongue if the value of the red color is higher than the value of the green color or causes a light blue color on the tongue. Suppose the value of the red color is less than the value of the green color. But if the value of the blue color is higher than the value of the green color by a large difference, it will cause a violet color on the tongue if the value of the red color is higher than the value of the green color, or it will cause a blue color on the tongue if the value of the red color is less than the value of the green color. In diagnosing asthma, the system has an accuracy rate of 86.667%. The system failed to diagnose only two cases. In the first case, the color of the tongue was pink, and the condition was considered healthy. The second failure was due to the color of the tongue was white, and the diagnosis was anemia.

3.2. Results Obtained by Simulating Tongue Colors

Some of the diseases affect the color of the tongue; however, the data for these diseases are not commonly available. Pictures of the tongue of people with these diseases were downloaded from the Internet and simulated by dyeing a normal tongue in the same color that those diseases cause to test the system in diagnosing those diseases, such as COVID-19 disease, which causes redness of the tongue depending on the degree of infection. Median rhomboid glossitis which causes a dark red tongue, and infections include fungal and bacterial infections, enlarged papillae infection, which causes a black hairy tongue, and Benign migratory glossitis or geographic tongue, which causes orange tongue [21]. Vitamin B-2 deficiency or Lack of oxygen in the blood or asthma, which causes purple tongue, and fungal infection or bile ducts and gallbladder or decrease in the body immune forces causes green tongue. Table 5 shows some pictures downloaded from the Internet for some diseases and their color values and simulations of some of them.

Table 5. Pictures downloaded and simulated for some diseases and their color values

Picture	R	G	B	Cb	Cr	Color	diagnoses
	185.46	218.79	185.51	118.4	115.74	simulation Green tongue	fungal infection or bile ducts and gallbladder or decrease in the body immune forces
	154.43	117.9	162.23	142.1	140.97	Purple	Vitamin B-2 deficiency. or Lack of oxygen in the blood or asthma
	182.48	137.34	211.98	154.09	142.49	simulation Purple tongue	Vitamin B-2 deficiency. or Lack of oxygen in the blood or asthma
	97.06	88.03	87.06	126.24	132.02	simulation Black tongue	pigmented fungiform papillae or infection of the enlarged papillae
	200.22	119.56	123.79	117.89	163.14	Light Red	mild severity of covid-19
	160.12	95.58	98.51	119.71	156.13	Red	moderate severity of covid-19
	171.96	35.94	42.1	110.59	187.32	Dark Red	Median rhomboid glossitis
	82.66	47.7	45.96	122.04	143.6	Black	pigmented fungiform papillae
	178.63	91.43	70.2	105.75	167.82	Orange	Benign migratory glossitis or geographic tongue

4. Conclusion

Computerized tongue color analysis systems can provide high accuracy in distinguishing tongue colors, especially in light of the technological development in the field of computers and cameras. In this study, a Logitech webcam was used, with a special device to capture the image of the tongue under specific conditions, and the MATLAB GUI program for analyzing the image of the tongue and displaying the result and giving a voice message about the result. The system was tested on more than 100 images of patients and healthy people, and other images downloaded from the Internet were simulated to cover other colors of the tongue that were not practically obtained. The results were encouraging and showed a diagnostic accuracy of 95.45%, giving the possibility of applying the system in medical fields to diagnose diseases that cause visible changes on the tongue. It provides a safe, effective, user-friendly, painless and inexpensive way to examine patients, is not affected by the difference in lighting in the surrounding environment, and does not rely on uncomfortable color calibration cards.

Future Works

What was presented in this thesis can be considered as a step in establishing a computerized system for diagnosing diseases in real-time for use in the medical field. After overcoming some difficulties and developing successful solutions to them to achieve the desired goal. In this paragraph, some directions and future work will be identified to develop and continue what this thesis has achieved.

1. Develop a system to determine the ROI using artificial intelligence methods and expert systems.
2. Design a graphical user interface program that can be installed on the Raspberry Pi and depended on it instead of the computer.
3. Apply the system and collect a larger database to increase the system's accuracy.

Acknowledgement

We would like to thank the staff of Mosul General Hospital, especially the doctors and nurses, who provided us with support and assistance in collecting data and images for the patients admitted and hospitalized in the hospital to accomplish this work and to test the system.

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