RESEARCH ARTICLE | SEPTEMBER 08 2023

Computer-aided diseases diagnosis system based on tongue color analysis: A review

Abdulghafor Khudhaer Abdullah; Saleem Lateef Mohammed; Ali Al-Naji

AIP Conf. Proc. 2804, 040003 (2023)
https://doi.org/10.1063/5.0154231

Computer-aided Diseases Diagnosis System Based on Tongue Color Analysis: A Review

Abdulghafor Khudhaer Abdullah[1, a)], Saleem Lateef Mohammed[1, b)] and Ali Al-Naji[1,2 c)]

[1] *Department of Medical Instrumentation Techniques Engineering, Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq.*
[2] *School of Engineering, University of South Australia, Adelaide, Australia.*

[a)] bdc0010@mtu.edu.iq
[b)] Saleem_lateef_mohammed@mtu.edu.iq
[c)] Corresponding author: ali_al_naji@mtu.edu.iq

Abstract. The tongue color is a mirror that reflects the health status of a patient. It could be used in diagnosing some diseases without any physical contact with the patient, which facilitates the process of primary healthcare. There are many studies that based on the analysis of tongue color, some of which have been addressed in this study. This study also reviewed many recent studies that were conducted in automated tongue diagnosis (ATD) and summarizes the performance of these studies in a table regarding the used methods, tools, ROIs, diagnoses of diseases and algorithms as well as the results obtained. Also, this study represents a comparative review of the recent studies while emphasizing their merits and demerits.

INTRODUCTION

With the progress of digital imaging technology, the use of computerized diagnostic systems in tongue inspection has been intensively investigated in recent years in the research community. There are symptoms that can be adopted as a vital criterion in computerized diagnostic systems, such as skin color, facial expressions, temperature, retinopathy and tongue color, which helps to diagnose and automatically analyze without any contact with the patient. Tongue color diagnosis is one of the important, influential and non-invasive methods for detecting the condition of the internal organs of the patient's body (Jung et al., 2012, 2014; Tania, Lwin and Hossain, 2019). Diagnosis of the tongue is often based on the expertise of specialists in visual examination of the color, movement, and surface of the tongue (Yamamoto et al., 2011). According to East Asian medicine (EAM) (Jung et al., 2012) , visual inspection of the tongue, including color, shape, moisture, and the tongue coating for color reflects some conditions for internal organs, such as the stomach, heart, liver, lung, and bladder. For instance, the appearance of the white greasy tongue indicates a cold syndrome, while the thick yellow color indicates a hot syndrome (Jiang1 et al., 2012). There is a link between these two syndromes with health conditions, such as stress, endocrine glands, infection, immune disorders in the body, and inflammation (Jiang1 et al., 2012). Another example, the dark red color that indicates inflammation or ulceration, and the white color indicates that the cold attacker is weak in the blood. These traits lead to cases of anemia. On the other hand, the yellow tongue shows diseases related to the liver and gallbladder, and the blue or purple color is associated with circulatory difficulties or weakness in the digestive system. In a healthy tongue, the color is pleasant pink, strong and sanguine (Balkrishna et al., 2017). The presence of some changes on the surface of the tongue also indicates some appendicitis (Pang and Zhang, 2005). In addition, the temperature of the tongue can affect its color and reflect some diseased states and patterns (Zhihao et al., 2008). Regarding the Coronavirus (COVID-19), it affects the color of the tongue according to the severity of the infection.

The Fourth Scientific Conference for Electrical Engineering Techniques Research (EETR2022)
AIP Conf. Proc. 2804, 040003-1–040003-11; https://doi.org/10.1063/5.0154231
Published by AIP Publishing. 978-0-7354-4637-3/$30.00

For example, the color of the tongue is pale pink in the case of mild COVID-19 infection, red in the medium CVOVID-19 injury, and dark red (burgundy) in the case of severe COVID-19 infection (Horzov1 et al., 2021). For contactless tongue color detection, computer-aided systems appear to be an advantageous approach that could be robust, safe, and cost-effective. However, these systems are still not at the required level and need support to help in the clinical decision to diagnose the tongue as an expert system that reduces human error. This paper focuses on a review of the literature on tongue color detection based on computer vision systems and introduces their advantages and limitations under different circumstances.

TONGUE DIAGNOSTIC BASED ON A COMPUTER VISION SYSTEM

The tongue color can be used as criteria for diagnosing some diseases such as Appendicitis, Thyroid hormone deficiency, sexual function, and cognitive decline, Inflammation, cold attacker, anemia, and diabetes. Many studies based on computer vision systems were published in the last decade. For instance, Horzov *et al.*, (2021) suggested a retrospective analysis of tongue images of COVID-19 infection patients using polymerase chain reaction. The disease was evaluated according to severity as mild, moderate, severe, and critical, using clinical symptoms and laboratory test results. The study used the Cochran Armitage test to examine the expected association between tongue color and tongue plaque color with disease severity. Pictures of the tongue were captured by a smartphone for 135 patients (males and females). The results showed that the most common colors are pale pink, red and dark red (burgundy), as 64.29% of patients with mild injury had a pale pink tongue, and 62.35% of patients with moderate infection had a red tongue, while in severely injured patients, 99% of them had a dark red tongue (burgundy). A study by Pang and Zhang (2005) described a tongue calculation model for diagnosing appendicitis by analyzing the amount 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. Another work by Park *et al.*, (2016) examined color parameters of tongue inspection based on a digital camera using different digital imaging software with excellent levels of Intra-class correlation coefficients ICCs. Visual patterns related to age, sexual function, and cognitive decline were considered in their study with 200 images of the tongue for females that were asked to make questionnaires about sputum pattern, temperature and yin deficiency. Balkrishna et al., (2017) suggested a computer-based analyzer system to diagnose diabetes using the visible changes of the tongue surface. Both color and substance feature sets were used, as these features map the tongue image to the corresponding diseases statistically. The experimental results used a data set of 100 tongue images, and the results were useful for classifying such diseases. A study by Srividhya E, (2019) proposed a support vector machine (SVM) classifier and advanced image processing techniques to detect and analyze the extracted textures from the color of the tongue using a digital camera. A new implicit correlation was investigated by Umadevi and Anand (2019) 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 medical college hospital and research institute and 97 UV-scanned tongue images captured from an iPhone with an HD camera. Another study by Ashour et al., (2021) proposed a new model based on an automated Internet of Things (IoT) and a deep neural network (DNN) to analyze stained tongue images for disease diagnosis and classification. To test the performance of the proposed model, a simulation of several standard tongue images was conducted, and the results were examined in various dimensions, and it was proven that the performance of the proposed model was better than several other methods, with a maximum accuracy of 0.984, 0.973 and 0.983. while Safia Naveed, (2020) 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. An Infrared tongue thermal imaging system was proposed by Usharani *et al.*, (2019) to measure tongue temperature for the diagnosis of diabetes. Where the proposed system classified diabetes depending on the temperature difference of the tongue using a Convolutional Neural Networks (CNN). Tongue thermogram data were collected using an infrared camera from 140 subjects.

To provide 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, Li and Liu, (2009) suggested a method for tongue color analysis based on spectra-angle spectra. The proposed work provided spectral properties in different wavelength regions based on hyper spectral 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. The method used a color ultra-spectrum camera to capture images of the tongue. Similar work by Li *et al.*, (2010) proposed a hyperspectral tongue imaging system based on American occupation therapy foundation (AOTF) that captures images of the tongue at sequential wavelengths. The system has no moving parts, which enables it to scan at very high rates. The AOTF acts as an adjustable optical band-pass filter. The light reflected from the tongue surface is first collected by a camera lens, then deflected by an AOTF transducer, and finally imaged on a CCD detector. When the filter is placed in the optical path of the camera, it passes different wavelengths as a function of time. Reveals spectral and spatial information of the tongue aiding in tongue diagnosis. The designed wavelength ranges are 400 - 800 nm and the spectral resolution is 2-6 nm. Another work by Yamamoto et al. (2011) suggested an ultra-spectrum analysis system of the tongue and the association between its color and thyroid hormone values. One hundred hyperspectral tongue images and blood samples were taken from 50 patients. The principal component analysis (PCA) method for tongue color spectra was performed, and correlation with thyroid hormones was determined using the vector rotation method. As a consequence, TH4 showed a significant correlation with the tongue color spectra. These results show that some diseases appear in the tongue, and they could be detected by hyperspectral tongue color analysis. Each study mentioned above, however, has its pros and cons at different assumptions, leading to several issues to be considered. Table 1 shows the works done in analyzing tongue color and diagnosing diseases.

TABLE 1. The research in analyzing tongue color and diagnosing diseases.

Ref.	**Used Sensors with Image Feature**	**ROIs**	**Used Technique**	**No. of Participants at a Time**	**number of samples**	**Results**
Horzov et al., (2021)	smart phone	tongue	polymerase chain reaction	COVID-19	135 patients aged between 18-82 years for both sexes	64.29% of patients with mild injury had a pale pink tongue. And 62.35% of patients with moderate infection had a red tongue, while in severely injured patients, 99% of them had a dark red tongue
Pang and Zhang (2005)	digital camera	tongue	TCoM	diagnosing appendicitis	12000 images	The results were encouraging
Park et al., (2016)	digital camera	tongue	three sets of digital imaging	sexual function, and cognitive decline	200 images	The validity and reliability of the examination of tongue color parameters as predictors of the presence of diseases
Balkrishna et al. (2017)	digital camera	tongue	Improving two types of features called, Color features and Gist features.	Inflammation, cold attacker, anemia, diseases related to the liver and gallbladder, weakness in the digestive system	100 images	The results illustrated that the color and gist features were more beneficial to classify the tongue image into a relevant disease
Srividhya E, (2019)	digital camera	tongue	suggested that a Support Vector Machine (SVM)	edge detection of the affected area of the tongue and identify abnormal images.	NA	NA

TABLE 1. Continued.

Ref.	Used Sensors with Image Feature	ROIs	Used Technique	No. of Participants at a Time	number of samples	Results
Umadevi and Anand, (2019)	iPhone with an HD camera	tongue	Versatile Tooth-Marked Region method (VTMR) with Matlab	Diagnosis of diabetes	183 images	performs well in terms of qualitatively and quantitatively and Classification of Efficiency, and Accuracy
Ashour et al. (2021)	IoT devices	tongue	automated Internet of Things (IoT) and deep learning	For different disease diagnosis	NA	model is better than several other methods, with a maximum accuracy of 0.984, 0.973 and 0.983.
(Safia (2020)	USB digital camera	tongue	fractional order Darwinian particle swarm optimization algorithm (FODPSO) with matlab	Diagnosis of diabetes	700 images	For diabetics, the papillae of the tongue are enlarged, few in number and irregularly distributed, in addition to large bumps on the surface of the tongue.
Usharani et al. (2019)	infrared camera	tongue	color images based on (RGB) and the gray-level matrix algorithm and the deep machine learning algorithm (CNN)	Diagnosis of diabetes	140 samples	It was found that the temperature of the tongue for diabetics is higher than normal.
Li and Liu, (2009)	ultra-spectrum camera	tongue	SAM algorithm	NA	200 samples	better classification performance
Li et al., (2010)	ultra-spectrum camera	tongue	AOTF	NA	NA	It can scan at very high rates
Yamamot o et al. (2011)	ultra-spectrum camera	tongue	Ultra-spectrum analysis of the tongue	Thyroid hormone evaluation	100 images	showed a significant correlation with the tongue color spectra and thyroid hormones

COLOR AND LIGHTING CONSIDERATIONS

Lighting is one of the most important prerequisites in diagnosing the tongue. There are different approaches in solving or reducing lighting issues while photographing the tongue. A study by Zhang *et al.*, (2005) presented a new method based on a support vector Regression (SVR) method for color calibration, which provides a reference for color calibration by aggregating the colors of 322 images. The analysis of results was made to compare the proposed method with a method based on polynomial regression. The results indicated that the SVR-based color calibration model gave a good calibration and helped produce a CATDS image of the CATDS system. The images were captured by a 3CCD core and a 250W cold-light halogen lamp with a 4800k color temperature to reduce distortion at a relative resolution of 720×576 pixels with white balance capability, 50 dB S/N ratio, as well as PAL and NTSC signal. As reported in (Wang and Zhang, 2010) to analyzed the tongue image by a computer and suggested a color correction scheme. First, the color correction requirements were analyzed to select the target area, and then the color correction algorithms were improved. This helps to reduce the color difference between images taken with different cameras at different illumination conditions to less than 0.0085, and increased the distances between the color centers of the tongue images by more than 95% while the images tend to cluster towards a “perfect tongue” or “standard” image. The performance of the proposed scheme was tested based on four groups of images captured by a CCD digital camera (a triple-chip CCD digital camera with 8-bit each channel and 768×576 spatial resolution) by calculating the color difference between the estimated values and the target reference values. The lamps used in the study were two standard D65 fluorescent tubes, having a color temperature of 6500 K, with a color rendering index (CRI) greater than 90. A new implicit correlation was investigated by Zhang *et al.*, (2013) to proposed a new method for diagnosing some diseases (mention some diseases here) based on objectively analyzing of tongue color through its color features. The tongue images 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.*, (2012) 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 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.*, (2013) proposed an imaging system based on Support Vector Machine (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. Another work by Banu and Devi, (2016) suggested an imaging method for extracting tongue color features that detected diabetes. It is an easy-to-understand and effective method with much less expense. All 12 colors in the color gamut were extracted. According to Ayurveda, the front one-third of the tongue relates to the chest, heart, lungs, and neck. The central area relates to the stomach, liver, spleen, and pancreas. It is explained first and then each pixel in front of the tongue is compared with the 12 colors in the color gamut. The color closest to the tab pixel is assigned with the color. This compensates for the tongue color features, and the system has been identified after careful analysis. External sun light is the best in photographing the tongue by phone or digital camera for the purpose of examination and diagnosis. As reported in (Cheng, Hu and Lan, 2017) a new model 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 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. While Zhao, *et al.* (2017) suggested a tongue color checker used with color calibration algorithms to standardize tongue images captured by a digital camera, and create a statistical color gradient from the tongue data. Different color spots were identified on the tongue color checker, by the CIELAB 1976 color difference calculation equation The results obtained by the proposed tongue color checker were compared with the Munsell color checker. The results proved that the proposed auditor gives a lower error rate. Another study by Lu *et al.*, (2018) proposed an imaging system based on a Deep Color Correction Network (DCCN) to help identify the mapping pattern between the visible color appearance of the target and color distorted captured images under different lighting conditions with different cameras. The experimental results showed that the proposed DCCN achieved high accuracy at the level of color correction scales for subjective and objective tongue images, and it was able to remove the effect of different lighting conditions. Finally, a study by Chen, *et al.* (2021) 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.

Each study mentioned above, however, has its pros and cons at different assumptions, leading to several issues to be considered. Table 1 shows the recent works that considered color and lighting conditions limitations.

TABLE 2. The studies that considered color and lighting conditions limitations.

Ref.	Used Sensors with Image Feature	ROIs	Used Technique	No. of Participants at a Time	number of samples	Results
Zhang et al., (2005)	a 3CCD core and a 250W cold-light halogen lamp	tongue	SVR	1	322 images	gives good calibration
Wang and Zhang, (2010)	triple-chip CCD	tongue	polynomial transform and Munsell Color Book	1	4 groups of images	Reduce the different lighting conditions to less than 0.0085
Zhang et al., (2013)	CCD camera and two D65 bulbs .	Tongue	RGB color analysis	1	143 healthy images and 902 sick images	showed that there is a relationship between tongue color and the state of the human body
Jung et al., (2012)	commercial digital camer	tongue	Tongue Diagnostic Systems (TDSs) And Munsell Color Book	1	NA	supply a convenient, prompt, and accurate information
Wang et al., (2013)	digital camera	tongue	Analyzing the statistical distribution of human tongue colors in depth	1	9000 tongue images	show that most disease-reflection features are located in the
Banu and Devi, (2016)	Phone camera	tongue	RGB color analysis	1	NA	easy to understand and efficient method with significantly lesser computation. All the 12 colors in the color gamut are successfully extracted.
Cheng et al. (2017)	Smart phone	tongue	SVM	1	NA	color correction method is effective for white fur detection
Zhao et al., (2017)	digital camera	tongue	tongue Color Checker color calibration algorithms and Munsell Color Book	1	NA	tongue Color Checker, which has 24 color patches, produces a smaller error
Lu et al., (2018)	manual camera within a simulated D65 illuminant environment	tongue	Deep Color Correction Network (DCCN)	1	140 patches	achieve high accuracy at the level of color correction scales for subjective and objective tongue images
Chen et al. (2021)	The CTIS-simulated images considering the color, texture, and moisture created from Munsell color book	tongue	developed a software in MATLAB, called computational tongue image simulation (CTIS) and Munsell Color Book	1	five participants	Improved a MATLAB software called CTIS that integrates 3 crucial elements of tongue images: color, texture, and moisture.

IMAGE SEGMENTATION AND FEATURE DETECTION CONSIDERATIONS

One of the most important tasks in the diagnosis of the tongue is the appropriate segmentation to extract the optimal features. First, the position of the tongue must be determined, and then the chromatic and spatial features must be detected using appropriate methods. For example, a study by Parcus *et al.*, (2017) used a mobile phone-based system, which collected images using the rear camera and phone flash and applied a real-time face detection (HAAR) algorithm to the image. Where the system automatically triggers the camera flash to illuminate the place after detecting the protrusion of the tongue, indicating that it is ready to obtain the image. After the location of the mouth and other points, the mouth area of interest is outlined to determine the most necessary and detailed features for tongue detection. The system was tested on (40) volunteers. The comparison of the data obtained with the data collected with the diagnosis through visual examination of Chinese medicine CM using Kappa Cohen to assess the practical value of the images with positive results. A new implicit correlation was investigated by Jiang *et al.* (2008) to use a digital camera with a resolution of 7.2 megapixels, to capture many images of the tongue, and then processed and analyzed physiologically. The proposed system helped to diagnose and treat without meeting the patient in person after integrating it with the telemedicine system. Created a database of 100 samples and took into account the conditions of individuals, such as gender, race and health status in the database. Another work by Jung *et al.*, (2014) suggested a method for obtaining images of the tongue by providing frontal and profile feedback gridlines to evaluate the resulting color and the possibility of repeating the shape. One hundred and twenty images of the tongue were taken by two digital cameras front (CCD) and one side (a Bayer) with three groups based on grid lines. In the first group, the grid lines were not used, and only the front grid lines were used. In the second and third group, the front grid lines were used with the profile in a pseudo-random order. After calculating intra-layer correlation coefficients (ICCs), the results were that the ICCs of all color features in the first group are less than in the second group, and in the third group, the ICCs of all color features are greater than in both the first and second groups. The proposed imaging process improved the reproducibility of features for color and shape.

To detect the chromatic and spatial features, a study by Chiu (2000) suggested a new computerized Tongue Examination System (CTES) using computerized image analysis based on chromatic and spatial compositional characteristics for traditional Chinese medical diagnosis of the tongue. Each image of the tongue was divided into four sub-regions (A) and (C) representing the health conditions of the liver and gallbladder. Region (B) corresponding to the stomach and spleen. Region (D) corresponding to the heart and lungs. The study tested 60 images of the tongue captured by a digital camera. The overall health rate for tongue characteristics examination by CTES was above 86%. Yamamoto *et al.*, (2011) proposed a hyperspectral imaging system and tongue region extraction using an integrated sphere and an ultra-spectrum camera with an artificial sunlight lamp to capture an ultra-spectrum image in a short period and without reflection. To extract the tongue region, the other regions are subtracted. It was discovered that each region of the face has different spectral characteristics, which helped to distinguish the region of the tongue effectively. Nine randomly selected hyperspectral images from 44 images were analyzed, with 20 minute regions selected manually and four regions of the tongue, a coated region, an uncoated region, and a lip region, and perioral areas. 600 and 800 nm (orange infrared) and the area around the mouth varies between 400 and 600 nm (yellow-violet). As reported in (Xu *et al.*, 2015) presented a Multi-Task Joint Learning (MTL) method for tongue image segmentation and classification, in which two modern deep neural network (Convolutional Networks for Biomedical Image Segmentation UNET and Discriminative Filter Learning DFL) variables are combined with MTL to perform both tasks. He used an advanced CCD digital camera with illumination (D50) commonly used to take pictures of the tongue. He collected 1858 pictures of the tongue and classified them into six different categories. After conducting experiments, he noticed that the results are superior to the current methods for characterizing the tongue. However; the proposed method does not achieve excellent performance and needs improvement. Another study by Zhang (2021) proposed a two-layer deep brief network (DBN) model and categorized the tongue color as red and yellow. A spectral range (400-1000) nm was used with the visible hyperspectral imaging system to collect the images of the tongue, where the model was applied to the spectral curve as well as to the spatial region in the first layer to extract the spectral and spatial feature, while the second layer was implemented to work as a classifier based on the DBN. The average accuracy was adopted. Retrieval of 0.7503 and 0.7651 for the tongue red color, and 0.8029 and 0.8151 for the yellow color of the tongue coating and an image resolution of 696×510. The components of the system were a CCD camera, a light source, and a computer. The selection was random and discrete on 100 pixels for the regions of the structure and coating of the tongue of the volunteer to obtain the spatial and spectral features, 800 pictures of the tongue of the volunteers were taken, a database was built for the correct red tongue and yellow tongue coating, relying on doctors with experience in clinical Chinese medicine to examine the tongue. Each study mentioned above, however, has its pros and cons at different assumptions, leading to several issues to be considered. Table 3 shows the work done in segmentation and feature detection of the tongue, segmenting the image of the tongue, and determining the relationship of each region of the tongue with the internal organs of the human body.

TABLE 3. The work done in segmentation and feature detection of the tongue.

Ref.	Used Sensors with Image Feature	ROIs	Used Technique	resolution	No. of Participants at a Time	number of samples	Results
(Parcus et al., 2017)	mobile phone camera	mouth area of interest is outlined, to determine the most necessary and detailed features for tongue detection	real-time face detection (HAAR) algorithm	NA	1	40 volunteers.	the results were positive. have got diagnosis accuracy over 75%.
(Jiang, Xu and Chen, 2008)	Sony DSC-T10 digital camera	tongue	HRDIS	7.2 megapixels	1	100 samples	Remote diagnosis and treatment
(Jung et al., 2014)	two digital cameras front(CCD) and one side(a Bayer)	tongue	frontal and profile feedback gridlines and intra-layer correlation coefficients (ICCs)	NA	1	120 pictures	If the grid lines not used the ICCs of all color features are less than when used, and they are greater when it used with the profile. improved the reproducibility In features for color and shape
(Chiu, 2000)	digital camera	tongue	CTES	440×400 pixels	1	60 images	The overall health rate was above 86%.
(Yamamoto et al., 2011)	ultra-spectrum camera	tongue	Hyper spectral imaging system	Spectrum range of 400-800 nm containing 81 bands of 5 nm resolution	1	44 images	The tongue color can be analyzed without the effect of coating, as well as the actual spectral properties of the tongue without specular reflection
(Xu et al., 2015)	CCD digital camera with illumination (D50)	tongue	two modern deep neural networks (UNET and DFL)	NA	1	1858 pictures	the results are superior to the current methods for characterizing the tongue
(Zhang and Processing, 2021)	ultra-spectrum camera, a light source, and a computer	tongue	two-layer deep network (DBN) model	696 × 510	1	800 pictures	the method fused the spectral and the spatial feature achieved the highest average precision and average recall.

SUGGESTIONS AND DISCUSSION

Through this review of the works in the field of autologous or computerized Tongue Diagnostics (ATD), it can be noticed that there is no complete work and there are some obstacles, including difficulty in linking ATD systems with each other and benefiting from the results of certain works in other similar works. In addition to the lack of a standard data set, specifically, tongue images can be used to broaden the horizon of tongue analysis and diagnosis (the terms of the Western Research Agreement), as well as the quality of the captured image, image segmentation, system design, and feature extraction. This reduces the accuracy and reliability of the systems. There is a need for independence in tongue diagnostic systems to fully reach the characteristics and capabilities of the tongue and apply them in primary health care systems. Figure 1 shows the block diagram of the ATD system. The image of the tongue is fetched from the computer memory or directly from the camera, and then processed and segmented using several features, such as color, shape, texture and fur. The extracted information is combined with the symptoms in an algorithm to give us the final outcome.

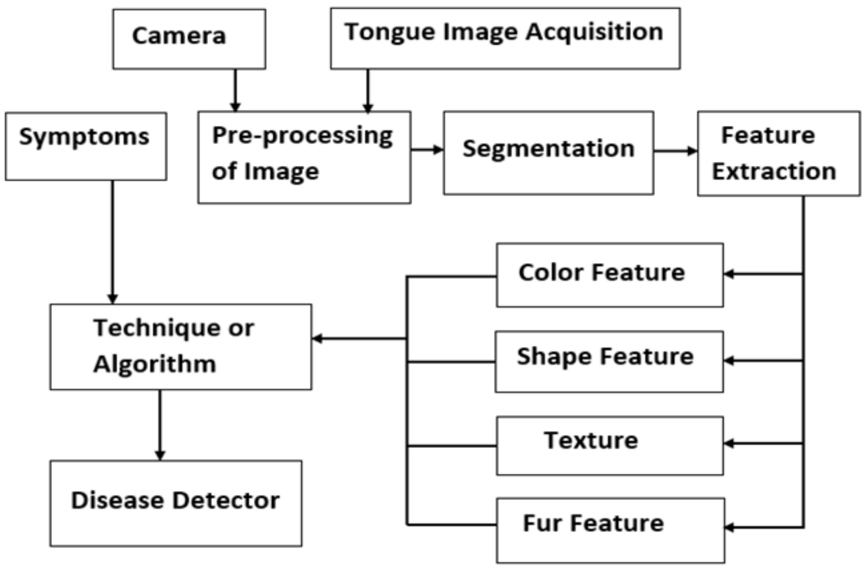

FIGURE 1. The block diagram of the ATD system.

CONCLUSION

In this review, automated and software ATD systems are explored for their capabilities to Supporting tongue diagnosis and integrating it into primary health care systems as a tool for early disease diagnosis. Considerable effort has been put into analyzing the tongue based on color, shape and other features in tongue projects, as well as the use of different methods and algorithms, including artificial intelligence algorithms, to detect and diagnose diseases without touching the patient. ATD are systems that open up a broad future that reduces reliance on human expertise so reduces human error. In light of the technological renaissance in the field of imaging and camera for smart devices, software and algorithms, there is a great opportunity to unify work and create a standard protocol that everyone can follow to build collective knowledge and develop modern medical devices that give an accurate diagnosis.

REFERENCES

1. R. F. M., M. M. A. and And Amal Adnan Ashour (2021) 'Internet of Things and Synergic Deep Learning Based Biomedical Tongue Color Image Analysis for Disease Diagnosis and Classification', *IEEE*, 9, pp. 94769–94779.

2. G.Umadevi, V.Malathy and M.Anand (2019) 'Diagnosis of Diabetes from Tongue Image Using Versatile Tooth-Marked Region Classification', *TEST Engineering & Management*, 81, pp. 5953–5965.
3. Balkrishna B. Gabhale1, Meenal S. Shinde2, Ashwini M. Kamble3, M. V. C. K. 1Student (2017) 'Tongue Image Analysis with Color and Gist Features for Diabetes Diagnosis.', *International Research Journal of Engineering and Technology (IRJET)*, 4(4), pp. 523–526. doi: 10.1038/srep00936.
4. Banu, R. and Devi, G. U. (2016) 'Diagnosis of Diabetes Using Tongue Color Analysis', 4(5), pp. 69–71.
5. Bo Pang a, David Zhang b,*, K. W. a (2005) 'Tongue image analysis for appendicitis diagnosis', *Information Sciences*, 175(L), pp. 160–176.
6. Chen, H., Jiang, S. C. C. and Lee, C. L. C. L. J. (2021) 'Computational tongue color simulation in tongue diagnosis', (July), pp. 1–14. doi: 10.1002/col.22717.
7. Cheng, M. H., Hu, M. C. and Lan, K. C. (2017) 'Tongue fur detection on the smartphone', *Proceedings - 2016 IEEE International Conference on Bioinformatics and Biomedicine, BIBM 2016*, pp. 1365–1371. doi: 10.1109/BIBM.2016.7822719.
8. Chiu, C. C. (2000) 'A novel approach based on computerized image analysis for traditional Chinese medical diagnosis of the tongue', *Computer Methods and Programs in Biomedicine*, 61(2), pp. 77–89. doi: 10.1016/S0169-2607(99)00031-0.
9. Horzov, L. *et al.* (2021) 'Analysis of Tongue Color-Associated Features among Patients with PCR-Confirmed COVID-19 Infection in Ukraine', *Association of Support to Oral Health Research - APESB*, pp. 1–11.
10. Jiang, L., Xu, W. and Chen, J. (2008) 'Digital imaging system for physiological analysis by tongue colour inspection', *2008 3rd IEEE Conference on Industrial Electronics and Applications, ICIEA 2008*, pp. 1833–1836. doi: 10.1109/ICIEA.2008.4582836.
11. Jiang, B. *et al.* (2012) 'Integrating next-generation sequencing and traditional tongue diagnosis to determine tongue coating microbiomee', *scientific reports*, pp. 1–12.
12. Jung, C. J. *et al.* (2012) 'Review on the current trends in tongue diagnosis systems', *Integrative Medicine Research*, 1(1), pp. 13–20. doi: 10.1016/j.imr.2012.09.001.
13. Jung, C. J. *et al.* (2014) 'Improving color and shape repeatability of tongue images for diagnosis by using feedback gridlines', *European Journal of Integrative Medicine*, 6(3), pp. 328–336. doi: 10.1016/j.eujim.2014.01.004.
14. Li, Q. *et al.* (2010) 'AOTF based hyperspectral tongue imaging system and its applications in computer-aided tongue disease diagnosis', *Proceedings - 2010 3rd International Conference on Biomedical Engineering and Informatics, BMEI 2010*, 4(Bmei), pp. 1424–1427. doi: 10.1109/BMEI.2010.5639418.
15. Li, Q. and Liu, Z. (2009) 'Tongue color analysis and discrimination based on hyperspectral images', *Computerized Medical Imaging and Graphics*, 33(3), pp. 217–221. doi: 10.1016/j.compmedimag.2008.12.004.
16. Lu, Y. *et al.* (2018) 'DCCN : A DEEP-COLOR CORRECTION NETWORK FOR TRADITIONAL CHINESE MEDICINE TONGUE IMAGES Signal & Information Processing Lab , Beijing University of Technology , Beijing , China', *2018 IEEE International Conference on Multimedia & Expo Workshops (ICMEW)*, pp. 1–6.
17. Parcus, R. *et al.* (2017) 'Development of a Mobile Phone Based Tongue Image Acquisition System'.
18. Park, Y. J. *et al.* (2016) 'Reliability and validity of tongue color analysis in the prediction of symptom patterns in terms of East Asian Medicine', *Journal of traditional Chinese medicine = Chung i tsa chih ying wen pan / sponsored by All-China Association of Traditional Chinese Medicine, Academy of Traditional Chinese Medicine*, 36(2), pp. 165–172. doi: 10.1016/s0254-6272(16)30023-1.
19. Safia Naveed, G. G. and L. S. (2020) 'Early Diabetes Discovery From Tongue Images', 0, pp. 1–14.
20. Srividhya E, M. A. (2019) 'Feature Extraction of Tongue Diseases Diagnosis Using SVM Classifier', *IEEE*, pp. 260–263.
21. Tania, M. H., Lwin, K. and Hossain, M. A. (2019) 'Integrative Medicine Research Advances in automated tongue diagnosis techniques', *Integrative Medicine Research*, 8(1), pp. 42–56. doi: 10.1016/j.imr.2018.03.001.
22. Usharani Thirunavukkarasu, 1 Snekhalatha Umapathy , 1 Palani Thanaraj Krishnan, 2 and Kumar Janardanan3 (2019) 'Human Tongue Thermography Could Be a Prognostic Tool for Prescreening the Type II Diabetes Mellitus', *Hindawi Evidence-Based Complementary and Alternative Medicine*, 2020(5953), pp. 1–16.

23. Wang, X. *et al.* (2013) 'Statistical analysis of tongue images for feature extraction and diagnostics', *IEEE Transactions on Image Processing*, 22(12), pp. 5336–5347. doi: 10.1109/TIP.2013.2284070.
24. Wang, X. and Zhang, D. (2010) 'An Optimized Tongue Image Color Correction Scheme', *Ieee Transactions on Information Technology in Biomedicine*, 14(6), pp. 1355–1364.
25. Xu, Q. *et al.* (2020) 'Multi-task Joint Learning Model for Segmenting and Classifying Tongue Images Using a Deep Neural Network', *IEEE Journal of Biomedical and Health Informatics*, 14(8), pp. 1–10. doi: 10.1109/JBHI.2020.2986376.
26. Yamamoto S, Ogawa-Ochiai K, Nakaguchi T, Tsumura N, Namiki T, M. Y. (2011) 'Detecting hyper-/hypothyroidism from tongue color spectrum', *IEEE*, pp. 18–20.
27. Yamamoto, S. *et al.* (2011) 'Regional image analysis of the tongue color spectrum', *International Journal of Computer Assisted Radiology and Surgery*, 6(1), pp. 143–152. doi: 10.1007/s11548-010-0492-x.
28. Zhang, B. *et al.* (2013) 'Tongue color analysis for medical application', *Evidence-based Complementary and Alternative Medicine*, 2013, pp. 1–11. doi: 10.1155/2013/264742.
29. Zhang, D. and Processing, S. I. (2021) 'What's wrong with the tongue: color grading quantization based on hyperspectral images', 11848(June), pp. 1–7. doi: 10.1117/12.2600149.
30. Zhang, H. Z. *et al.* (2005) 'SVR based color calibration for tongue image', *2005 International Conference on Machine Learning and Cybernetics, ICMLC 2005*, (August), pp. 5065–5070. doi: 10.1109/icmlc.2005.1527836.
31. Zhao, Q., Zhang, D. and Zhang, B. (2017) 'Digital tongue image analysis in medical applications using a new tongue ColorChecker', *2016 2nd IEEE International Conference on Computer and Communications, ICCC 2016 - Proceedings*, pp. 803–807. doi: 10.1109/CompComm.2016.7924814.
32. Zhihao, J. *et al.* (2008) 'Analysis of Tongue Information in Coronary Artery Disease', *IEEE International Symposium on IT in Medicine and Education*, pp. 278–290.