Computer Aided Image Enhancement of Tongue for Diagnosis in Ayurvedic Medical Treatment

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Abstract
Ayurveda is one of the traditional medical systems practiced in India and south Asian countries from ancient times. Tongue diagnosis is one of the important areas in physical diagnosis of treatment of health disorders in Ayurveda. The diagnosis is usually carried out by the medical practitioner with visually understanding the tongue, but the process of understanding the tongue image is not an easy task to carry out. The difficulty arises because of the irregular shape of the tongue, overlapping of colors, effect of outside light, dominance of saliva on cracks and buds etc. In this paper, we propose an application of computer aided digital image enhancement methods for processing the tongue image to highlight the true color and white coating, cracks, pimples/buds etc., so that the practitioner can get more valuable information compared to direct visual examination of the tongue. The method mainly consists of two techniques; first, color image filtering and enhancement for identifying the true nature of colors on different parts of the tongue and to bring out white coating; second, contrast enhancement and image sharpening in grey scale for highlighting the shape, cracks, buds and pimples. The aim of our method is to help in reducing the complexity in tongue image understanding for the practitioner. The data of the experimental results reveal that our method produces significant useful result for the tongue diagnosis.

Keywords: Ayurveda; Tongue diagnosis; Digital Image Processing; Image enhancement.

Introduction

Ayurvedic medical system is one of the popular medical systems followed in India and other south Asian countries along with Allopathy, Homeopathy and Naturopathy. Ayurvedic Medical practitioners rely on noninvasive diagnosis like understanding symptoms on patient's bodies to tell them when something is wrong in their body. Besides the skin, hair, eyes, lips and nails as indicators of internal imbalances, the tongue also provides them with vital clues [1]. In Indian Ayurvedic medicine, observation of the tongue describes the current state of an individual's health, as well as their inherited constitution. Tongue diagnosis is a way of viewing inherited tendencies and illnesses that could occur, depending upon the person's nature and lifestyle. It reveals existing disease process and is a means of health evaluation. Although not backed by documented scientific research, tongue diagnosis dates back several thousand years, and has long been used as an investigative tool by practitioners of the traditional schools of medicine. At one time, both pulse and tongue assessments were important diagnostic techniques used in the Western medicine

tradition, particularly by the Physiomedicalist. But unlike Chinese, neither much research was done in this area nor the use of latest technologies like computer and imaging technologies were used to enhance the scope of this system. In Ayurveda, the tongue is examined to assist in diagnosis and to the extent in which the tongue changes with treatment can indicate how successful the treatment has been.

Tongue Diagnoses InAyurvedic Treatment

Ayurveda is the traditional system of medicine of India and is at least 5,000 years old. It has an accumulated knowledge of disease diagnosis and treatment formulated by several Rishis(knowledgeable persons) through thousands of years. As with other medicine systems, it has its own understanding of body functions and the imbalances which cause diseases [2]. Physical observation of body parts of the patient and changes in them during the course of treatment is an important way of diagnosing the disease and health condition of the patient. The tongue is one of the important body parts that can beanalysed to assess the exact nature of digestion, metabolism, affected parts of the body and type of disease. Changes in the tongue can take weeks to years, giving the practitioner information about the depth and length of the illness. At the heart of Ayurvedic medicine is what is called the Tridosha. These tridoshas are to some degree similar to the old European medieval idea of the humours. The tridosha are vata, pitta and kapha. In a patient's health they are responsible for the function and structure of body. However, if they become excessive or deficient either individually, or in combination, then they cause illness in the patient. Size, shape, contour, surface, margins and color are the characteristics one can observe on the tongue. Few symptoms are: 1) A pale tongue may indicate an anemic condition or lack of blood in the body.2) A yellowish tongue may suggest that excess bile present in the gallbladder or a possible liver disorder.3) A blue tongue is normally an indication of problems with the heart. 4) Different areas of the tongue correspond to different organs of the body. Hence by correlating the location of the blemishes on the tongue, the Ayurvedic practitioner can determine which organs of the body are out of balance. 5) A whitish tongue indicates Kapha imbalance and mucus accumulation. 6) A red or yellow green tongue indicated a Pitta imbalance. 7) A vata imbalance is manifested by a black to brown coloration on the tongue. 8) If the tongue is covered by a coating, it may indicate the presence of toxins in the stomach, small intestine or large intestine. 9) If the posterior part of the tongue is coated, it will indicate that toxins are present in the large intestine. 10) If the middle of the tongue is coated, the toxins are present in the stomach and in the small intestine [3]. The tongue image with different parts of body reflected at different parts of tongue is shown in below Figure 1.
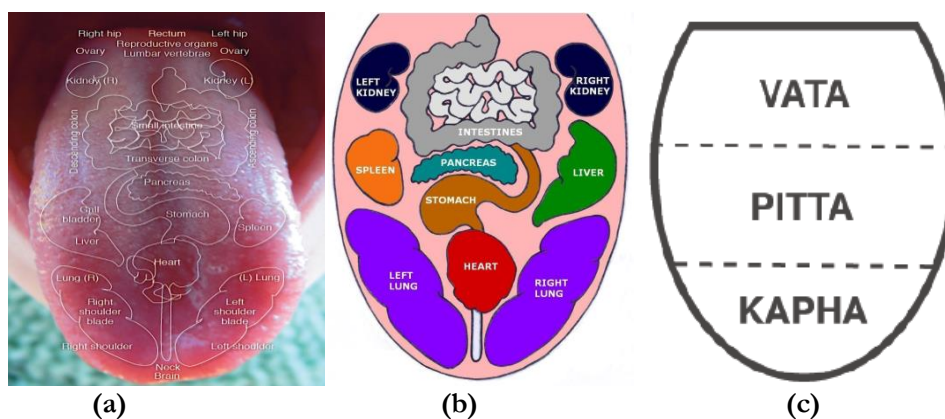

| (a) | (b) | (c) |

Figure 1. (a) Tongue image. **(b)**Representation of different parts of body on tongue. **(c)** Division of tongue according to Ayurvedic medical system.

According to Ayurveda, body organs are superimposed on the tongue upside down as shown in

Figure 1. Tip of tongue represents top of the body. Back of the tongue represents the bottom of your spine. Right and left sides of the tongue represent corresponding sides of the patient. Middle vertical third of the tongue represents organs like liver, gall bladder, stomach, spleen and pancreas.

A healthy tongue (as shown in Figure 2) should look like a children's tongue: symmetric and evenly pink, should be supple, free of cracks and not quiver or tremble. It should be slightly moist. It is neither too thick nor too thin, and oval in shape. When the tongue is sticking out, it's naturally straight rather than curving to one side. It should remain still, not trembling, flaccid, and flat-tipped or stiff. It should have a thin, transparent coating, coloring the tongue pink. All the taste buds are flat, orderly and free from strawberry-looking bumps, deep cuts, lines, cracks and patches. It should not have foam, hair, fur, be too dry or too wet or have a foul odor or taste; a healthy tongue should have some coating.

Figure 2. Sample image of a healthy tongue.

Problems Faced In Tongue Diagnosis

'Tongue analysis' is one of the diagnosis processes in the Ayurvedic system of patient management. Ayurvedic practitioners ask the patient to open their mouth and show the tongue to extract the visual information. The practitioner's interest in the tongue are – 1) size and shape of the tongue 2)tip 3)width 4)thickness 5) color 6)texture 7) projections 8) fissures & cuts 9) coating/fur 10) swelling 11)bleeding 12) above conditions in different parts of the tongue, etc. Based on this information and their knowledge and experience, Medical practitioners try to understand the condition of the patient. But the problems faced by the practitioners are: 1) While the visual information that can be extracted from the patient's tongue is same, all practitioners do not have the same level of knowledge and experience to analyze it 2) As the Ayurvedic practitioners have to depend on their eye's perceivability to understand the tongue of patient, either because of old age or because of problem in their visual capability or due to any other reason, practitioners can also make mistakes; 3) Even though some instruments are there like MRI, CT scan etc., they are very costly for procuring as well as diagnosing and as their main purpose is different, no practitioner can advise the patient to diagnose the tongue with these costly equipments.

Due to the above criticalities in analyzing the tongue, the role of computer aided digital image processing comes as a tool developer to mitigate the above said issues. Tongue image processing needs some special attention in the field of image processing because of the irregular shape, color, texture, etc…of the tongue. Hence, for the analysis of tongue image, it is better if we examine the shape feature, color feature and texture feature of the tongue image separately. Texture identification provides a clear processing of the tongue image. The processing of tongue image navigates through different steps like: enhancement of image, identifying the color and texture of the tongue, highlighting the irregularities etc.

At present, there are two major concerns in the tongue analysis. The first is the illustration of tongue's color, texture and coating with the support of image analysis technology and the second one is the enhancement of tongue. A number of methods have been developed to efficiently process the digital image as the need of an accurate and well equipped processing method comes more frequently. Though researchers have made significant advancement in the standardization and

quantification of medical image diagnosis, there are still significant problems with the existing approaches. First, some methods are only concerned with the detection of features in image. Second, the original validity of these methods and systems is usually derived from a comparison between the diagnostic results that are acquired from the methods or systems and the judgments made by skillful practitioners of diagnosis. Third, only few samples were used in the experiments and this is far from meeting the requirements of obtaining a reasonable result in statistical pattern recognition.

So, for an effective diagnostic standard for tongue image diagnosis, we propose a new method, step by step processing of the tongue image. The system consists of four steps; taking the tongue image of the patient, color image enhancement for identifying true color and coating, grey image enhancement for identifying cracks, fissures and pimples/buds with the help of intensity measures. The evaluation of the results of sample images showed that the proposed method provided expected results in diagnosing the tongue image.

Methods

Computer Aided Image Enhancement of Tongue

Tongue images are one of the elementary features for diagnosis of various diseases in Ayurveda. For the ease of the diagnosis by a practitioner, the tongue images should be processed clearly and properly. The main features that are to be extracted properly for diagnosing the tongue are its shape, color, coating, pimples and cracks on the surface.

Tongue image is a two dimensional data denoted by two-dimensional functions of the form $f(x, y)$. The value or amplitude of f at spatial coordinates (x, y) is a positive scalar quantity. When an image is generated from a physical process, its values are proportional to energy radiated by a physical source(e.g., electromagnetic waves).As a consequence, $f(x, y)$ is nonzero and finite; that is, $0 < f(x, y) < q$. Tongue image can be represented as a function $f(x, y)$ and is sampled so that the resulting digital image has M rows and N columns with P nunber of pixels and with intensity function I added to each pixel.
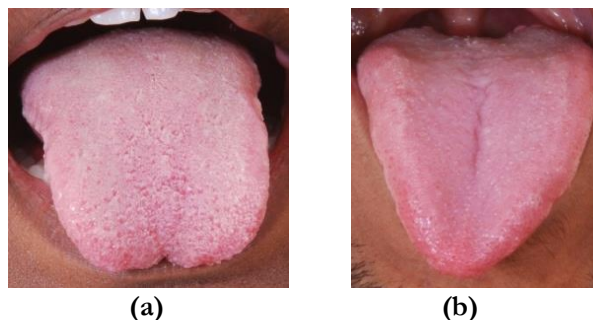

(a)   **(b)**

Figure 3: (a) & (b) are the tongue images with different shape characteristics

The image of tongue varies person by person, body nature, disease, tine of treatment etc. The Figure 3 shows images of the two tongues that shows different shapes and characteristics. While considering a tongue, one should be aware about the diagnosing factors of the tongue. The shape, size, color, etc. descraibes the features of the tongue. Here, the Figure 4 shows the tongue images with different colors and textures.
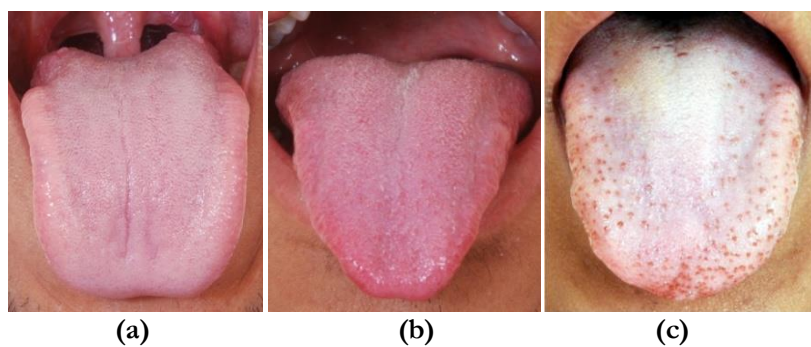
(a)   **(b)**   **(c)**

Figure 4. (a), (b) & (c) are the tongue images with various colors and textures

Colour Image Processing

In the colour enchancement of the image , amethod with sequential approach for the tongue image proccessing is being introduced. The sequential process consists of enhancement of image for its true color and coating.

Enchancement of True Colour and White Coating

The colour feature is extracted with the help of image averaging and gradient sharpening methods. The colour of the tongue is extracted on the basis of the intensities presented in the different areas of the tongue and its background [4]. This feature is applied to all colors R, G and B because intensity levels of different colors will be different for different areas of the tongue. So with the help of this intensity method, extract the color feature, the coating and true color of the tongue. The white coating may dominantly present in some tongues and in some others it will be less dominant. The main aim is to match the skin color of the person in the tongue image with that of the normal person.

Algorithm for extracting the True color and Coating on the Tongue

Step1: Read input image f(x,y);
Step2: Crop the image f(x,y), according to the tongue boarders, to get the image fc(x,y);
Step3: Split the color image into fr(x,y)= fc(:, :, 1); fg(x,y)=fc(:, :, 2); fb(x,y)= fc(:, :, 3);
Step4: Find the Threshold values THr,THg & THb of images fr(x,y), fg(x,y) and fb(x,y) respectively; (This is an iterative process as a correct value has to be found. The correct threshold value is the one that makes the skin color in the image as natural.)Step5: Find out the common threshold value THc, Where THc = Avg(THr, THg, THb) ;
Step6: Subtract 'THc 'value from each image intensity values, to get fR(x,y); fG(x,y); and fB(x,y);
Step7: Reconstruct the RGB image to get frgb(x,y), by adding fR(x,y); fG(x,y); and fB(x,y);
Step8: Apply Image Averaging Technique on the frgb(x,y) to get f^{a}rgb(x,y);
Step9: Apply Gradient technique on the image to sharpen the image f^{s}rgb(x,y)
Step10: Resultant image is the output image.

The Figure 5 shows the detection of white coating in the tongue. In the unprocessed image the coating is not pronounced and it got mixed up in the normal red color of the tongue. In the processed image, the white coating can be clearly seen. The coating and the true color of the tongue is seen in the processed image. Also it can be seen in the image that the skin color is natural after filtering the image.
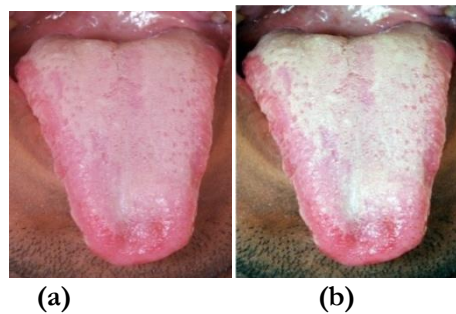
(a)   **(b)**

Figure 5. Detection of fur coating & true color of tongue image **(a)** original image **(b)** Enhanced image.

Enchancenent of Cracks and Pimples

For the detection of cracks and pimples in the tongue, the image of the tongue is processed through color to grey-scale conversion and then image sharpening and contrast stretchingmethods. Initially, the image is converted from the color image into the gray scale image. Then the different intensity values in different areas of the tongue are found through the histogram method. After selecting the particular area, a threshold value is assigned for sharpening the image bringing out more of the skeletal detail.

Algorithm for enhancement of Cracks, Pimples/ Buds of Tongue Image
Step1: Read the input image $fC(x,y)$;
Step2: Crop the image $f(x,y)$, according to the tongue boarders,
Step3: Convert RGB color image $f(x,y)$ into grayscale image $g(x,y)$;
Step4: Apply the median filter on $g(x,y)$ to remove noise;
Step5: Apply Local Contrast enhancement technique to get image $gc(x,y)$;
Step6: Find threshold value of $gc(x,y)$ from histogram equalization method;
Step7: Apply image sharpening technique on $gc(x,y)$ to get the image $ge(x,y)$;
Step8: Extract the texture of the image, which is $gt(x,y)$;
Step9: The resultant image is the output image.

(a)   **(b)**   **(c)**   **(d)**
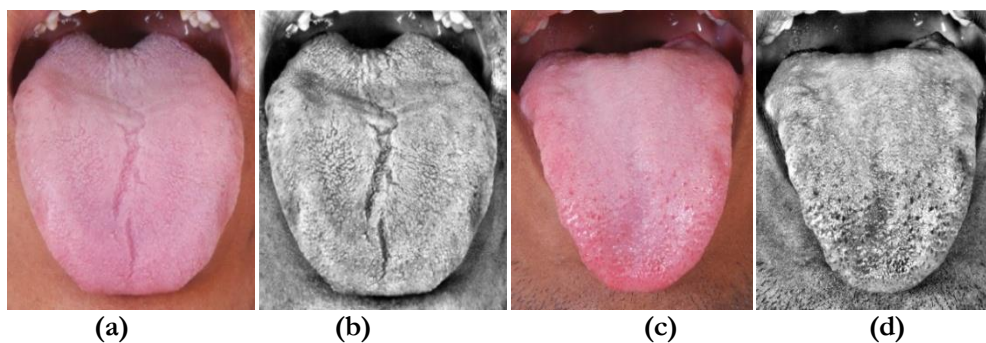
Figure 6. Detection of cracks and buds. **(a)** Original image **(b)** Enhanced Grey Scale image with cracks. **(c)** Original image **(d)** Enhanced Grey Scale image with pimples.

The Figure 6. shows the unprocessed and processed images of two tongues using above mentioned approach. The processed images clearly highlight the cracks, buds and pimples. In the first and third figures, one can see in the unprocessed image, the cracks almost invisible due to thin in nature and also due to dominance of red color and saliva. But in the processed image, one can clearly identify the cracks of the tongue. Similarly in the second image buds are highlighted which are not properly visible in original image.

Experimental Study

For the testing of the proposed method, campus students of hostel of JNTUH College of Engineering, Karimnagar, A.P., India were selected by the authors for taking the samples. According to the requirement of data, digital tongue images were taken from 236 campus students In this process two problems were faced in the collection of tongue images of students; one is to maintain the constant lighting to camera and second is, the tongue is a soft tissue, in stretching tongue, its shape varies with the sitting postures. The right method of stretching tongue is found to be as follows: Students open their mouth as wide as possible, the tip of the tongue stands out and gets down, and the tongue body relaxes, the tongue surface spreads horizontally. First, the students did tongue-stretching training 2-3 times before the image collection to ensure correct posture. Then, students put their head on fix support equipments and stretched their tongue. Last, with the digital cameras take the tongue pictures from the front side of the face. Of the 236 students involved in the current experiments, 191 were all healthy students and 45 were diseased at present or in recent past. There were totally 6 common internal diseases observed. In those 45 diseased ones, present health condition of 10 students was not good. Out of 10 diseased ones 9 students are suffering from cold and 1 from fever. In the observation of past two week's health condition, 14 students suffered from cold, 7 from fever, 1 from stomachache and 1 from headache. If considered the previous major ill health condition of students, 3 suffered from cold, 5 suffered from fever, 5 suffered from Typhoid, 2 suffered from malaria, 2 suffered from jaundice and 3 suffered from dengue. The 236 digital tongue images from the database were used to evaluate the accuracy rate of the present methods, and satisfactory results are shown is Table-1.

The Figure 7. shows the tongue of a person who is suffering with the headache. Herein the processed image the tip of the tongue is with a red patch without any coating indicating the problem in chest and above part of the body and the student statement is that he is suffering from the headache. The problem is also related to the heart, spleen and gall bladder areas as observed as buds in the side regions of the tongue image. Heart and head are closely related as about forty percent of the blood is pumped to the head of a body.

| (a) | (b) | (c) |
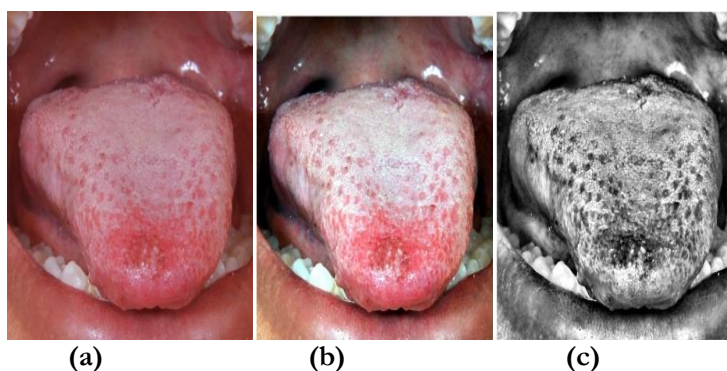
Figure 7. Tongue of a person who is suffering from headache **(a)** Original image. **(b)** Enhanced True color image. **(c)** Enhanced Grey Scale image.

The Figure 8. shows the person's tongue who inforned us that he is suffering with Stomachache. Here the crack in the middle portion of the tongue indicates the symptom for the problem in stomach and intestine region and this is clearly appearing in the processed grey scale image. As the white coating is nornal and no other significant observations are there on the tongue, the problen is mostly related to only intestinal portion of the body.

The Table 1 shows some processed sample images by applying the current methods. The column fields of the table contain the Image identity number, original extracted image from the student, Grey scale image which is processed by applying the above mentioned algorithm, an extracted True color image with coating, information given by the student abouthis/her health condition and the last field gives the inference on the student's tongue image by the Ayurvedic medical practitioner.
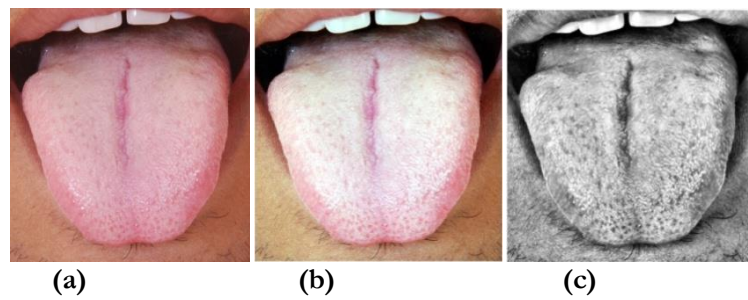
| **(a)** | **(b)** | **(c)** |
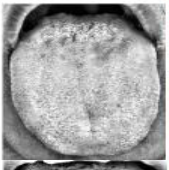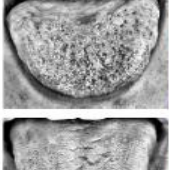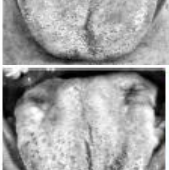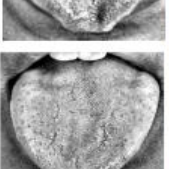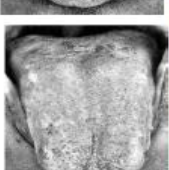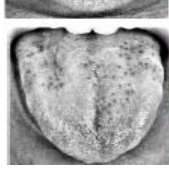
Figure 8. Tongue image of a person who is suffering from Stomachache. **(a)** Original image. **(b)** Enhanced True color image. **(c)** Enhanced Grey Scale image.

Table 1. Samples of processed images

Image No.	Original Images	Grey Scale Images	True Color Images	Students statement of health condition	Practitioners Remarks
I253				Present: Suffrering with Stomach upsetPast: health condition was good	Problem in stomach area
I248				Present: Suffering from cold Past: health condition was good	Problem in heart and head regions
I172				Present: suffering with headache Past: suffered with headache	Problem in nature of the body
I174				Present: Suffering with Stress Past: health condition was good	Stress

Table 1.(contin.) Samples of processed images

Image No.	Original Images	Grey Scale Images	True Color Images	Students statement of health condition	Practitioners Remarks
I234				Present: Good Past:Suffered with cold	Normal
I290				Present: Suffering with headache Past: health condition was good	Some problem in intestinal region
I191				Present: Suffering with fever Past: health condition wasgood	Problem in urinal function
I223				Present: Good Past:Suffered with fever	Normal
I215				Present:Good Past: Suffered with sleeping problem**ms**	Problems in intestinal region
I229				Present:Suffering with Headache Past: nornal	Past problem in heart region
I205				Present:Suffering with chronic caugh Past: health condition was good	Past problem in chest region
I185				Present: worked restless Past: health condition was good	Normal
I187				Present:Suffering with headache Past: health condition was good	Normal
I212				Present:sto**machache** Past:health condition was good	Normal

Results and Discussion

Even though the aim of a medical practitioner is to identify the disease/unhealthy part of the patient's body, but the aim of a technologist is to give a tool to the practitioner for his/her better understanding of the patient. All diagnosis need not give results in the form of outcome of name of disease of the patient but it should show the way of clear understanding of the patient health and tongue diagnosis is also a similar one. So the results of our experiment were to improve the image quality for better understanding by the practitioner. After 236 Tongue images are tested by applying the proposed methods, the improvement results of the images are shown in the Table 2. The results were analyzed for the qualitative improvement in the image; the qualitative factors were taken as 'Better' and 'Good'. 'Better' indicates a distinguishable improvement of enhanced image over the original image and 'Good' indicates a visible improvement of the enhanced image over the original image.

Table 2. Result Analysis

S.No	Extracted Feature	Total No. of Images	No. of Images appeared "Better"	% of images appeared "Better"	No. of Images appeared "Good"	% of images appeared "Good"	No. of Images withno improvement	% of imageswith no improvement
1.	True Color	236	180	**76.3**	56	**23.7**	0	**0**
2.	Cracks	236	64	**27.1**	65	**27.5**	107	**45.3**
3.	Pimples/ Buds	236	110	**46.6**	101	**42.8**	25	**10.6**
4.	Texture	236	161	**68.2**	75	**31.8**	0	**0**
5.	White Coating	236	120	**50.9**	88	**37.3**	28	**11.9**

Out of 236 tongue images, True Color of 180 images is appearing "Better" (% of images appearing "Better" is 76.3), 56 images of True Color is appearing "Good"(% of images appearing "Good" is 23.7) and almost all enhanced images are showing improved results over their original appearance. Out of 236 tongue images enhanced in grey scale; in 64 images, Cracks are appearing "Better"(% of images appearing "Better" is 27.1), 65 images are appearing "Good" (% of images appearing "Good" is 27.5) and 107 images do not have any Cracks, hence showed as "No improvement" (% of images have no Cracks is 45.3). In 110 processed images, Pimple/Buds are appearing "Better"(% of images appearing "Better" is 46.6), 101 images are appearing as "Good"(% of images appearing "Good" is 42.8) and 25images have no Pimples/Buds, hence showed as "No improvement" (% of images have no Pimples/Buds is 10.6). Out of 236 images, in 161 images Texture of tongue is appearing as "Better"(% of images appearing "Better" is 68.2), 75 images appearing "Good"(% of images appearing "Good" is 31.8) and almost all images improved their appearance over their originals. Of all the images, in 120 images White Coating is appearing "Better"(% of images appearing "Better" is 50.9), in 88 images appearing "Good"(% of images appear "Good" is 37.3) and 28images have no White Coating, hence showed as "No improvement" (% of images have no White Coating is 10.6).

Conclusion

Tongue image analysis is anon invasive diagnostic tool for Ayurvedic medical practitioner. The tongue image enhancement is one of the important tools in the tongue image analysis to make it more useful to the practitioner; hence there are different methods available for the effective processing of tongue images. Thus, in current method, enhancement is done by finding suitable threshold to reproduce true image and white coating of the tongue by color image processing. Cracks and pimples/buds were highlighted by processing the image in grey scale. Disease or

unhealthy parts of the body could be identified by looking for the symptoms in different parts of the processed images by the practitioner. From the evaluation of the results it is showed that the proposed methods gives the appropriate results with qualitative improvement and is well suited for the tongue image processing. Further enhancement to the system can be done by improving the localized intensity methods and calculation of the features and giving an empirical table to identify the disease.

Authors' Contributions

The authors tried to explore the world of Ayurveda and to make an understanding of its processes of diagnosis and treatment. They formulated the software program to process the digital image of the tongue. The image data of 236 students were taken and processed it with the program they developed. The results were discussed with an Ayurvedic medical practitioner and the results were tabulated for analysis.

Acknowledgement

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