TongueDx: A tongue diagnosis system for personal health care on smartphone

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Abstract – On the TongueDx system, users can keep track of their health condition by recording the color of tongue coating and body on smartphones. In fact, this method is based on the Traditional Chinese Medicine (TCM) theories. Tongue diagnosis is one of the important diagnosing techniques in TCM. In order to avoid color error affected by surrounding light, a tongue color calibration by using teeth color as a standard is proposed in this paper. K-means algorithm is used to separate tongue coating from body. From the line graph of tongue coating and body color displayed on smartphones, people could know their health conditions timely and early discovery of some diseases without going to the hospital comes to be possible. If necessary, the personal tongue images can be sent to TCM practitioners to get further diagnosis. In the long run, the tongue image database is probably valuable for TCM research from time being.

Keywords: Tongue diagnosis, Traditional Chinese Medicine, Image processing, Smartphone, Health condition

1. Introduction

Recently health applications based on medical health diagnosing technique running on smartphones have been popular. We found that Tongue Diagnosis, which is one of the important health diagnosing techniques in Traditional Chinese Medicine (TCM), is a promising medical technique for these applications. In this paper, TongueDx - a tongue diagnosis application on smartphone is developed for those who care about their health. By taking photos of the tongue with smartphone, users can check how's their health is going on. Furthermore, some potential diseases in their bodies can be prevented before it really happens.

2. Related work

2.1 Tongue diagnosis of TCM

For thousands of years, tongue diagnosis has played an indispensable role in the Traditional Chinese Medicine (TCM). Tongue reflects the condition of the digestive system of a person from rectum to esophagus, including the stomach, small intestines, colon (large intestine), pancreas, spleen, liver and gall bladder, because the organs mentioned above associated with blood, nutrient assimilation, and excretion that affect tongue surface [1].

In fact, tongue color can reflect some health information. A healthy tongue should be *warm and pinkish colored*. For instance, when the tongue looks *sort of white and pasty*, it could mean that your blood is lacking hemoglobin - the iron-containing protein found in red blood cells. The symptom normally is reflected on tiredness and lethargy. A *red inflamed tongue* indicates lack of certain nutrients, especially iron and vitamin B. If tongue color is *close to purple*, this could mean you are suffering from high cholesterol, which could result in heart problems. A *purple* tongue could also indicate chronic bronchitis, which cuts down the efficiency of the airwaves bringing oxygen to the bloodstream.

2.2 Computer aided tongue diagnosis

Early tongue diagnosis mainly depends on TCM practitioners' judgment. However, not all of the TCM practitioners have same level of TCM knowledge so that they have to rely on their own experiences to get into patients. Therefore, the computer aided tongue diagnosis is expected to solve the difficulties that are happened on traditional tongue diagnosis. Wang have presented a technique for automated tongue edge detection by merging polar edge detector and active contour model. Bo has presented a tongue-computing model (TCoM) for the diagnosis of appendicitis based on quantitative measurements that comprise chromatic and textural metrics [2].

Fang and his group established an automatic analysis and recognition system by detecting tongue coating and body color [3]. They have identified coating and body area by their "splitting-merging" algorithm. In this paper, we used K-means algorithm to identify the two areas by color, because we expect optimal separation is achieved by the established clustering method, and isolated areas should not be merged for color diagnostic. Fang also grouped five types of tongue coating color and six types of tongue body color in both RGB and HIS color patterns. The classified colors were established on the typical tongue photographs in clinical practice. The classified tongue coating and body colors are used as standard colors in the daily-tongue-color-graph of our TongueDx system.

2.3 Other health/ medical applications

Many recent health-care applications for smartphones are designed for a diet. Some smartphone applications allow users to self-monitor caloric balance in real time and help users to track their behaviors related to weight management [4].

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There are not many tongue diagnostic applications for smartphones. The two closest applications can be found from iPhone/Android market. One is an application [5] that recommends most suitable herbal tea by image-processing user's tongue pictures. The other one is named "Tongue Disease Diagnosis" [6], which gives plenty of medical information indicating several tongue illustrations.

3. TongueDx

3.1 Tongue color calibration by Teeth

When we apply digital tongues diagnosis to the smartphones that will be used in a wide variety of lighting conditions, the color error will cause a lot of inaccuracy.

Sometimes, the color of photograph is not correct because the surrounding light at the place where the photo is taken has various color spectrums, and they affect the color of the photo. Color calibration to adjust the "white balance" is commonly applied when a precise colored picture is taken. One of the white balancing methods is to take a photograph with a gray-colored card next to the object, and adjust the white balance of the taken picture so that the gray card appears gray (same RGB values).

The gray card method is not acceptable in a smartphone application that will be used in everyday situation, because the picture taking process becomes burdensome and the gray card will be easily lost. In this study, we propose to utilize user's teeth, instead of gray card, to calibrate the white balance of tongue pictures. In order to get the color of tongue without distortion, the feasible of white balance calibration by teeth color is verified to the tongue image color calibration. This method is feasible because teeth color is unchanged in ordinary situation, and their color is close to white.

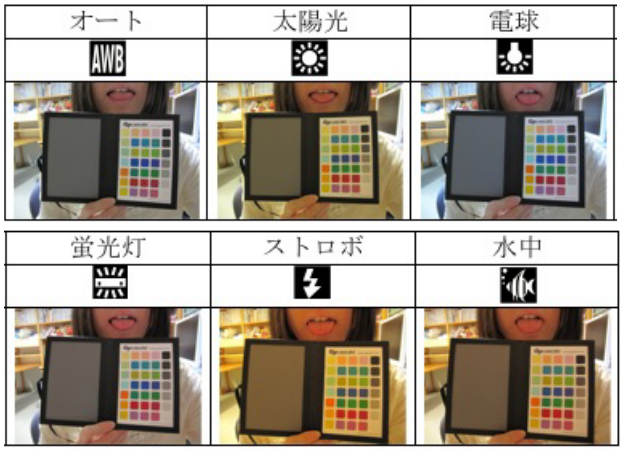


Figure 1. Images in different white balance modes

To evaluate our method of using teeth color as a color reference, following experiment with three steps has been carried out:

Step 1: Take photos in different white balance modes (Figure 1.): Auto White balance, Daylight, Tungsten, Fluorescent, Flash and Underwater (Use camera Cannon G10). All the photos are taken under mixture of fluorescent light and indirect sunlight from windows. Incorrect pre-fixed white balance setting produces deviated colored pictures that emulate failure of automatic white balancing affected by surrounding light. We can retouch these pictures as in the following step when color reference such as a gray card or a color chart is included in the picture.

Step 2: Pick random (n=5) pixels from teeth area, gray card area and pink color chart area - the closest to the tongue color. Then, calculate the average Red, Green and Blue (RGB) values of random (n=5) pixels and use white balance algorithm (1) to get calibrated pink's average RGB values.

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} \Gamma_R & 0 & 0 \\ 0 & \Gamma_G & 0 \\ 0 & 0 & \Gamma_B \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

In the case of Gray card as a standard:

$\Gamma_R = 129 / gr$;

$\Gamma_G = 129 / gg$;

$\Gamma_B = 129 / gb$. where gr, gg, gb represent the averaged RGB (from 0 to 255) of random pixels on the gray card area in raw image.

In the case of Teeth color as a standard:

$\Gamma_R = tr / tr0$;

$\Gamma_G = tg / tg0$;

$\Gamma_B = tb / tb0$. where rt, tg, tb represent the averaged RGB value of random pixels on the teeth area in calibrated picture by auto white balance function bye the camera, and tr0, tg0, tb0 are on the teeth area in raw image.

Step 3: Compare the square sum of RGB errors of calibrated pink pixels (n=5) to the auto-white-balanced pink pixels. Besides non-calibrated (do nothing) results, two calibration methods of using teeth and gray card are compared.

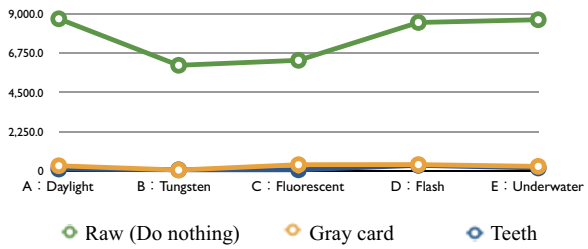


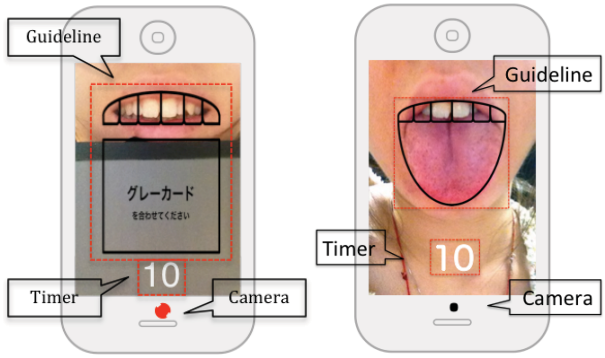
Figure 2. The color error of Raw, Gray card and Teeth

Figure 2 shows square sum of errors in pink color – which is close to tongue color – pixels in raw image, image calibrated by teeth and gray card. In the five white balance modes: daylight, tungsten, fluorescent, flash and underwater, it can be

seen from the graph that both of the calibration method using Gray card and Teeth have almost equivalent performance, and both of them can significantly improve the color deviation in the raw image.

According to the result, the handy calibration method by teeth is proved to be feasible. The result of experiment shows that white balancing of tongue image calibrated by gray card and teeth has almost the same effect.

We have applied the tongue color calibration method by teeth to our TongueDx application. When a user starts to use the application, he/she will be asked to take one reference teeth picture with a gray card. The user is asked to flip the camera up to down, and to show teeth and gray card followed by the guild line on the screen. Picture will be automatically taken in 10 second. We found that the smartphone camera on the bottom of the screen can get teeth and tongue picture easier than the camera on the top of the screen (Figure 3(a)).



(a) (b)

Figure 3. (a) Screenshot of taking teeth picture with gray card (b) Screenshot of taking tongue pictures

Once the reference teeth picture is taken, the RGB values of calibrated teeth color will be written into the property list file of the application. According to the RGB values of reference teeth color, the tongue image color could be automatically calibrated by teeth, which are included in tongue picture as shown in Figure 3(b). A user does not have to use any gray card in the following tongue picture taking.

To perform color calibration by teeth, we have implemented following teeth detection algorithm in our application. The recognition of teeth algorithm is based on the brightness formula (Brightness = 0.229R + 0.587G + 0.114B). In the program, when the current pixel's brightness value is less than the specific brightness threshold value (b0), it will be marked as blue (Figure 4). Then the system changes b0 from 50 to 200 and marks under-the-threshold pixels blue, until two full horizontal runs of blue pixels in the upper and lower half of detection rectangle. The last b0 value is used to separate teeth area from the background.

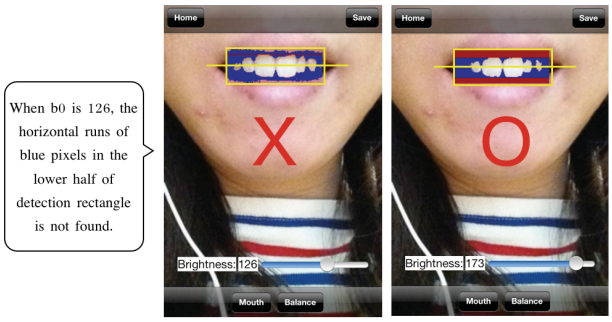


Figure 4. The example of teeth recognition process

3.2 Tongue Color Extraction and Separation

From acquired tongue images, our application tries to identify two major parts of a tongue, coating and body, because healthy color for each part is different. Coating and body parts can be separated by their color, as they have slightly different colors.

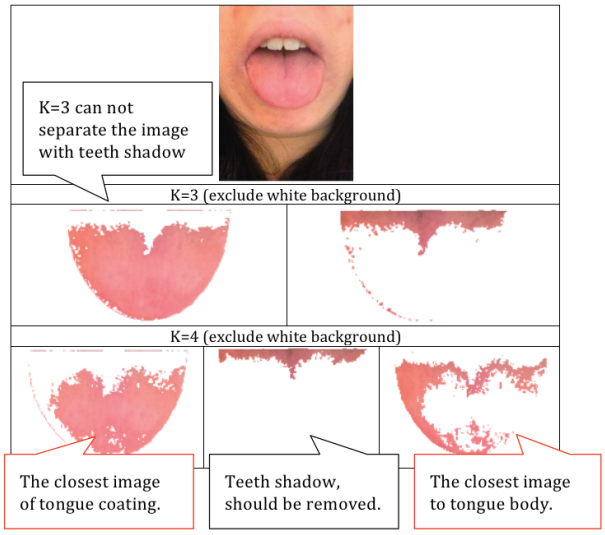


Figure 5. The optimal choice of tongue coating and body

The color separation of tongue coating and body uses K-means algorithm. K-means is one of the simplest learning algorithms that solve the well-known clustering problem. It separates data into set of k mutually excessive groups. By iterative such partitioning, K-means minimizes the sum of distance from each data to its clusters. First, our system crops tongue area inside the tongue guideline that is shown in the Fig. 3(b), and fills other background part in white (RGB=255). Second, it clusters pixels into 3 (k=3) and 4 (k=4) groups. In the 3 (k=3) groups clustering, we expected to separate pixels into tongue coating, body, and background (white color). Some tongue picture has teeth shadow in the upper part, and 4 (k=4) group clustering is appropriate for these images. Thus, in the third step, our system compares all the five tongue images processed by k=3, k=4, and chooses the closest image

of tongue coating or body, as shown in Figure 5. In this example, there is a pixel cluster at the upper part of the tongue, and this is considered to be a teeth shadow. As a result, k=4 clustering is preferable to this tongue picture. Another issue in the tongue clustering is that K-means algorithm is sensitive in initial starting points. Ordinary K-means method generates initial cluster randomly. When random initial starting points close to the final solution, K-means has high possibility to find out the stable cluster center. Otherwise, it will lead to incorrect clustering results. In order to avoid the incorrect and unstable results, we do not chose the initial points randomly, but chose them based on the following assumption: the two parts has different brightness.

$$Y = 0.299R + 0.587G + 0.114B \quad (2)$$

Therefore the initial starting points are chosen by brightness value in our system. A brightness value defined by Formula (2) is assigned to each pixel. Then one threshold is chosen to equally divide into two groups when k is 3, and two thresholds is chosen to divide into three groups when k is 4. Finally, we can get the unique and stable tongue coating and body images as expected as show in Figure 6.

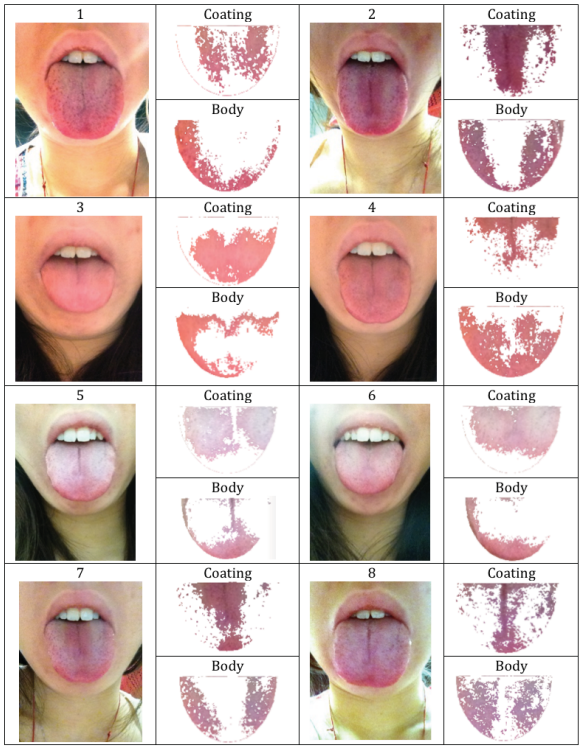


Figure 6. Samples of separated tongue body and coating

3.3 Personal health condition graph

We are now developing personal health management function by using the tongue color. By this function, users can keep track of their health condition by recording the color of tongue coating and body on smartphone (Figure 7). When the line graph is smooth and the tongue body and coating color is near to the pink and light white, respectively, that indicates you are healthy; Otherwise, it indicates that there's probably something wrong with your body and you are suggested to ask for more advice from experienced doctors.

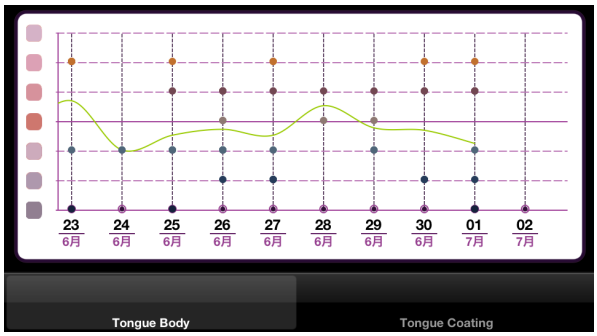


Figure 7. The tongue color graph reflecting health

4. Conclusions

We have developed the image processing function for tongue diagnosis application for smartphones named TongueDx. On this system, the tongue color calibration by teeth is proposed as solution to color error affected by surrounding light. K-means algorithm is used to separate tongue coating and body.. Although further improvement is required in the color calibration and tongue coating and body clustering, we believe that the tongue diagnosis on smartphone will get users new experience on health diagnosis.

References

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