TongueDx: A Tongue Diagnosis for Health Care on Smartphones

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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, our system uses tongue diagnosis techniques originated from Traditional Chinese Medicine (TCM) theories. In the theories, tongue symptom as one of the important diagnosing indicators can tell the health of human body. To avoid color error affected by surrounding light, a tongue color calibration by using teeth color is proposed to adjust white balance of the tongue picture. 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 can know their health conditions timely. We have evaluated the TongueDx performance for one month in the preliminary user experience.

Author Keywords
Tongue diagnosis, Traditional Chinese Medicine, Health management, Smartphones

ACM Classification Keywords
J.3. Life and Medical Sciences: Health

INTRODUCTION
Recently health check applications based on medical health diagnosing technique running on smartphones have become popular. We discover 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 [1]. According to TCM, practitioners conclude one's health condition by examining his tongue color, coating (normally white fur) and body shapes as well as other features appeared on the tongue.

TONGUEDX
We have developed a tongue diagnosis application on smartphones named TongueDx (Fig. 1). In our system, we try to find out solutions to calibrate tongue color and separately identify tongue coating and body, which are applicable to smartphones. Therefore, we carry out white balance adjustment as color calibration via referring the teeth color to resolve possible deviation caused by arbitrary lighting conditions. And K-means algorithm is used to distinguish tongue coating from body and prevent the affect from teeth shadow.

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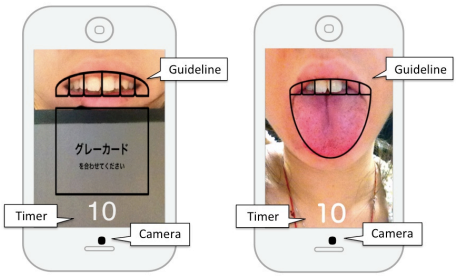

Figure 1. Illustration of our system. Prior to the use, gray card and teeth picture is taken once (left), and then, teeth and tongue pictures are taken everyday (right).

Tongue Color Calibration by Teeth
Sometimes, the color of photograph is deviated because the surrounding light has various color spectrums, and it affects 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 commonly used 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).

However, 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 is not convenient to keep in daily life. In this study, we propose to utilize user's teeth, instead of gray card, to calibrate the white balance of tongue pictures. This method is feasible because teeth color is not easily to be changed in ordinary situations, and their color is close to white.

To evaluate our method of using teeth color as a color reference, we carry out an experiment by comparing the white-balancing accuracy between teeth color and a gray card as calibration methods. According to the result, the handy calibration method by teeth is proved to be feasible. In order to adjust white balance by teeth in a photograph, we have developed following teeth recognition algorithm. Firstly, our program crops the teeth part rectangle from the picture. Secondly, it marks pixels with blue color when the brightness of the pixel is more than the specific threshold value (b_0).

We use the brightness formula ($Brightness = 0.229R + 0.587G + 0.114B$) here. It changes b_0 from 50 to 200, until more than two full horizontal runs of blue pixels are found in the teeth part rectangle. If the horizontal runs of bright pixels are found, our program considers that teeth are detected successfully, and uses these pixels for adjusting white balance. We asked 7 people for the teeth recognition test. Most of their teeth area are successfully detected except when the surrounding light is unusual or the picture is poorly taken.

Tongue Color Extraction and Separation

From acquired tongue images, our application tries to identify two major parts of tongue coating and body (Fig. 2), because healthy color for each part is differently defined. Coating and body parts can be separated by their color, as they have distinctly different colors. Although it is common that coating is brighter than body, there are exceptions depending on user's health. Thus, our system uses "user selection" for separated part to determine tongue coating and body once for the first time of use, and in the later operation, it chooses the closest color as coating or body automatically.

Xu et al. have identified coating and body area by their "splitting-merging" algorithm, which is utilized to separate two parts of tongue as two continuous areas by color similarity [2]. Nevertheless, we prefer to use K-means algorithm to identify the two areas by color, because we expect optimal separation is achieved by the established clustering method, and each area is not always continuous. Meanwhile, we find that some tongue pictures have teeth shadow in the upper part, and it can affect the accuracy of tongue parts separation. Therefore, our system clusters pixels into 4 ($k = 4$) groups to check the teeth shadow. In this clustering, we expect to differentiate pixels into tongue coating, body, teeth shadow and background (white color). Then it compares the pixels area of upper to the lower part. If the numbers of pixels in upper part is more than the lower part to the specific threshold value (set to 700), we cluster pixels into 4 ($k = 4$) groups. Otherwise, the teeth shadow is unlikely included, and 3 ($k = 3$) groups clustering is expected to differentiate pixels successfully into coating, body and background (white color).

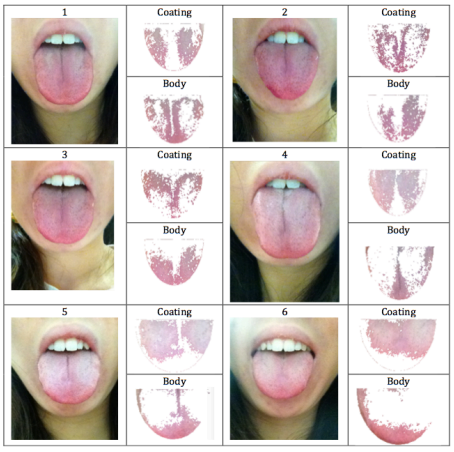

Figure 2. Separated tongue body and coating.

PERSONAL HEALTH CONDITION GRAPH

The daily-tongue-color-graph was designed for users to take their health development timely. Users can keep track of their health condition by recording the color of tongue coating and body on smartphones (Fig. 3). When the line graph is smooth and the tongue body and coating color is near to the pink and light white, respectively, it indicates the user is healthy; if the line fluctuates and the tongue color is far from pink, it is possible that there is something wrong with the user's body, and it is better to ask for more advice from experienced doctors.

PERFORMANCE EVALUATION

In the preliminary user experience, one of the authors (20s female) used the TongueDx application and write body condition diary for one month. Fig. 3 actually shows the real data about her tongue color graph. It shows in one day the tongue body color significantly changed from *Pale* to *Purple* and appeared unstable. In her health condition diary, it referred that her digestive system was in trouble in that day because of overeating and over stress, and felt uncomfortable after that day. Therefore, we think our tongue color graph could give users and doctors some useful reference value in physical health inspection. As further feasibility test, we are asking 20s collage students to use the TongueDx application.

Figure 3. The tongue body (left) and coating (right) color graph reflecting health condition.

CONCLUSION

In this paper, TongueDx - a tongue diagnosis application on smartphones - is developed for users to diagnose their own health condition by taking pictures of their tongue. We are planning to carry out further user study, to improve the accuracy of tongue diagnosis, and to collaborate with TCM researchers.

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