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.

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 in a photograph. 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 \((\text{Brightness} = 0.229R + 0.587G + 0.114B)\) 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).