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Original article

Improving color and shape repeatability of tongue images for diagnosis by using feedback gridlines

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Abstract

Introduction: In traditional East Asian medicine, the color and shape features of a tongue reflect the health of the body. The repeatability of computerized tongue diagnosis is highly dependent on the image acquisition process. In this study, a method for providing frontal and profile feedback gridlines for the tongue image acquisition process was proposed and the resulting color and shape repeatability was assessed.
Methods: Eight subjects were recruited and 120 images were acquired. For each subject, 15 tongue images were acquired with three different gridline types, including no gridline (Group I), frontal gridlines (Group II), and frontal and profile gridlines (Group III) in a pseudo-randomized order. To evaluate repeatability, intra-class correlation coefficients (ICCs) were calculated from the mean values and histogram fitting parameters for Commission Internationale de l'Éclairage $L^*a^*b^*$, profile angles, and tongue area ratios (TARs) of four edge regions, respectively.
Results: The ICCs for all the color features in Group I were lower as compared with those in Group II and additionally, the ICCs for all the color features in Group III were larger compared with those in Group II. The ICCs of the shape features were lower than those of the color features. The ICCs of TARs in Group I were lower than those in Groups II and III. From the tip to the root of the tongue region, the ICCs of mean luminance tended to decrease in all the groups, but the intensity of the decline in Group III was lower than those in Group I and Group II.
Conclusions: The proposed tongue image acquisition process with frontal and profile gridlines improved the repeatability of color and shape features and potentially improve diagnostic accuracy of computerized tongue diagnosis.

Keywords: Color and shape repeatability; Feedback gridlines; Tongue image; Tongue diagnosis; Methodology; Measurement

Introduction

The color and shape features of a tongue reflect the physiological and clinico-pathological condition of the body in traditional East Asian medicine (TEAM) and each part of the tongue is related to corresponding internal organs [1]. Recently, various computerized tongue diagnosis systems (CTDSs) have been developed for accurate diagnosis based on quantitative and objective tongue features. In a CTDS, a patient's tongue image is captured via a digital camera, and a tongue region is segmented from the image. The quantitative features of the tongue, such as color values in regions of interest, textural parameters, and geometric information, are calculated from the tongue image and are used for the patient diagnosis. For instance, with thickness of a tongue coating, the patient's condition is classified into presence or absence of pathogenic qi by using the color features of the tongue image [2,3].

Furthermore, previous research has found that the features of the tongue image can be used for an estimation of specific diseases. The color distributions of the tongue in appendicitis and pancreatitis have appeared different from those in normal subjects, and a tongue deviation angle has been shown to be useful for a stroke diagnosis [4,5].

The feature values of color and shape in the tongue image, however, are highly dependent on the image acquisition process. In particular, different tongue positions can have a strong influence on the color and shape information in the tongue imaging owing to differences in the curvature of the tongue and the angle

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of light incidence. A color correction method for the tongue image was developed based on a color checker and used in the various CTDSs to correct the distortion of illuminators and cameras [6], but it is still difficult to correct the color and shape distortion caused from the tongue posture. Establishing the position of the tongue is an important condition for the repeatability of the tongue diagnosis.

Owing to this problem, several CTDSs have provided the contact area of a cheekbone or chin to fix the location of the head during the tongue image acquisition process [7,8]. However, it is still difficult to constantly control the tongue position even if the head is fixed. In this study, a method for providing frontal and profile feedback gridlines for the tongue image acquisition process was proposed and the repeatability of the color and shape in the images of the tongue was assessed.

Materials and methods

Image acquisition device for feedback gridlines

To provide frontal and profile feedback gridlines to subjects, two digital cameras and an LCD monitor were used. A three-charge-coupled device (CCD) digital camera with six-megapixels was located in front of the tongue and a Bayer digital camera was located at the right side of the tongue as shown in Fig. 1(a).

The LCD monitor was located in front of a subject's eyes to allow the subject to observe the tongue position and prevent it from changing. In order to minimize the distortion from uncontrolled light, the images were acquired in a semi-closed box. A high-brightness white LED ring array was used as a main illuminator for frontal image acquisition and two white LEDs were used as sub-illuminators for profile image acquisition. The frontal and profile images were acquired within an interval of 20 ms and the brightness of the main illuminator was attenuated during the profile image acquisition to avoid overexposure.

The graphical user interface with gridlines consisted of a frontal preview image and a profile preview image as shown in Fig. 1(b). Because the length and the width of the tongue are different according to each subject, the gridlines consist of five horizontal and five vertical lines, which help the subject judge their tongue position. The gridlines in the frontal preview were used for adjusting the position of the tongue and the red vertical grid in the profile preview was used for adjusting the angle and the posture of the tongue as a subject stuck out their tongue.

Experimental procedures

Eight healthy subjects (mean age: 30.3 ± 3 years) volunteered to participate in this study. Before the experiment, all subjects were allowed to practice the procedures for using the gridlines.

The procedure for guiding the tongue in front consisted of three steps. In the first step, a subject was required to move the locations of the corners of their mouth in line with the top horizontal gridline in the preview image. In the second and the third step, the subject was required to open their mouth while keeping the location of their head steady and sticking out their tongue onto the bottom horizontal gridline in the preview image.

When using both frontal and profile gridlines, the subject was required to change the profile angle of their tongue or head in order to relocate their tongue between the two red vertical gridlines in the profile preview image, following the frontal gridline procedure.

For each subject, fifteen tongue images were acquired with three different gridline types including no gridline (Group I), frontal gridlines (Group II), and frontal and profile gridlines (Group III). Five images were acquired for each gridline type and all the acquisition processes were performed in a pseudo-randomized order.

Image processing

To extract features from images for statistical analysis, image processing was performed for the 120 images which had been acquired. From the frontal image, a tongue region was segmented with the combining polar edge method [9] and the gradient vector flow snake technique [10]. The polar edge points were detected by using the external energy of the snake energy field instead of color information. Following the snake processing, manual validation was performed by using a contour modification tool that provides a graphical user interface and an active contour function. The contour modification tool automatically modified the manual validation result by using the external energy of the snake algorithm, so that the manual operator cannot modify the result. The manual validation played a role in modifications of large misalignment of segmented contours.

Pixel values in the RGB color space were converted to the Commission Internationale de l'Éclairage (CIE) $L^*a^*b^*$ space, and high-luminance regions, which were caused by light reflection from saliva, were removed from the tongue region. The a^* value from the CIE $L^*a^*b^*$ color space is widely used for the chroma feature of the tongue diagnosis since the a^* value is appropriate for representing the red intensity [11,12].

For evaluating the color, color features were extracted from the entire tongue as well as from separate tongue regions because the color of each part of the tongue represents the state of corresponding internal organs [1]. The mean values of L^* and a^* were calculated for the entire tongue and for the six separate regions, as shown in Fig. 2(a). The histograms of L^* and a^* for the entire tongue were computed as features for the color distribution. In order to evaluate the change in the color features in the vertical direction, mean values of L^* and a^* were calculated from the 10 separate regions as shown in Fig. 2(b).

For evaluating the shape, each tongue area ratio (TAR), which is the ratio of the tongue area to the area of the rectangular grid (EA_i), of the four regions including the edge was computed, as shown in Fig. 2(c), where i = A, B, C, and D. The TAR is the ratio of the pixel count in the tongue region to the pixel count of the corresponding region for each of the four regions. A horizontal center distance (HCD) was obtained from the difference between the horizontal center location of the tongue and the center point of the image, as shown in Fig. 2(d).