Segmentation of Sublingual Veins from Near Infrared Sublingual Images

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Abstract—**Characteristics of tongue pose the most important information for tongue diagnosis. So far, extensive studies have been made on extracting tongue surface features. Meanwhile, the sublingual vein diagnosis, one important part of tongue diagnosis, has received increasing attention. In this paper, a novel image acquisition device specially designed for capturing sublingual vein images is introduced. Different from existing tongue image acquisition devices, monochrome industrial CCD with enhanced near infrared sensitivity is used under near infrared light source. Corresponding segmentation method of sublingual veins for the captured near infrared sublingual images is proposed subsequently. Experimental results reveal that the proposed method did indeed segment the sublingual veins from the near infrared sublingual images with an acceptable degree of accuracy.**

I. Introduction

TONGUE diagnosis, which inspects tongue to examine the physiological function and pathological changes of human body, is one of the most important diagnostic methods in the Traditional Chinese Medicine (TCM). The advantage of tongue diagnosis is its simplicity and immediacy in that the examination of tongue can instantly clarify the main pathological process [1], [2]. In recent years, research on the feature extraction of tongue surface has achieved considerable progress [3]. Meanwhile, the sublingual vein diagnosis (SVD), which is also one important part of tongue diagnosis, has received increasing attention. Tongue diagnosis argued that, inspection of sublingual veins can provide valuable insights into the healthy condition of humans. In certain circumstance, this diagnostic method behaves even more effectively than that of western medicine. For example, in western medicine, the Portal Hypertension Syndrome (PHS), exacerbation of which will consequentially devitalize the sufferer's life, is always diagnosed by applying several invasive and painful diagnostic methods to potential PHS patients, and the fear of pangs always scares away the patients and finally they lose the optimal remedial opportunity. But, in TCM, examination of sublingual veins can provide the primary diagnostic evidences during diagnosing PHS with high diagnostic accuracy [4], [5], especially that the diagnostic process is no pain and no injury. Therefore, it is undoubtedly of significance to popularize this diagnostic theory all over the world. However, the subjective characteristic of TCM impedes this objective in that SVD is usually based on detailed visual discrimination, which mainly depends on the subjective analysis of the examiners. Therefore, it is necessary to establish a quantitative and objective inspection system for SVD.

In early researches, experiments are all implemented on sublingual images acquired by ordinary camera under visible light source [6]-[9]. Thus, only the color information of sublingual veins from the sublingual images was considered. Among them, Chiu et al. [8] tried to develop a computerized inspection system in order to quantitatively extract the chromatic and geometrical properties of sublingual veins. Specific threshold is appointed to extract the sublingual veins, and then quantitative features of twenty four subjects, which were grouped into three categories based on the severity of blood stasis, were recomposed to serve as the parameters for classifying them into each category. Yan et al. [9] focus on establishing a feature quantification framework for inspecting sublingual veins of healthy humans from the TCM point of view. At first, they adaptively segmented the sublingual veins by considering the statistical characteristics of the colors of sublingual veins from five hundreds sublingual images of healthy humans. And then, the chromatic and breadth features of sublingual veins with diagnostic significance were quantified.

Generally speaking, researches mentioned above acquired sublingual images by using a color 3CCD camera under a standard visible light source. In fact, sublingual veins are covered by sublingual mucosa which lacks of elasticity. Due to different degree of varicosity, both the thickness and transparence of sublingual mucosa may change. Thus, the color of sublingual veins presenting through sublingual mucosa also changes, leading to that in some sublingual images the sublingual veins are clear, but blurry in others and the contours of sublingual veins are difficult to be figured out.

Therefore, in order to acquire high-quality sublingual images that retain more invariable information of sublingual veins, proper light sources for capturing the images need to be selected. In this paper, a newly-invented sublingual image acquisition device based on near infrared [10] is introduced. The corresponding segmentation method of sublingual veins

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is proposed subsequently.

II. The Near Infrared Sublingual Images

Tongue diagnosis argued that, the sublingual veins can faithfully reflect the evolution of diseases. The sublingual veins emerge when one roll up tongue. Sublingual veins of patients suffering from special diseases seem to be cirsoid under the sublingual mucosa, and both the length and breadth of them are markedly increased.

Near infrared can penetrate body tissues in different depth with different wavelength. Besides, deoxidized haemoglobin, the main component of blood, has strong absorbability toward near infrared. This property results in more absorption of the irradiating light by the veins than the surrounding tissue, when using near infrared as the light source.

Based on the principle mentioned above, a novel image acquisition device specially designed for capturing sublingual veins is invented [10]. Different from existing tongue image acquisition device, monochrome industrial CCD with enhanced near infrared sensitivity is used under near infrared light source. When projecting near infrared onto the dorsum of tongue, the reflected near infrared signal with different light intensity, corresponding to vein regions and non-vein-regions ascribing to different absorbability of near infrared, will be received by the device and immediately imaging on the display. The captured area of the sublingual images limits to the region compassed by the lips, upper and lower teeth, which not only maintains the entire sublingual region of the dorsum of tongue, but also keeps the consistency of the human perception to the actual location of sublingual veins. In the captured near infrared sublingual images, the sublingual vein regions are much darker than the surrounding tongue proper. An acquired sample sublingual image is illustrated in Fig. 1.

Through inspecting the captrued near infrared sublingual images we find that, the light-reflecting-points are inevitably formed due to the saliva. Besides, when near infrared radiating the dorsum of tongue, the upper and lower teeth may block off some benches of near infrared and lead to the shadow forming on the edge of the dorsum of tongue. In order to elimimate the interference of these two situations, the designed segmentation method of sublingual veins is composed of following four procedures: background removal, light-reflecting-points removal, dynamic thresholding for binarization, and extraction of sublingual vein regions.

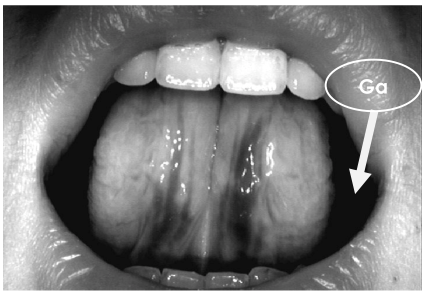


Fig. 1. A sample image acquired by using the introduced sublingual image acquisition device

III. Segmentation of Sublingual Veins

A. Background Removal

When capturing, patients need to open their mouths as broad as possible and then roll up the tongue, this gesture may inevitably create some gaps between the lips and the edge of tongue. When near infrared irradiating the dorsum of tongue, rays that irradiate the gaps rarely reflect back and received by the acquisition device, which may lead to the darkness on that region of the captured sublingual image, as shown in Fig. 1. Thus, the tongue body is compassed by a black annular region in irregular shape formed by the gaps. This region can roughly isolate the tongue body from other parts of the sublingual image. The gap here is named as the “Isolation Band”, which can be utilized as regional markers to label the tongue body.

Fig. 2 illustrates the detailed process of background removal. The morphological gradient of the initial sublingual image is computed first. And then, watershed segmentation is applied to the gradient image and regions characterized by small variations in gray levels will be segmented out and labeled by different colors, as shown in Fig. 2(b). It is evident that the tongue body is isolated by the “Isolation Band” from other parts of the image. To obtain the edge information of Fig. 2(b), the horizontal gradient is computed and illustrated in Fig. 2(c). Morphological filtering is then applied to Fig. 2(c) to acquire the binary image that effectively retains the profile of the “Isolation Band” for subsequent implementations, as shown in Fig. 2(d).

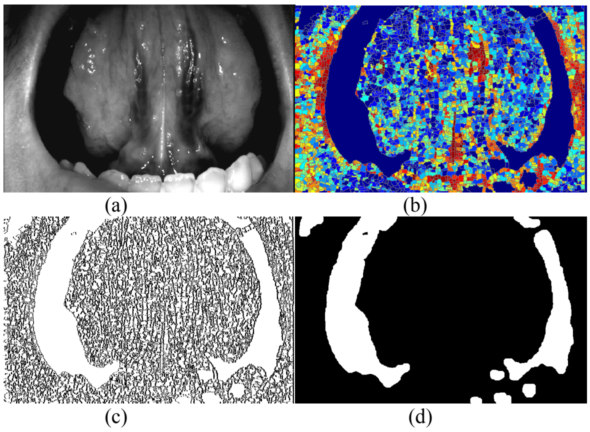


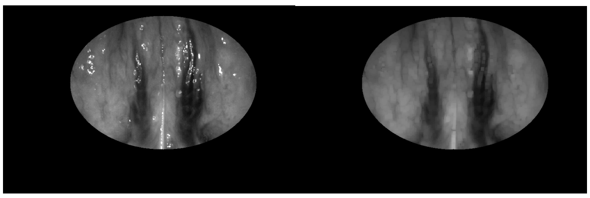
Fig. 2. Background removal: (a) original near infrared sublingual image, (b) result image after applying watershed algorithm, (c) the horizontal gradient image of (b), (d) binary image with “Isolation

Because the primary objective of the segmentation algorithm is to find the contour of sublingual veins, it is sufficient to extract the region that contains the sublingual veins from the region compassed by the “Isolation Band”, namely the tongue body. Through observing large amount of sublingual images, we find that the contour of the dorsum of tongue is approximately elliptic. Furthermore, sublingual veins locate on the dorsum of tongue with certainty. Based on these concepts, the largest elliptical region existing within the "Isolation Band" is considered, and the sublingual veins must be locating inside this region. The selection of the elliptical region may be summarized by the following procedures: firstly, the geometrical centre of the "Isolation Band" is selected as the centre of the elliptical region; and then, the widest line passing through the centre point obtained by previous procedure and locating within the "Isolation Band" is considered to be the horizontal axes; lastly, the vertical axes is determined by the line passing the elliptical centre, and bidirectional growing from the centre point along the direction perpendicular to the horizontal axes until the area of the compassed white region, in Fig. 2(d), within current ellipse reaches given threshold.

By implementing previous procedures, the largest ellipse contains the sublingual veins is acquired. The intermediate image only containing the dorsum of tongue after background removal is illustrated in Fig. 3(a), which contains the whole sublingual vein regions.

B. Light-reflecting-points Removal

The light-reflecting-points are inevitably formed because of the reflection of the saliva. When light reflection happens above the sublingual vein regions, the formed light-reflecting-points may directly influence the segmentation accuracy of sublingual veins. Experimental observations reveal that the intensity value of the light-reflecting-points mainly fluctuates around 250. Ascribing to the invariant illumination condition, some threshold can be set to eliminate these points. In order to keep and restore the useful information of sublingual vein regions, the intensity values of the detected light-reflecting-points are substituted by the minimum intensity values of their 8-neighbourhood. Whereafter, morphological opening operation is applied to remove the highlight points, whose 8-neighbourhood are all light-reflecting-points. Result image of light-reflecting-points removal is illustrated in Fig. 3(b). Adaptive histogram equalization is then implemented to Fig. 3(b) to further enhance the contrast between sublingual vein regions and the surrounding tongue proper, as shown in Fig. 4(a).



(a) (b)

Fig. 3. Light-reflecting-points removal: (a) intermediate image only contains the dorsum of tongue, (b) image after light-reflecting-points removal

C. Dynamic Thresholding for Binarization

To further approximate the actual sublingual vein regions and guarantee the exact segmentation of sublingual veins, proper binarization method should be selected. In this paper, dynamic thresholding technique is applied to threshold the image obtained after previous procedures. Firstly, initial estimate for threshold T is obtained by applying statistical treatment to the histogram of the region of interest. And then, we segment the image by using T. This will form two groups of pixels: G_1, consisting of pixels with intensity values $> T$, and G_2, consisting of pixels with intensity values $\leq T$. Compute the average intensity values μ_1 and μ_2 for the pixels in groups G_1 and G_2. Then, the Euclidean distances between pixels inside each group and μ_1, μ_2 are computed by using (1). The pixels will be labeled black (0) or white (255) according to the calculated Euclidean distances by using (2).

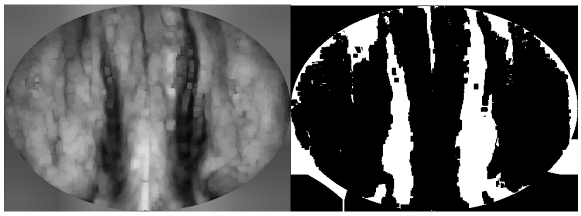
$$d_i = \left| f(x,y) - \overline{\mu_i} \right| \quad i = 1,2 \qquad (1)$$

$$f(x,y) = \begin{cases} 255 & d_1 < d_2 \\ 0 & d_1 \geq d_2 \end{cases} \qquad (2)$$

Fig. 4(b) illustrates the results acquired by applying the proposed dynamic thresholding technique. It is obvious that this technique not only keeps the whole area of the sublingual vein regions, but it also eliminates the interference of useless information, namely, the surrounding tongue proper regions.

D. Extraction of Sublingual Vein Regions

The segmentation algorithm of sublingual veins proposed in this paper provides a framework for incorporating knowledge-based constraints in the segmentation process, and the constraints utilized here is the intensity information of the initial near infrared sublingual image. The result binary image after thresholding keeps not only the real sublingual veins regions, but also the false one, namely the white regions along the edge of the elliptical region as shown in Fig. 4(b). To eliminate the false sublingual vein regions, the intensity information is considered. Due to the characteristic of the near infrared sublingual image as mentioned in previous paragraphs, the intensity value of sublingual vein region is small comparing to the surrounding tongue proper, nearly black. Therefore, the average intensity values of given regions, corresponding to each connected components of Fig. 4(b), in the initial near infrared sublingual image is computed. The regions, whose corresponding average intensity values are higher than the average intensity value of the whole elliptical



(a) (b)

Fig. 4. Binarization: (a) image after applying adaptive histogram equalization to Fig. 3(b), (b) binary image obtained by using dynamic thresholding.

region extracted in background removal procedure, will be

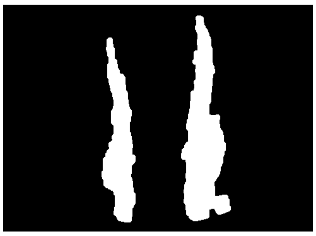


Fig. 5. Refined binary image of potential sublingual vein regions.

ignored in the subsequent processing. Fig. 5 illustrates the potential sublingual vein regions remained.

Then, region growing is implemented to find the boundaries of sublingual veins from the potential sublingual vein regions. As the principle of the image acquisition device we mentioned, the sublingual vein regions in the acquired sublingual image looks darker than the surrounding tongue proper regions, thus, we select the darkest pixels inside each potential sublingual vein region as the seed points for region growing. Here, two criteria are considered for a pixel to be annexed to a vein region: (1) the absolute gray-level difference between the pixel and the seed point has to be less than given value, which is adaptively growing from 0. Iteratively increase this value until the size of the region being growing is comparative to the region under consideration. (2) To be included in some region, the pixel has to be 8-connected to at least one pixel of that region, and if a pixel is found to be connected to more than one region, these regions should be merged. Superimposing the boundaries of the extracted sublingual vein regions on the original near infrared sublingual image reveals that the region growing procedure did indeed segment the sublingual veins with an acceptable degree of accuracy, as illustrated in Fig. 6.

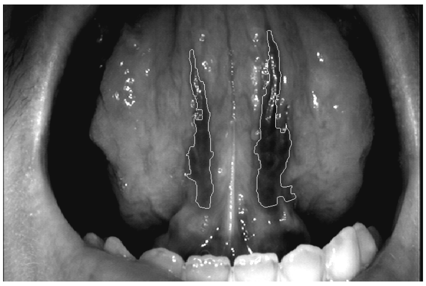


Fig. 6. The final result image by superimposing the boundaries of the extracted sublingual vein regions on the original near infrared sublingual image.

IV. Experimental Results

The near infrared sublingual images utilized in this paper are all captured with the introduced image acquisition device [10]. The subjects involved in this paper are the inpatients from Harbin 211 hospital and the healthy student volunteers from Harbin Institute of Technology. The proposed processing procedures are applied to 100 sublingual images of inpatients and 28 that of healthy volunteers. 105 images got sublingual vein contours with diagnostic significance authorized by TCM doctors, and the average correct segmentation rate is up to 82.0%. Some experimental result images obtained by implementing the proposed sublingual vein segmentation method are illustrated in Fig. 7.

Through analyzing the experimental results we find that, the main factor that resulted in inferior segmentation was the information loss of certain sublingual images, which were captured from some subjects that cannot roll up their tongues or make their sublingual regions get captured, and these incomplete images finally influence the segmentation results.

V. Conclusion

In this paper, we introduce a novel image acquisition device specially designed for capturing sublingual images, which can provide insight observations of sublingual veins to assist computerizing the sublingual vein diagnosis, one important part of tongue diagnosis. Furthermore, the corresponding segmentation method of sublingual veins in the captured near infrared sublingual images is proposed, which is composed of four procedures□ background removal, light-reflecting-points removal, dynamic thresholding for binarization, and extraction of sublingual vein regions, respectively. Experimental results reveal that, the proposed segmentation method for near infrared sublingual image did indeed segment the sublingual veins with an acceptable degree of accuracy.

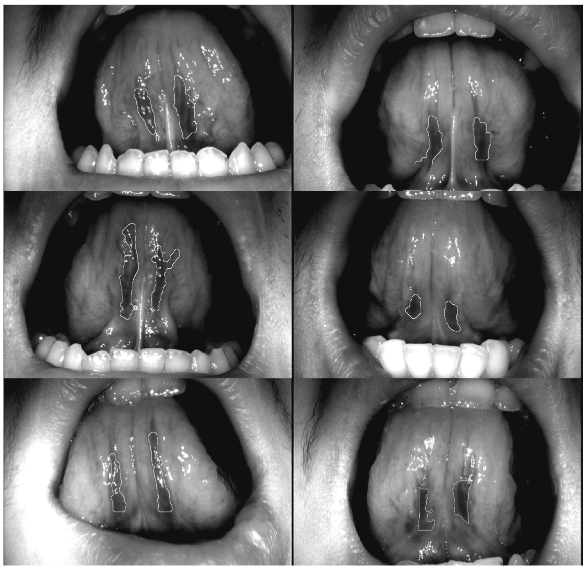


Fig. 7. Result images obtained by implementing the proposed sublingual vein segmentation method to corresponding near infrared sublingual images.

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