An Algorithm for Extraction of Near Infrared Sublingual Veins

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Abstract

Sublingual vein is one important diagnostic measurement in Tongue Diagnosis. Segmentation method of sublingual veins from the near infrared sublingual images is proposed in this paper. According to the characteristic of the captured near infrared sublingual images, the radial projection method based on watershed algorithm is firstly applied to acquire the entire contour of the sublingual region, and then dynamic thresholding is utilized to complete the binarization of the obtained effective sublingual region, and further confirm the candidate sublingual veins regions by considering the intensity feature of near infrared sublingual vein image. Finally, region growing is iteratively performed, which is restricted by original intensity feature of the near infrared sublingual image, to trace the contour of sublingual veins. Experimental results reveal that, the proposed methods did effectively isolate the sublingual veins and the surrounding tongue proper, and precisely trace the boundary of the sublingual veins.

1. 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. In recent years, research on the feature extraction of tongue surface has achieved considerable progress [1-3]. But the sublingual vein diagnosis (SVD), which is also one important part of tongue diagnosis [4], is rarely referred. Inspection of sublingual veins can provide valuable insights into the healthy condition of humans. Especially, according to the theory of Tongue Diagnosis, the shape and breadth of sublingual vein is the golden standard for diagnosing Portal Hypertension and Blood Stasis [5]. However, 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 images acquired by ordinary camera under visible light source, thus, only the color information from the sublingual veins was considered. However, under normal conditions, the appearances of sublingual veins of both healthy humans and patients, which are traveling naturally with or without meandering or exhibiting any varicosity, and covered by lingual mucosa, usually show little difference beyond the tongue proper. Therefore, a new sublingual vein image acquisition device that can acquire the features of sublingual veins more accurately is badly needed. In this paper, a new sublingual image acquisition device [6] is applied to capture the sublingual veins, and the corresponding segmentation method of sublingual veins is proposed.

2. Segmentation of tongue body

When capturing image, there are gaps between tongue and the lips. Only a little infrared light is reflected back when irradiating the gaps, which makes the corresponding regions look dark in the captured sublingual image, as shown in Figure 1(a). The tongue body is compassed by the gaps formed by black irregular annular regions. The tongue body can be roughly isolated from other parts of images by using this region, which is named “Isolation Band” (IB) here.

Morphological gradient image of the original sublingual image is firstly calculated, as shown in Figure 1(b). Watershed algorithm is then applied to Figure 1(b) to describe pixels with similar gray level values using same colors, as shown in Figure 1(c). It is clear that, the tongue body is compassed by the unclosed IB. Edges of IB can be extracted from the

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gradient image of Figure 1(c). And then, morphological filtering is applied to obtain the binary image which can effectively extract IB region, as shown in Figure 1(d).

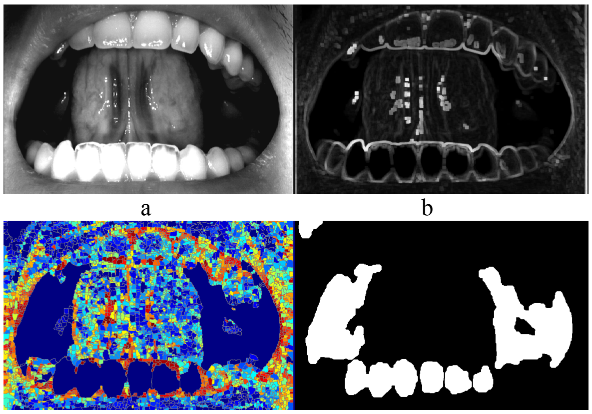

Figure 1. Acquiring the Isolation Band. (a) Near infrared sublingual vein image; (b) morphological gradient image of (a); (c) after applying watershed algorithm to (b); (d) binary image of "Isolation Band" after morphological filtering.

The sublingual region is mainly located in the middle of the captured sublingual image; therefore, the centre of the image must be inside the sublingual region. Choosing this point as the centre of some circle, which emitting radial lines with certain angle to each direction. When encountering the IB region, the nearest intersection point of the radial line and the IB is considered to be the candidate edge point determined by the radial line emitted from current angle, as shown in Figure 2(a). The distance between the centre and the candidate edge point is then denoted as the "radius" of the corresponding edge point. When the radius of the candidate edge point less than the average value of the radii of all candidate edge points, then this candidate edge point is considered to be a real edge point belong to the sublingual region; otherwise a fake one. Painting the real edge points green and fake ones red, as shown in Figure2(b). Curve fitting is then applied with the obtained real edge points to form the contour of the sublingual region, as shown in Figure 2(c). Superimposing this contour on the initial near infrared sublingual image is shown in Figure 2(d). Furthermore, morphological filtering can be applied to the acquired sublingual region to eliminate the influence of shadow.

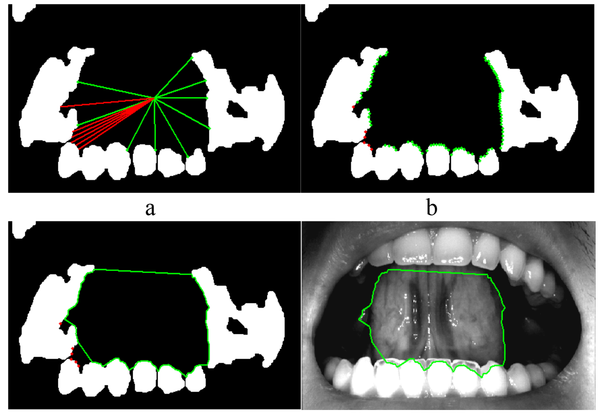

Figure 2. Segmentation of sublingual region. (a) Schematic Diagram of Radial projection; (b) edge points and fake edge points of the contour of sublingual region; (c) fitting contour with candidate edge points; (d) final contour of sublingual region.

3. Removal of light-reflecting points

The light-reflecting points in the potential sublingual vein image are evident. These points are formed because of the reflection of the saliva secreted by the salivary gland. When light reflection happened above the candidate sublingual vein regions may directly influence the segmentation of sublingual vein. Based on experimental observations, the intensity value of the light-reflecting points mainly fluctuate around 250, due to the invariance illlustration condition, some threshold can be set based on experiments to eliminate them. In order to keep and restore the useful information of sublingual veins region, 8-neighbourhood minimum value is utilized to substitue the intensity value of the detected light-reflecting region. Whereafter, morphological opening operation is applied to entirely eliminate the highlight points, whose 8-neighbourhood are all light-reflecting points.

Figure 3(a) is the result image obtained by implementing previous procedure to another near infrared subligual image. Morphological filtering is then applied to eliminate the interference of shadow, as shown in Figure 3(b). Result of light-reflecting points removal is shown in Figure 3(d). Adaptive histogram equalization is finally implemented to further enhance the contrast between the sublingual veins regions and the surrounding tongue proper, as shown in Figure 4 (a).

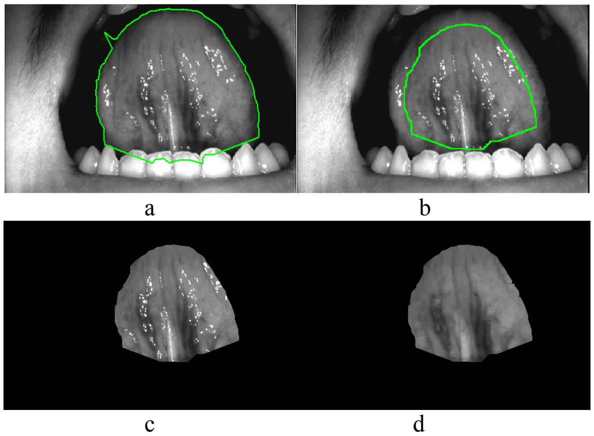

Figure 3. Light-reflecting points removal. (a) Near infrared sublingual vein image; (b) contour of sublingual region obtained by radial projection method; (c) sublingual region remained after morphological filtering; (d) sublingual image after light-reflecting points removal.

4. Extraction of the candidate sublingual veins regions

To further approximate the potential sublingual vein region and guarantee the exact segmentation of sublingual veins, proper binarization method should be selected to obtain the candidate sublingual vein regions. In this paper, Dynamic Thresholding is applied to threshold the image obtained after previous procedures. Firstly, initial estimate for threshold *T* is obtained by applying statistical treatment to histogram of region of interest. And then segment the image using T. This will produce two groups of pixels: G_1 consisting of all pixels with gray level values > T and G_2 consisting of pixels with values ≤ T. Compute the average gray level values μ_1 and μ_2 for the pixels in regions G_1 and G_2. Then, the Euclidean distance between pixels inside each region and μ_1, μ_2 is computed using formula (1). The pixels will be labeled black (0) or white (255) when satisfying formula (2).

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

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

Figure 4(b) illustrates the results acquired by applying proposed dynamic thresholding technique. It is clearly that the proposed dynamic thresholding technique not only keeps the whole compass of the sublingual veins regions, but it also eliminates the interference of useless information, namely, the region of surrounding tongue proper.

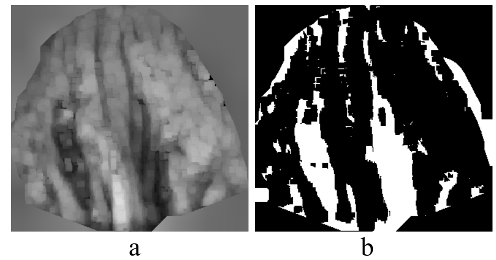

Figure 4. Binarization of the candidate sublingual veins regions. (a) Image after applying adaptive histogram equalization; (b) Binary image obtained by using dynamic thresholding technique.

5. Segmentation of sublingual veins

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 candidates sublingual veins regions, but also the false one, as shown in Figure 4(b). To eliminate the false sublingual veins region, the intensity information is considered. Due to the characteristic of the near infrared sublingual image, the gray level of sublingual vein region is low compare to the surrounding tongue proper, nearly black. Therefore, the average intensity of the corresponding region of each connected components in the binary image mapped to the initial near infrared sublingual image is computed, and the regions, whose corresponding average intensity higher than the average intensity of the sublingual region extracted during previous procedures, will be ignored in the subsequent processing.

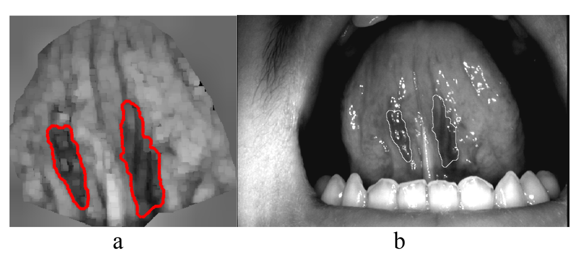

Figure 5. Segmentation result. (a) Superimposing the boundaries of sublingual veins regions to sublingual region; (b) superimposing the boundaries of sublingual veins regions to initial near infrared sublingual image.

Region growing is implemented to finding the boundaries of sublingual veins from the candidate sublingual veins regions. The darkest pixels inside each candidate sublingual veins region are selected as the seed points due to the features of the near infrared sublingual image. Here, two criteria are considered for a pixel to be annexed to a region: (1) the absolute gray-level difference between any pixel and the seed had to be less than given value, which is adaptively growing from 0. Iteratively increasing this value until the size of the region being grown is comparative to the region under consideration. (2) To be included in one of the regions, the pixel had to be 8-connected to at least one pixel in that region, and if a pixel was found to be connected to more than one region, the regions were merged; the segmentation result is shown in Figure 5.

6. Experimental results

The near infrared sublingual images utilized in this paper are all captured with special image acquisition device [6], which is composed of near infrared light source and infrared camera. The subjects involved in this paper are the inpatients from Harbin 211 hospital and the healthy student volunteers from Harbin Institute of Technology. The whole processing procedures are applied to 100 sublingual image of inpatients and 28 that of healthy volunteers and the experimental results is illustrated in Table 1.

Table 1. Results of segmentation of sublingual veins

Images	Number of image for testing	Number of correctly segmented images	Ratio of correct segmentation
Sublingual images of inpatient	100	83	83.0%
Sublingual images of healthy volunteers	28	22	78.6%
Total	128	105	82.0%

105 result images get satisfactory sublingual vein contours, and the averaged correct segmentation rate is up to 82.0%. From the experimental results we find that, the main factor that results in inferior segmentation is due to that some subjects cannot roll up their tongues or make their sublingual regions get captured, which lead to information loss and finally influence the segmentation results.

7. Conclusion

An algorithm for sublingual vein segmentation in near infrared sublingual images is proposed in this paper. This algorithm firstly applied watershed based radial projection method to acquire the region of tongue body, so as to get rid of the influence of lips, teeth and other surrounding useless background. Dynamic thresholding together with the intensity information of the initial sublingual image is then utilized to obtain the candidate sublingual veins regions. And finally segment out the sublingual veins by using region growing. 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.

8. Acknowledgements

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9. References

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