Automatic Sublingual Vein Feature Extraction System

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Abstract—The quintessence of the diagnosis in traditional Chinese medicine is syndrome differentiation and treatment. Syndrome differentiation consists of four methods: observing, hearing as well as smelling, asking, and touching. The examination of the observing is the most important procedure in the method of “tongue.” In recent years, numerous medical studies have identified the close relations between sublingual veins and human organs. Therefore, sublingual pathological symptoms, as well as demographical information of patients, imply pathological changes in the organs, and early diagnosis is beneficial for early treatment. However, the diagnosis of sublingual pathological symptoms is usually influenced by the doctor’s subjective interpretation, experience, and environmental factors. The results can easily be limited by subjective factors such as knowledge, experience, mentality, diagnostic techniques, color perception and interpretation. Different doctors may make different judgments on the same tongue, presenting less than desirable repeatability. Therefore, assisting doctors’ diagnoses with scientific methods and standardizing the differentiating process to obtain reliable diagnoses and enhance the clinical applicability of Chinese medicine is an important issue. In its wake, this study aims to construct an Automatic Sublingual Vein Feature Extraction System based on image processing technologies to allow objective and quantified computer readings. The extraction of sublingual vein features mainly captures the back of the tongue and extract the sublingual vein area for feature expression analysis. Firstly, the patient’s back of the tongue is photographed and color-graded to compensate for color distortion, and then the tongue-back area is extracted. This study extracts tongue-back imagery by analyzing the RGB color expression of the back of the tongue, lips, teeth and skin, translating it into the HSI color space easily perceived by the human eye, along with skin area removal, rectangle detection, teeth area removal, black area removal and control point detection. The captured tongue-back image goes through histogram equalization and hue shift to enhance color contrast. Sublingual veins are extracted through analyzing RGB color component shift, hues, saturation and brightness. Then the sublingual vein color information and positioning are used to differentiate hues, lengths and branches. Thinning analysis is used to determine the presence of varicose veins. At the same time, the surrounding features of sublingual veins, such as columnar vein, bubbly vein, petechiae and bloodshot, are extracted. The information regarding features and lingual vein conditions are integrated and analyzed for doctors’ clinical reference. This study utilizes 199 lingual images for statistic testing and three lingual diagnostic experts in Chinese medicine for lingual reading. The accuracy for the extractions are: tongue-back 86%; sublingual vein 80%; varicose veins 90%, branches 87%; and the accuracy rates for columnar veins and bubbly veins are 87%, 88% and 73% respectively.

Keywords—tongue diagnosis; sublingual veins; tongue-back imagery; histogram equalization

I. INTRODUCTION

Diagnostics in traditional Chinese medicine is an important key to connecting Chinese medicine theory and its clinical application. Accurate diagnosis is an essential basis for effective treatment. Syndrome differentiation in Chinese medicine consists of four methods: observing, hearing as well as smelling, asking, and touching. The examination of the observing is the most important procedure in the method of “tongue” [1-4]. Lingual diagnosis mainly consists of observing tongue colors, tongue fur and sublingual veins. Tongue colors, tongue fur and sublingual veins consistently represent the pathological changes in the human body. Lingual diagnosis can tell the coldness, warmth, deficiency and strength in the body and the rise and fall of blood and qi in the organs. It helps, in line with the holistic view of traditional Chinese medicine, understand the overall disorder in the body, adjust qi, blood and organs to balance and achieve recovery through integrated treatments. Lingual diagnosis is an important indicator in syndrome differentiation in clinical Chinese medicine and a reliable method of diagnosis. Recent studies have pointed out that sublingual vein diagnosis can be used for blood stasis, tumor, cardiac diseases, pulmonary diseases, hepatic diseases, cerebrovascular diseases, gastric diseases, kidney diseases, age-related illnesses and high or low vein pressure. Based on modern medical examinations, a normal person’s sublingual veins take up under 3/5 of tongue length and measures within 2.7 mm in width. It has no branch and is hidden under tongue mucosa, with the color of light purple. A tongue with sublingual veins having a ratio in tongue length above 3/5 and over 2.7 mm in width, branches, bulging of sublingual veins, or colored blue-ish purple or dark purple, may indicate abnormalities caused by blockage of qi and blood, hepatic diseases or other diseases.
Lingual diagnosis is an easily practicable and practical aid in diagnoses [6,7]. The use of lingual diagnosis is beneficial in determining treatment principles and choosing the suitable medicinal formulae. However, clinically, sublingual diagnosis is based on the doctors' personal knowledge and experience, observing through the eye the colors on the tongue, the overall expression and the amount of saliva to determine the condition of the patients. The results can easily be limited by subjective factors such as knowledge, experience, mentality, diagnostic techniques, color perception and interpretation. One doctor's readings of the same tongue in different circumstances may be vastly different [5] without accuracy and quantification and do not meet the needs for repeatability in research. Therefore, the use of computer sciences in extracting tongue features and quantification for objective research is the inevitable trend in lingual diagnosis in traditional Chinese medicine. Through combining lingual diagnosis with modern technology, translating the knowledge and theories in Chinese medicine into scientific outcome of lingual feature extraction and quantification with computing and image processing technologies, objective, accurate and quantitative statistics can be an aid for doctors of Chinese medicine in clinical diagnosis for reliable conclusions, raising the accuracy of diagnoses and efficiency of treatments.

In recent years, substantial progress has been made in tongue-surface features extraction research [8]. Sublingual veins, on the other hand, are less mentioned. Currently some researchers are devoted to the investigation into the relationship between sublingual veins and diseases. Such studies include the findings that follow: Research by Shanghai Medical College revealed that the sublingual veins of brain tumor, brain stroke and hepatic disease patients are prone to blood stasis [9]. F.W. Wang [10] et al. found that in the collected and analyzed 112 sets of sublingual veins of coronary atherosclerotic heart disease patients, as the condition progresses, there are aggravated symptoms of branches, varicose veins, expansion and darkening purple color. Y.P. Yang et al. discovered that comparing the sublingual veins of diabetes patients, diabetic vasculopathy patients and normal people, the number of those with sublingual vein expansion, lengthening, varicose veins, bubbles or blood stasis is much larger than those in the other two groups. The change in vein features and the progression of disease have positive correlations and can serve as one of the indicators for early diabetes diagnosis.

The studies above are mostly clinical observations by doctors—not concrete quantitative analysis of sublingual veins—and may not be objective diagnosis because of environmental and human factors. In addition, current research on related features quantification is limited to the extraction of color change in sublingual veins [12, 13, 14]. Comprehensive information on sublingual vein expression or surrounding vein features is insufficient. This study, therefore, offers a method of sublingual vein extraction and divide sublingual features into six symptoms—varicose veins, branches, columnar vein, bubbly vein, petechiae and bloodshot. Firstly, the Automatic Sublingual Vein Feature Extraction System put the tongue imagery through image calibration, teeth and oral cavity area identification, control point detection to determine the tongue-back region. Then it uses HSI color space and histogram equalization to enhance the color contrast between sublingual veins and tongue color, determining the sublingual vein region with the color of sublingual veins. Next it is able to analyze the extracted expression to obtain the length, width, number of branches and color of sublingual veins, summarizing the surrounding features with thinning and regional color statistics, in conjunction with the lingual diagnostic theories in traditional Chinese medicine, offering an analysis of lingual vein expression.

II. BACK OF THE TONGUE AND FEATURE EXTRACTION

There are mainly two parts to the Automatic Sublingual Vein Feature Extraction System—tongue-back region extraction and feature analysis. The obtained tongue imagery first go through color calibration to lower the influence of environmental lighting, then the removal of the skin around the mouth and the preliminary selection of tongue-back and oral cavity regions, after which are teeth region detection, black region detection and control point detection, to determine the contour of the back of the tongue. As the tongue-back region is obtained, observable features including sublingual veins, branches, varicose veins, columnar veins, bubbly veins, petechiae and bloodshot are extracted and analyzed. The process is shown in Fig. 1.

A. Color calibration

To minimize influence from the environment and the equipment in the tongue imagery processing of the tongue-back region, and maintain the consistency of color expression, color calibration must be performed first. Based on the 12 colors in the color chart on the left side of the tongue image, it is calibrated according to the standard value obtained in standard condition. The calibration method is the image color calibration algorithm proposed by Roullot, E. [15], using its general case method. The general case uses constrained least squares to make m colors conform to the equation and p-m colors to conform to the equation as much as possible. p is the number of different color blocks in the color chart, and m is the number of selected color blocks from the color chart. This

![Fig. 1. Tongue-back and sublingual feature extraction process.](image-url)
and, the color hues and remains the same, and . When represents the removal limits of skin area. Make therein are calibrated colors. increases and decreases once. When and , until the accumulated and , all calibration conversion, the color chart for image capture, and matrix is the color chart for image standard (the number of color charts is ), to make solution x converse to M matrix, image pixels can be corrected after color chart conversion, the target of investigation in this mechanism. Firstly, under the condition of , find the minimum of constraint the minimum of colors, in which matrix is the color chart for image and matrix is the color chart for image standard. Where , , are un-calibrated colors. Fig. (a) is the original image and (b) is the calibrated result. In the calibrated image, the color chart information and pixel value are compensated. With postpositional tongue surface feature extraction, chances of error are lowered.

B. Skin removal and rectangle detection

The subject of sublingual diagnosis, and therefore the removal of skin - the largest area in the image - is beneficial for later extraction of tongue-back area. The hue statistics after translating the calibrated image into HIS color space. The horizontal axis is the accumulative number of pixels, and the vertical axis is the hue value in the range exceeding half of the overall image. If not, skin range is expanded, make and initialize and . The range of represents the removal limits of skin area. Make the statistic of hue . When , remains the same, and decreases once. When , remains the same, and increases once. Repeat the above conditions to accumulate the number of pixels between hues and , until the accumulated number of pixels is approximately half of the number of pixels overall, as shown in the following formula.

Remove the hue value in the range and excessive information such as skin and color chart can be screened out. Fig. shows the result of skin separation. After skin removal, pixels with gray level values that are not can be used in selecting the back of the tongue and surrounding areas, observing the features in tongue image, identifying the upside, downside, left side and right side boundaries of the tongue. Fig. shows the result of tongue-back region selection.

C. Teeth and black region detection

The selected rectangular range of the tongue may include teeth, lips or darker regions in the oral cavity that are not the back of the tongue, and those parts should be eliminated. In the HIS color model, the hue value difference between teeth and tongue is used in identifying teeth region, with the following condition.

Where is the hue value of teeth. Under this condition, the reflection spots on the tongue and part of the surrounding skin are falsely identified as teeth. Therefore, using the continuity and high brightness of teeth and connected components, the regions of sizes too small and lower brightness can be screened out, and the remaining parts are teeth region. The Fig. shows the detection results of teeth region.

During diagnosis, the patient opens the mouth and reveals the oral cavity in a black color. The I value (brightness) of black region is apparently lower than other regions, this is
used for filtration. Fig. 5b shows the detection result of black region.

D. Control point detection

The Control point search method consist of two parts—interior point search and exterior point search. The boundary point detection method is the polar coordinates transformation proposed by W.M. Zuo et el. [16], searching for the boundary between the tongue and the lips by changing the radius of the circle on every angle, using the pixel center of the removed skin image in the rectangular area. Make the removed skin image in the rectangular area (Fig. 6(a)) $I_{new}$ and the center of the coordinates $(x_c, y_c)$, then the formula for pixel coordinates transformation into polar coordinates is:

$$I_{new}(x, y) = I_{new}(r \cos \theta + x_c, r \sin \theta + y_c)$$

(4)

The rectangular area’s gray level image is $I_{gray}$ for exterior point search. The control point search goes from inside out. The search method is grouping 20×20 pixel blocks, and it stops when the average brightness value of the block drops below 30. If not, it searches for the minimum of the average brightness value. Fig. 6b shows the detection results of exterior control points of the back of the tongue.

Interior points search uses the boundary between lips and skin after skin removal in the rectangular area as initial boundary control points, searching for the boundary between the back of the tongue and the lips from outside toward the inside. In the searched pixels, consider their neighboring pixels and see them as a small group. Set a $r \geq 50$ radius around the search point and calculate the sum of gray level differences between this range and the current search point. Because there are apparently darker regions in the lips and the boundary of the back of the tongue, the one with greater difference is chosen as control point. Fig. 6c shows the detection result of the back of the tongue interior control points.

Finally, the control points from teeth and black region detection and the two sets of potential control points from the interior and exterior of the back of the tongue are integrated. The groups of control points are matched to obtain those with the least steepness for tongue-back contour control points. Fig. 6(d) shows the detection results of tongue-back contour control points.

E. Tongue-back extraction

The contour of the tongue can be determined with control point detection. Because part of the tongue area is an arc shape, the pixels beyond the arc must be removed for ease of tongue-back feature differentiation. Using the detection method of differentiating whether a point belong on the inside of the closed curve formed by control points, the extraction of the back of the tongue can be performed, as shown in Fig. 7.

The method for differentiating an interior point is as follows: The feature of an interior point is that extending toward any direction; it only contacts an odd number of sides. The tongue is a streamlined shape without any curves crossing each other. Thus, this method is used in determining whether a point belongs on the interior of the curve.

F. Sublingual veins

Sublingual veins are the light purple or red purple regions on the back of the tongue. To contrast the hues of sublingual veins and the surrounding tongue mass, HSI color space is used for the hue shift of tongue-back image and saturation enhancement preprocessing. Observation shows that in the tongue-back image, when hue shifts 60° and saturation is up 50, the readability is preferable. After shifting and enhancing, the R, G, B values of the converted tongue-back image go through histogram equalization to enhance the contrast of lingual veins. After the above processing is completed, the H value and S value in the image show a relatively apparent difference from those of the tongue mass (Fig. 8b). The sublingual veins is close to blue, and the tongue mass is closer to red, so the preliminary definition of H value of sublingual veins after histogram equalization ranges between 190° ~ 320°, and the I value must be above 80. However, the selected area based on the defined H value only roughly covers the sublingual vein region. To more accurately extract
sublingual veins, differentiating using S value is needed. In the image, the S value closer to the sublingual vein trunk is higher and is relatively low in tongue mass, but the S value in the back of the tongue is also affected by the lighting in the environment, resulting in darker regions such as those near the caruncle, oral cavity or lips having S values higher than the center of the back of the tongue after preprocessing. Therefore, the screening threshold for S value needs to be adjusted for each of the areas. The screening method is calculating the S average \( \mu \) and standard deviation \( \sigma \), using standard deviation range to screen out un-qualifying pixels with the following condition:

\[
S(x, y) < \mu - 0.9 \sigma \quad \text{and} \quad \mu > 0.9
\]

\[
S(x, y) < \mu - 0.67 \sigma \quad \text{and} \quad 0.6 \leq \mu < 0.9
\]

\[
S(x, y) < \mu - 0.5 \sigma \quad \text{and} \quad 0.5 \leq \mu < 0.6
\]

\[
S(x, y) < \mu - 0.45 \sigma \quad \text{and} \quad 0.35 \leq \mu < 0.5
\]

\[
S(x, y) < \mu - 0.3 \sigma \quad \text{and} \quad \mu < 0.35
\]

Through the above screening process, sublingual and surrounding columnar vein or bubbly vein regions can be obtained. On the other hand, the contour of the back of the tongue is prone to have a blue expression because of low brightness and is retained; the region adjacent to the contour of the tongue must be therefore removed (Fig. 8c). The remaining regions then go through morphological processing, using a 2×2 mask for dilation and erosion calculations. This process connects the broken-up small regions and removes the fine noise in the image, and the contour of the region can appear smoother, as shown in Fig. 8d. The area after processing contains not only sublingual veins but the surrounding columnar veins and bubbly veins. According to criteria including the position of sublingual veins, size of the area and color, the regions that do not qualify are screened out, and the blank spaces of the color blocks are filled in, eventually obtaining the range of sublingual veins, as shown in Fig. 8e.

G. The width and length ratio of sublingual veins

The sublingual length ratio is defined as the length of the veins divided by the length of the tongue and is a clinical indicator of key importance. In normal conditions, the ratio does not exceed 3/5. The length of the tongue is the distance between the tip of the tongue and the sublingual caruncle; the length of the veins is based on the length of the vertical axis of vein pixels of the extracted vein image projected to the y axis. Because the stretching of sublingual veins is the protrusion of the tip of the tongue toward the place between the teeth and the palate, so the tongue is blocked by the teeth or lips, making it impossible to measure the length of the overall back of the tongue. Therefore, the tongue-tip simulation method is used wherein the tongue surface of the subject is photographed, then after processing, placed in three-dimensional space for plane bending and scaling to simulate tongue stretching in sublingual vein examination (Fig. 9a). The bended contour of the tongue surface and tongue-back area are superposed (Fig. 9b). The protruding part from the back of the tongue through the surface of the tongue is considered the tip of the tongue. Using the distance between the bottom of the tongue-back area to the simulated tip of the tongue as the length of the back of the tongue, the length ratio of sublingual veins and the tongue can be obtained through the above process.

Width of sublingual veins less than 2.7 mm is considered normal, but the width of the veins is not consistent in different regions. Therefore, doctors generally measure the widest part of sublingual veins as the basis. Firstly, the acquired sublingual veins go through thinning. After thinning, the central axes of vein structure can be obtained separately (Fig. 10a). Using each structure point as the center, circles are drawn in search of tangents with the veins. The diameters at which tangents occur are recorded, and the greatest of them is set as the width of the veins. The size of pixels can be calculated using the height of pixels the color chart takes up in the image, and the actual width of the greatest diameter can be obtained. The search result is shown in Fig. 10b.

H. The color of sublingual veins

Based on clinical observation of sublingual veins, the colors of veins are divided into four types—light purple, purple-ish red, blue-ish purple and dark purple. According to the color ring in the HSI color model, light purple and purple-ish red are located between 300° - 360°, blue-ish purple between 260° - 300° and dark purple below 260°. After obtaining the sublingual vein region, convert it to HSI colors and calculate the expectation of hue, \( H_{xp} \), and expectation of saturation, \( S_{xp} \), and categorize the colors according to the types above. In addition, light purple and purple-ish red overlap and requires \( S_{xp} \) for determination. The saturation of light purple is lower, so a color is defined as light purple when \( S_{xp} \leq 0.18 \) otherwise, it is defined as purple-ish red.

I. Branches

![Fig. 8. (a) Result of tongue-back extraction. (b) Processing result of hue shift and histogram equalization. (c) Result of saturation screening. (d) Result of erosion and dilation calculations. (e) Result of sublingual vein extraction.](image-url)
Branches are the separated veins on the side of the trunk of sublingual veins. When conducting sublingual vein extraction, part of the branches will be connected to the trunk because of dilation calculations. Therefore, before extracting branches, the tongue mass that connects the branches and the trunk must be removed for ease of branch differentiation. The R value of veins is lower than the R value of the surrounding tongue mass. Obtain the gray level value from the R value as brightness and conduct histogram equalization using the R value of the pixels covered in the left and right vein ranges separately to make the veins and the remaining tongue mass in the veins distinguishable in brightness. Set 10 pixels as a range and calculate the average of all the pixels, \( \mu \). If the gray level value of a pixel which in the range is lower than average, the region is considered tongue mass. Remove the tongue mass and fill in the blank regions in the remaining parts, and the tips of the branches can be obtained using the processed image.

There are interstices between branches. Using the interstices as boundaries for blocks and perform horizontal cutting from the top down. The boundary between the cut and the interstice can produce separated blocks, as shown in Fig. 11a. Through the search for the top-most point of each block under the condition that the height of the block must be above 15, branch points can be obtained. Fig. 11b shows the branch differentiation results.

J. Varicose veins differentiation

Varicose veins are the winding and tortuous appearance of sublingual veins. The veins of healthy individuals appear straight or slightly curved. Based on this feature, the curving (angle) of sublingual veins can be calculated to determine whether there are varicose veins. Thinning algorithm is used to obtain vein structure, and the thinning retains the original path structure of the veins, which makes the subsequent feature point extraction and curve angle calculation faster and more easily. The feature point extraction method is the Douglas-Peucker algorithm [17]. This algorithm minimizes the number of consisting points of the curve on the prerequisite that the shape of the curve remains the same, meaning that it compresses the image signals to extract the points required. In the algorithm, the two end points of a curve is connected with a straight line, and the vertical distance from each point to the line is calculated. The greatest distance is recorded as \( d_{\text{max}} \), and the point of that distance is defined as \( P \) and compared with the set tolerance \( D \). If \( d_{\text{max}} \leq D \), all the points in that range in the line are removed. If \( d_{\text{max}} > D \), point \( P \) is retained and set as the boundary for the iteration process of both parts.

Regarding the curve angle calculation, the conjoining points generated by the Douglas-Peucker algorithm are designated as \( \{ P_1, P_2, ..., P_n \} \) in a top-to-bottom and left-to-right sequence. Select \( P_2 \) to \( P_{-1} \) and calculate the degrees of the angle formed by each point and its adjacent points. A path having more than two angles smaller than 100° is considered a varicose vein.

K. Columnar veins and bubbly veins

In the sublingual veins, aside from the two major veins, there are branches hidden in the back of the tongue around the vein trunk. Because the veins are deep in the back of the tongue and are not clearly visible, they are not connected to the sublingual veins visibly and mostly appear light purple of purple-lish red. The parts that appear columnar with larger area coverage are columnar veins; those that appear bubbly with smaller area coverage are bubbly veins. In the extraction of sublingual veins, the surrounding light purple or purple-lish red regions are recorded. Therefore, the extraction of columnar veins and bubbly veins can be performed using the parts that remain after removing sublingual vein. In the remaining parts, aside from columnar veins and bubbly veins, there is the contour of the back of the tongue that contains the same color elements. The tongue-back contour is removed, and the remaining parts are sorted according to the different shapes and sizes of columnar vein and bubbly vein regions.

Fig. 11. (a) Diagram for branch interstices and horizontal cutting. (b) result of branch extraction.

Fig. 12. (a) Result of columnar veins petechia extraction. (b) Result of bubbly veins columnar veins petechia extraction.
Eventually the screening result of columnar veins and bubbly veins is obtained. Fig. 12a and 12b shows the result of Columnar veins extraction and bubbly veins extraction, respectively.

L. Petechiae

Petechiae are the small spots that appear dark red or dark purple against the back of the tongue. In the R, G, B color changes of petechiae in the test image, R>50 and G<70 are observed. The R and B value differences therein is greater than the R and B value differences in the surrounding tongue mass, and the R and B value differences changes with R value, as shown below.

\[
\begin{align*}
50 &< R \leq 60 \text{ and } R-B > 35 \\
60 &< R \leq 70 \text{ and } R-B > 38 \\
70 &< R \leq 80 \text{ and } R-B > 45 \\
90 &< R \leq 100 \text{ and } R-B > 40 \\
100 &> R \text{ and } R-B > 35 
\end{align*}
\]  \hspace{1cm} (6)

Using only the conditions above can result in the excessive size in some of the petechiae area extracted. Therefore, R, G, B are again converted to HSI color space, using saturation conditions to remove non-petechiae regions. The darker part of the centers of petechiae has higher saturation. For petechiae with larger areas, the average saturation \( \bar{M}_G \) and standard deviation \( \bar{M}_G \) are calculated to retain the centers of the petechiae using the following condition:

\[
S(x_i,y_i) < \mu + \sigma \times 1.1 \hspace{1cm} (7)
\]

The differences between the final remaining parts and the surrounding tongue mass must be calculated. Because the B value and G value of the petechiae are smaller compared with the tongue mass, a range extended from the area selected in the preceding process is used to calculate the average G and B value differences between the petechia area and the extended area. When conforming to the conditions of \( \text{Avg}G-\text{Avg}G' \geq 9.5 \) and \( \text{Avg}B-\text{Avg}B' \geq 9.5 \), an area is considered a petechia. Fig. 13 shows the result of petechiae extraction.

M. Bloodshot

On the back of the tongue, the silky forms with a somewhat dark red color are bloodshot. To distinguish bloodshot and tongue mass, the tongue-back image first go through Gamma conversion. After Gamma conversion, separate the converted image into a 50×50 set of blocks. Histogram equalization is performed on each block. The reason is that bloodshot is spread over the back of the tongue, subtle and close to tongue mass in color. If histogram equalization is performed on the tongue-back image as a whole, the information of the fine lines are easily lost, so enhancement is performed on each block separately.

After the image preprocessing above, bloodshot is observed in HSI color space. The hue value ranges in \( 330^\circ \sim 360^\circ \), and the gray level value of G is smaller than 100. Then the gray level value G in the block selected using the conditions above, is used in calculating top-to-bottom the average value \( \mu_i \), and standard deviation \( \sigma_i \), of horizontal lines and calculating left-to-right the average value \( \mu_i \) and standard deviation \( \sigma_i \). The formula below is then applied to retain the center of the block where the G value is lower:

\[
I_{x,y}(x_i,y_j) > \mu_i + 0.9 \times \sigma_i \hspace{1cm} (8)
\]

The above process produces a sporadic block of image. After connecting nearby blocks, because bloodshot covers little area, the regions with larger area are removed. Based on the feature of bloodshot that its G value is smaller than the G value of tongue mass, the retained range where the gray level value is smaller is extended and used to calculate the average of the retained area and the extended range. The average G of the retained area is set as \( M_\mu \) and the average of the extended area as \( M_\sigma \), shown below:

\[
G_{\text{ret}} = M_\mu - \frac{M_\sigma}{2} \hspace{1cm} (9)
\]

Smaller \( G_{\text{ret}} \) indicates smaller difference between the G of the retained area and the extended area. If \( G_{\text{ret}} < 2.8 \), bloodshot is ruled out. Finally, it is determined whether the shape of the area conforms to the shape of bloodshot, removing areas of shapes that are close to circle or square.

<table>
<thead>
<tr>
<th>Sublingual veins</th>
<th>Width</th>
<th>Left veins: 0.26 cm</th>
<th>Right veins: 0.26 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Over 3/5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>Blue-ish purple</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varicose veins</td>
<td>Left varicose veins: Negative</td>
<td>Right varicose veins: Negative</td>
<td></td>
</tr>
<tr>
<td>Branches</td>
<td>Left branches: Negative</td>
<td>Right branches: 3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Columnar veins</th>
<th>Left columnar veins: Positive</th>
<th>Right columnar veins: Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bubbly veins</td>
<td>Left bubbly veins: Negative</td>
<td>Right bubbly veins: Negative</td>
</tr>
<tr>
<td>Petechiae</td>
<td>Right petechiae: Negative</td>
<td>Left petechiae: Positive</td>
</tr>
<tr>
<td>Bloodshot</td>
<td>Right bloodshot: Positive</td>
<td>Left bloodshot: Positive</td>
</tr>
</tbody>
</table>
This study is able to consistently capture ideal tongue-back images and extract sublingual veins for the differentiation of color, width, branches and varicose veins. At the same time, other features on the back of the tongue such as columnar veins, bubbly veins, petechiae and bloodshot are extracted. This study utilizes 199 lingual images for statistic testing, marking sublingual features with different colors and hires three lingual diagnostic experts in Chinese medicine for lingual reading. Comparing the readings by the System and experts, there are 18 images with incomplete tongue-back capture, 23 with sublingual vein position misreading, incomplete extraction or excessive extraction, 12 with misreading of varicose veins and 15 with misreading of branches. The numbers of misread images for columnar veins and bubbly veins are 16 and 13 respectively, which leaves room for improvement. There are 20 with non-petechia area misreading and 33 with bloodshot misreading, which is less than ideal. TABLE 1. show the analysis of tongue-back features.

IV. CONCLUSIONS

The tongue reflects the internal state of the body; pathological conditions can be observed from the changes in the tongue. Lingual diagnosis holds a pivotal place in the diagnostics of traditional Chinese medicine, and sublingual diagnosis has been receiving increasing attention. Because traditional lingual diagnosis has reached an unsurpassable bottleneck, adopting scientific methods has become an inevitable trend. This study extracts the contour of the back of the tongue through digitizing sublingual veins, with HSI color space conversion, skin removal, rectangle detection, teeth and black area detection and control point detection. The extracted tongue-back image is examined based on the color element changes of the features, and the result generally agrees with the readings of lingual diagnosis experts. In the future, enhancing the detection of sublingual features can allow improvements on extracting the less distinguishable veins deep in the back of the tongue, and the reading accuracy of the features surrounding the veins such as columnar veins, bubbly veins, petechiae and bloodshot. Quantified statistics are also incorporated into the features for consistent results and for doctors' reference in diagnosis.

Currently, the interpretation standard for the extraction results of the Automatic Sublingual Vein Feature Extraction System is the product of discussions with experts. To prove the practicality of the System in clinical research, it has to go through consistency studies, investigating into ability for feature detection statistics to stay consistent in various photographical environments with variants such as lighting change, camera placement, corrective color chart placement and tongue angles. Also, the analytical results of the System are compared with the survey conducted on doctors of traditional Chinese medicine for study of their level of agreement. Once the consistency of the System is achieved, the process can be used in clinical syndrome observation and differentiation in traditional Chinese medicine. Through conducting mass image capture, analysis, statistics and summarization, new Chinese medical theories can be proposed and traditional lingual diagnosis can be further perfected.

REFERENCES