*A Novel Automatic Tongue Image Segmentation Algorithm: Color Enhancement Method Based on L*a*b* Color Space*

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***Abstract*—As the first step of tongue image analysis, tongue segmentation plays a significant role in this field. In this paper, we present a new method to segment the tongue using multiple color spaces. Based on the hue channel in HSV space, a threshold control function can be given, revealing the chromatic feature of image. Then we can extract our interested area according to the function, so that the color enhancement method can be applied in this region. In the end, we can obtain the complete outlines using the luminance features in L*a*b color space. Compared to existing tongue segmentation algorithms, our method demonstrates satisfying performance in robustness, efficiency and accuracy.**

Keywords—Tongue image segmentation; Color enhancement; L*a*b* color space

I. Introduction

In the field of Traditional Chinese Medicine (TCM), tongue image analysis provides plenty of valuable diagnostic information to reveal the disorder or even pathological changes of human organs in computerized tongue diagnosis systems [1], so tongue image edge detection is a popular application. How to separate tongue body from face skin and lip which have similar color is regarded as a major issue in tongue image analysis.

Many algorithms have been proposed recently aiming to solve these problems, Studies forwarded recently mainly focus on active contour model (ACM), or ”Snake” such like polar edge detector [2], watershed [3], General Gradient Vector Flow (GGVF)[4] Double Snake [5],etc.

Existing works usually focus on one color space, failing to utilize some potential advantage of specific characteristics of tongue images in other color spaces. Our CEM-$L^*A^*B^*$ algorithm use a hue threshold control function to determine a proper threshold value for preliminary separation of tongue region. The selected region is then enhanced with a certain proportion to obtain a better luminance which is more suitable for tongue segmentation in $L^*A^*B^*$ color space. Evaluation experiments are conducted to validate the effectiveness of the proposed methods. The algorithm demonstrates satisfying robustness, efficiency and accuracy when processing different chromatic tongue pictures.

II. CEM-L*A*B* algorithm:

Tongue images, with their own color characteristics, differ from other general images. The main body of tongue is red, which is one of the most important characteristics and can be exploited as a region of interest to be strengthened deliberately for further edge detection. Our CEM-L*A*B* (color enhancement method based on L*a*b* color space) algorithm offers a brand new idea of utilizing information in color difference and conducts the edge detection based on L*a*b* color space effectively.

A．CEM

CEM (color enhancement method) focuses on the main body of tongue. It can augment the brightness of the target region, which facilitates the efficiency of edge detection method based on CIEL*A*B* color space in the next step.

Determining the main body of tongue is the first step of CEM. The original RGB images are transformed into HSV color space in advance to preprocess. HSV stands for hue, saturation and value respectively. Compared to RGB, it can distinguish the colors much more effectively. Here we only focus on the H channel to extract the red main body of tongue image.

Here we just focus on the red part of the image as the characteristic of tongue. The value of standard hue channel reflecting the target region is made up of two parts, ranging from [0,30] and [330,360]. To make hue channel value continuous to all red color, we need to do some

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preprocessing to the standard value as following:

$$h=\begin{cases} H-330 & H>330 \\ H+30 & H<330 \end{cases}$$

According to our experiment, the original image can be divided into three main parts, the tongue, the lips and the skin of face, assuming the picture is taken at an appropriate distance and cropped into a suitable size. The hue value of the face is larger than other two parts, regardless of the gender and ethnicity; meanwhile, the area of lips and tongues are quite different, and the oral cavity can also help distinguish the two parts. Three main parts have separate hue values noted as h1, h2 (tongues and lips) and h3 (faces) respectively. We can model the relationship between the value of h and hue threshold control function f(h), the number of pixels with hue value larger than the h. The representation of f(h) shows as following(what h1 and h2 represent need be determined by area and cavity, here we assume h1 represents hue value of tongues):

$$f(\mathrm{h})=\begin{cases} n_0 & 0<h<h_1 \\ \dfrac{n_0+n_1}{2} & h=h_1 \\ n_1 & h_1<h<h_2 \\ \dfrac{n_1+n_2}{2} & h=h_2 \\ n_2 & h_2<h<h_3 \\ \dfrac{n_2+0}{2} & h=h_3 \\ 0 & h>h_3 \end{cases}$$

n_0 signifies the total number of pixels in the image.

Naturally, all characteristics of Heaviside step function can be applied to do the research on f(h). Apparently, h1 plays an important role in f(h), for h2 marks the largest h value of tongue image. Such a threshold for preliminary tongue image separation is used to transform those pixels with h value larger than it into pure black. So we can obtain the preliminary separated tongue region, noted as S.

However, the hue values of real tongue lips and skin are not uniform and change gradually instead. We denote the actual hue threshold control function as g(h), which is an image-dependent function. First of all, Polynomial fitting can be used to fit g(h) and get a fitted actual hue threshold control function G(h). Then we can pay attention to the second derivative function of G(h), noted as G''(h), which reflects the concavity and the convexity of G(h). For certain h_0, when G''(h_0) equals to the troughs and crests of G''(h), it corresponds to the inflection point of G(h). The change of value in G(h) may not be regular, resulting in many little peaks in G''(h), which interferes with the determination of threshold value of h. To avoid such situation, a minimum peak value is set to sort out those troughs and crests worthy for analysis. Base on that we can get region of interest S to continue our color enhancement method.

Our CEM algorithm offers a novel method to enhance the luminance of tongue. We can get the top 20% pixels as reference pixels(pixels with $R+G+B>700$ excluded). Based on that, we can enhance the color of pixels in S as following:

$$R_{ref}=\sum_{i\in top20\%} R_i$$

$$\mathrm{G}_{ref}=\sum_{i\in top20\%} \mathrm{G}_i$$

$$B_{ref}=\sum_{i\in top20\%} B_i$$

$$[\mathrm{aR},\mathrm{aG},\mathrm{aB}]=[\frac{255}{R_{ref}},\frac{255}{G_{ref}},\frac{255}{B_{ref}}]$$

$$[\mathrm{R}_i',\mathrm{G}_i',\mathrm{B}_i']=[\mathrm{R}_i*\mathrm{aR},\mathrm{G}_i*\mathrm{aG},\mathrm{B}_i*\mathrm{aB}] \qquad (i\in S)$$

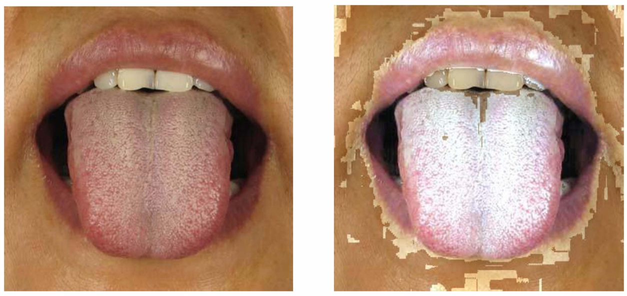


Fig.2.1 sample tongue image before and after CEM.

After CEM, the L, a, b channel values change significantly. Shown in Fig.2.2 and 2.3, the tongue body is not identifiable through either of the channels, interfered seriously by the thick tongue coating. So we can only get the partly and sparsely coating part of tongue by analyzing images in L*a*b* color space.

However, when CEM is applied, with the color enhancement mainly on the tongue body and lip, L channel value in such areas will be greatly increased nearly to its maximum value. Meanwhile, pixels in skin area are unchanged. Moreover, the originally lower G and B channel value increase more drastically than R channel value during color enhancement and cause the pixel turning white, which is of lower value in a and b channel. So the low value area around tongue body in a and b channels also provides discernable separate line when detecting tongue image.

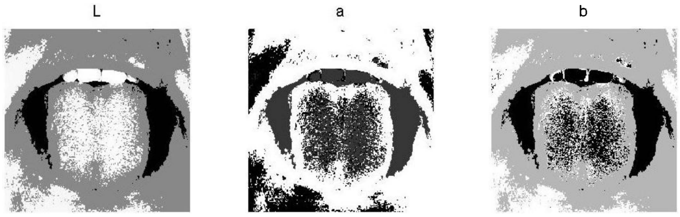


Fig.2.2 L, a, b channels before CEM

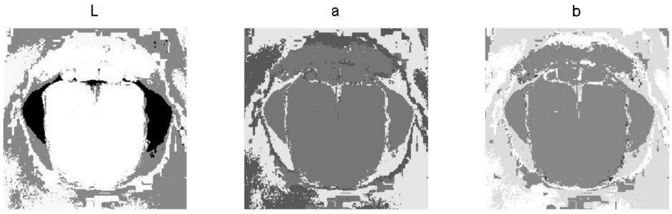
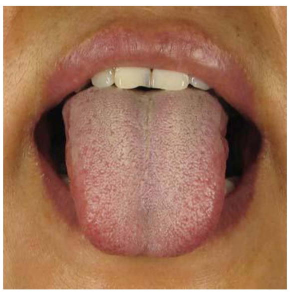


Fig.2.3 L, a, b channels after CEM

*B. Edge detection algorithm based on L*A*B* color space*

We transform the image after CEM from RGB color space to L*A*B* space. The L,a,b values of white node equal to 100, 0, 0 respectively. So we just need find those pixels with L falling in [97.5,102.5], a and b falling in [-2.5,2.5] can be regarded as our interested pixel. Extracting the regions in the range, we can get some eligible areas. Choosing the largest region after open operation, we can obtain our interest region. To smooth the edge we detected, we use the expansion algorithm to merge the background pixels.

III. A Sample tongue segmentation with CEM-L*A*B* algorithm



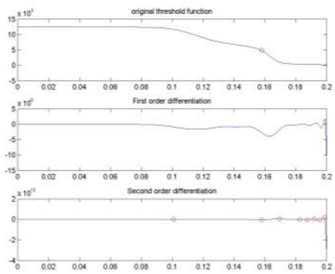


Fig.3.1 Original image

Fig.3.2 Analysis on fitted actual hue threshold control function G(h)

Fig.3.3 Selected areas after CEM

Fig.3.4 Select valid pixels in L*a*b* color space

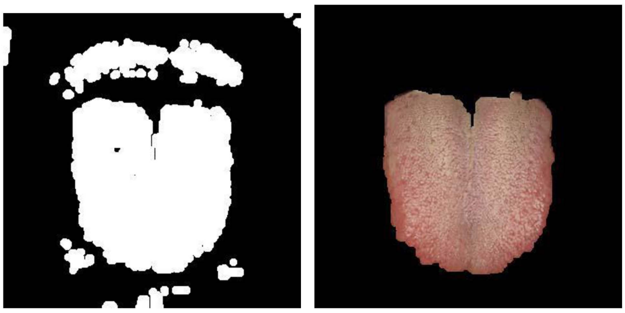


Fig.3.5 After open operation

Fig.3.6 Final tongue image detected by CEM-L*A*B*

IV. Comparison

The algorithm is of high robustness, accuracy and efficiency, compared with some classical and recent tongue segmentation algorithms in most cases.

Clinical tongue image database offered by Shanghai University of Traditional Chinese Medicine, provides many samples and standard images, which are segmented by experienced doctors with various tongue colors and shapes. We define an index Q to evaluate the accuracy of the algorithm:

$$Q = \frac{S^{`} - S^{``}}{S_0} \qquad (S^{`} + S^{``} = S_1)$$

Where S_0 is the area of the standard image, S_1 is area of the region we segmented, $S^{`}$ is the overlapping area of the S_0 and S_1.

We test our algorithm, with more than 70 percent of tongue images with Q larger than 0.9. Fig.4.1 show some of the ideally segmented samples. In some cases, the color between lip and tongue is highly similar, resulting in incorrect combination of these two parts .

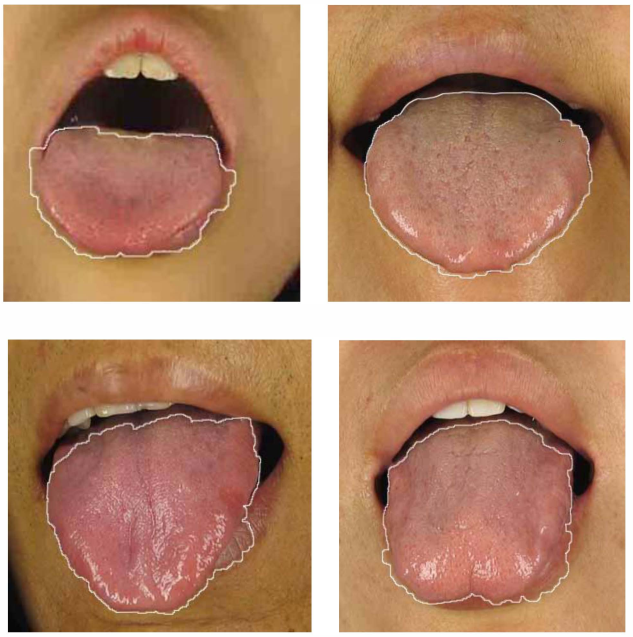


Fig.4.1 samples used CEM-L*A*B* in tongue segmentation

Compared with other classical and recent tongue segmentation algorithms [6-9], shown in Fig.4.2, our algorithm is higher in accuracy and faster in time. The algorithm is much better than the classical algorithm, like watershed and snake in shape completeness. The algorithm proposed by Shi M J, *et al.* [9], who also provide database images, is highly accurate and has similar detection results as ours, nevertheless, their time consumption is 17.28 times slower than ours.

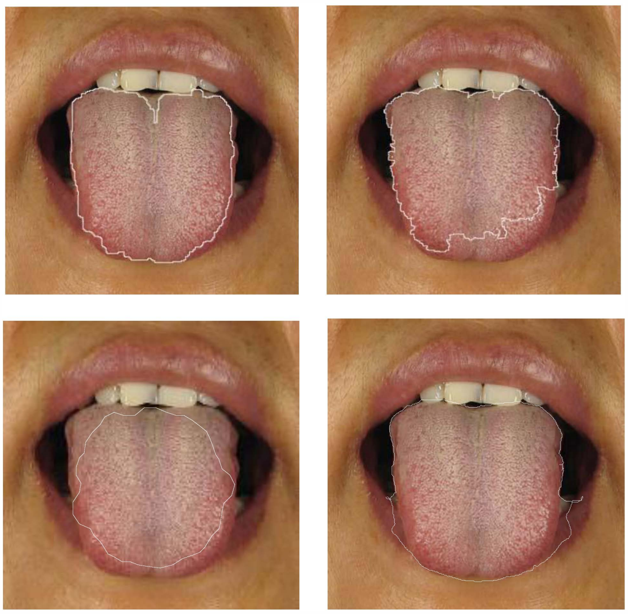


Fig.4.2 Tongue segmentation effect between CEM-L*A*B*, watershed, Original snake and C2G2FSnake algorithm

Table4.1 Speed and accuracy test (Tested in Matlab 2014a on Windows 8.1)

Algorithm	**CEM-*L**A*B***	**watershed**	**Original snake**	**C2G2FSnake**
Speed (s)	0.630	1.65	4.01	11.46
Q (%)	98.9	89.0	73.4	98.4

V. Conclusion

In this paper, we presented a novel automatic tongue image segmentation algorithm. The algorithm is applicable to most tongue images with various tongue colors and shapes. Over 70 percent images yield satisfactory segmentation results. Meanwhile, the algorithm is fast in computing, in the comparison between other three segmentation algorithms, it exceeds the slowest one by more than 17 times with similar segmentation result.

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