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A New Method of Color Tongue Image Segmentation Based on Random Walk

Mingfeng Zhu*, Jianqiang Du
School of Computer Science, Jiangxi University of Traditional Chinese Medicine, Nanchang 330004, China
*Corresponding author, e-mail: ohogod@yeah.net

Abstract

This paper introduced a kind of new method for color tongue image segmentation by improving random walk algorithm. Firstly, we introduced an improved toboggan algorithm which adopted new classification rules to classify a image into initial regions. Secondly, we built a weighted-graph according to initial regions in which only those adjacent regions were connected. Thirdly, we adopted random walk algorithm to segment images by newly designed weight function. Fourthly, we used mathematical morphology operations to remove small holes on the target region of the segment result of the third step. In the experiment, we compared our method with traditional random walk algorithm. And as the experiment results show, our method achieves basically ideal effects, which are much better than those of traditional random walk image segmentation algorithm.

Keywords: *color tongue image segmentation, toboggan algorithm, random walk algorithm, HSI color model*

1. Introduction

Tongue diagnosis is one of important contents in four Traditional Chinese Medicine diagnoses. Traditional tongue diagnosis depends on the observations on the features of tongues. The results of tongue diagnoses are influenced not only by both the experience and knowledge of doctors, but also by the environments. Therefore, many researchers utilized digital cameras to take photos of tongues and check the tongue images quantitively using computers. To check tongue images quantitively, we need to segment the tongue body region from background first, i. e. tongue image segmentation.

In Recent years, random walk algorithm is an arisen image segmentation algorithm. It utilizes weight values among nodes in weighted-graph to make clustering of image regions, so as to segment images. Many researchers proposed various kinds of transmutations of random walk algorithms. Yufeng Yi *et al.* [1] introduced a kind of random walk image segmentation algorithm based on Mean Shift in order to solve the problem that the contour of the object was easy to be disturbed by the natural texture of the background. Meng Liu *et al.* [2] combined interactive segmentation algorithm with Kalman filter to introduce random walk algorithm based on Kalman filter which was used to solve shadow and occlusion in traffic video surveillance. Li Guo *et al.* [3-4] introduced a toboggan based random walk image segmentation algorithm. Li Guo *et al.* [5] introduced a method of accurate vehicle detection in multi-vehicle video by random walk algorithm based on edge detection. Zhaoyu Pian *et al.* [6] proposed a novel approach for image segmentation by applying structure tensor to random walk. Yihua Lan *et al.* [7] proposed a novel image segmentation method based on random walk model which can overcome the disadvantage for segmenting the large scale image while selecting initial value randomly. Richard Rzeszutek *et al.* [8] proposed an extension to random walk algorithm without significantly modifying the original algorithm.

In the former researches, there were 2 methods which might be mentioned and could be used to segment color tongue images and under some circumstances they could successfully segment tongue images. One method was HSI-based threshold method, which was introduced by Zhongxu Zhao *et al.* [9]. This method transited RGB color model of original tongue images into HSI color model and utilized hue histogram to segment tongue images. The other one was HSI-based transfixation method, which was introduced by Jianqiang Du *et al.*

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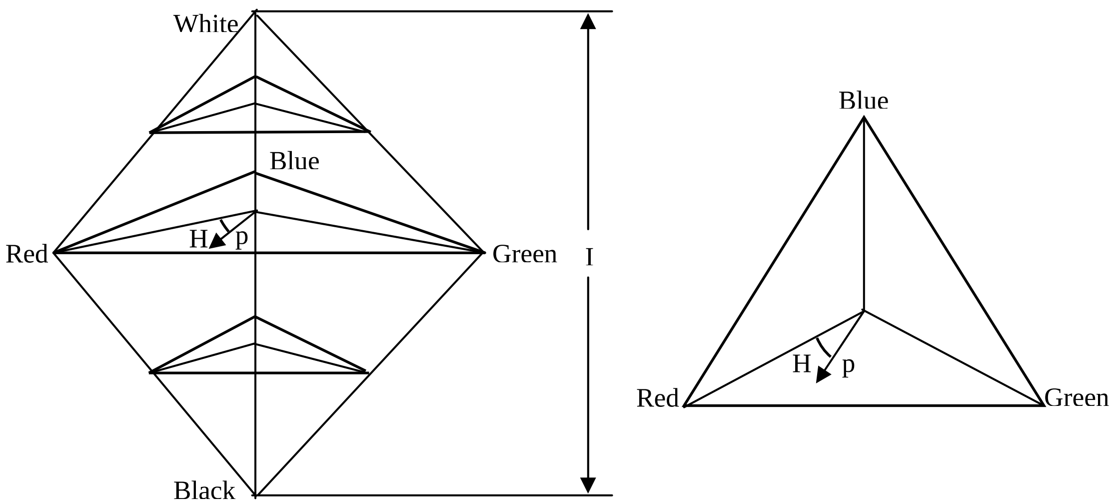
[10]. This method utilized hue value of tongue images as the key segmentation factor and combined HSI color model with transfixation algorithm in order to segment tongue images.

In the problem of color tongue image segmentation, because the intensity of tongue region may be same as adjacent regions, such as mouth region and face region, so we can not use intensity to build weight function and segment tongue images. Herein, we introduced both hue and intensity to build a compound weight function, which conformed to the principles of human vision of color. In addition, traditional random walk algorithm doesn’t fully take advantage of spatial information to segment images. In this paper, we fully utilize spatial information and before using random walk algorithm to make final segmentation we build a weighted-graph in which only those adjacent regions are connected. Therefore, our algorithm is more practical and can achieve much better segmentation effects. From now on, we will discuss the principles of our method which we suggest to make color tongue image segmentation.

2. HSI Color Model

Traditionally, a pixel is represented by red, green and blue 3 kinds of colors. RGB color model is usually used to represent a static image. But in HSI color model a pixel is transformed into hue, saturation and intensity 3 kinds of color components. Hue is used to determine the type of the color. Saturation is the degree to which a certain color is mixed into the other colors. And intensity is the degree of the brightness of a pixel. The HSI color model is shown as Figure 1.



(a) (b)

Figure 1. HSI Color Model (a) HSI 3-dimension color space, (b) cross-section of HSI color space

As Figure 1(a) shows, any color can be denoted as the color point p in HSI 3-dimensional color space. In HSI 3-dimensional color space, hue component is denoted as the angle between vector p and red axis, saturation component is denoted as the length of vector p, and intensity component can be measured by a direct line through the center of the triangles. As Figure 1(b) shows, 0-degree represents red, 120-degree represents green and 240-degree represents blue.

Relative to RGB color model, HSI color model is more closer to human vision of color. And as the former work has proved that using HSI color model to identify tongue region and segment tongue image is feasible.

3. The Principle of Image Segmentation Based on HSI Color Model

Some traditional image segmentation methods use grayscale to segment images. Due to grayscale value of a pixel is a combination of red, green and blue components, it can only reflect the brightnesss of images. Although grayscale information of a image is enough for many applications of image segmentations. But in the application of color tongue image segmentation, using grayscale to segment tongue region from the background regions, such as teeth, mouth and face regions, is very difficult.

Figure 2. Grayscale Tongue Image

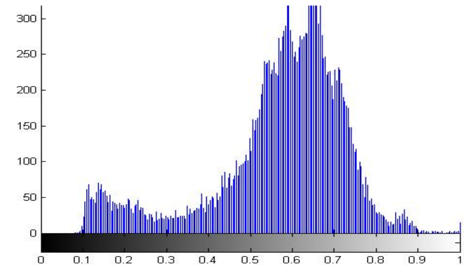


Figure 3. Histogram of Grayscale Tongue Image

As Figure 2 shows, the grayscale values of tongue region and those of face region are quite close and similar. As Figure 3 shows, the main peak of the histogram of grayscale tongue image is only one. And this peak represents both the tongue region and face region. Therefore, we can not distinguish the tongue region and face region only by grayscale information of tongue images.

In HSI color model, hue component can be used to identify the color type of a pixel. And the main color type of tongue region is red which is basically different from those of teeth region and face region. Even if the main color type of tongue region and that of mouth region is close, the spatial positions of tongue region and mouth region are different. Therefore, utilizing the hue information and spatial information of color tongue images to segment tongue images may be feasible.

When identifying the hue value of tongue region, the hue value of tongue region is usually red. The red color is 0-degree or 360-degree in hue histogram. If we only use the hue values to distinguish the color of tongue region, this may lead to an incorrect segmentation result.

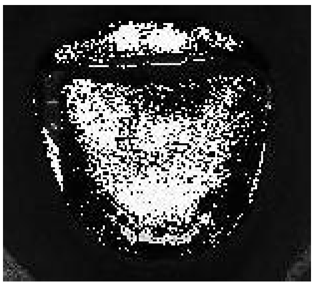


Figure 4. Hue Image of Tongue

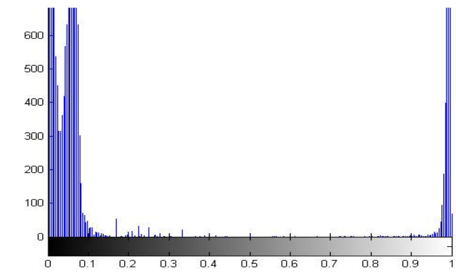


Figure 5. Hue Histogram of Tongue Image

As Figure 4 shows, there are not only high hue value points but also low hue value points on the tongue region. As Figure 5 shows, hue values of tongue which is red lies at the start positions and the end positions of hue histogram of the tongue image. And the start positions of hue represent the tongue pixels with low hue values and the end positions of hue represent the tongue pixels with high hue values. In order to let those pixels with both low and high hue values gather at one peak in the hue histogram of the tongue image, we need to transform the range of hue in the hue image of tongue. Concretely, if the range of hue is from 0-degree to 360-degree, we move those hue values from 0-degree to 180-degree to the end. And we subtract 180-degree from all the hue values.

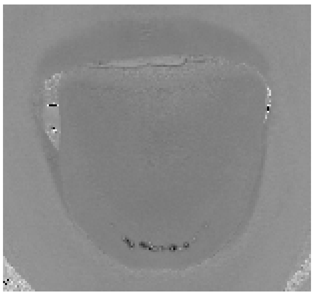


Figure 6. Hue Image after Transformation

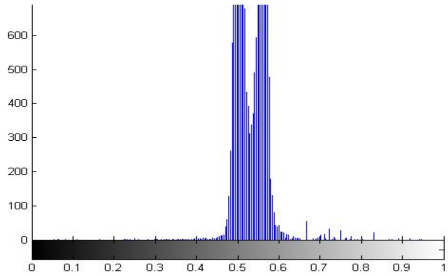


Figure 7. Hue Histogram after Transformation

As Figure 6 shows, after the transformation as mentioned before, the tongue pixels gathers in the connective region and the tongue and the mouth lie in the 2 different regions. As Figure 7 shows, the hue histogram of the tongue image after the tranformation presents a 2-peak distribution, the feature of which can be used to separate the foreground part from the background part.

4. Random Walk Image Segmentation Algorithm

Random walk algorithm is a kind of semi-automatic image segmentation algorithm, which is successfully applied in the field of image segmentation. It utilizes the probability between any 2 pixels to segment image. The random walk algorithm is mainly divided into 3 steps. Firstly, choose segmentation mark points. Secondly, build connection weight function. Thirdly, realize segmentation by solving transfer probabilities. Now, let's discuss this algorithm in detail.

Firstly, we need to define a discrete weighted-graph G for the original image. The weighted-graph can be denoted as G=(V, E), which is composed of vertex $v \in V$ and edge $e \in E$. Herein, V is a set which is composed of finite elements of vertex v_i and E is a set which is composed of finite elements of edge e_i. The pixels in the original image are denoted as nodes in weighted-graph and the relationship between 2 pixels is denoted as an edge. Additionally, there is a connection weight W_{ij} on each edge, which is used to describe the connectivity between 2 nodes. During image segmentation, weights of edges are used to describe the difference or similarity among adjacent pixels. The weight function can be denoted as following:

$$W_{ij} = e^{-\beta(I_i - I_j)^2} \quad (1)$$

Herein, I_i and I_j are the intensities of pixel i and pixel j respectively and β is a scale parameter which is larger than 0. When taking the spatial information into consideration, the weight function can also be denoted as following:

$$W_{ij} = e^{-\beta(I_i - I_j)^2 - (h_i - h_j)^2} \quad (2)$$

Herein, h_i is the position of the pixel i.

Random walk algorithm is a kind of interactive image segmentation algorithm. After the weighted-graph is built, we need to specify the seeds for object region and background region. These seeds provide the bases for classification of unmarked points. After manual marking of the seeds, the nodes in the weighted-graph are divided into multiple subsets. Let marked nodes be the seeds, the set of which is denoted as M. And unmarked nodes are denoted as a set N. Herein, $M \bigcup N = V$ and $M \bigcap N = f$. Then decompose marked point set M to get object seeds $O \subset M$ and background seeds $B \subset M$. Herein, $O \bigcup B = M$ and $O \bigcap B = f$. Therefore the connection relationship between 2 nodes replaced the relationship between 2 pixels. And the problem of image segmentation transforms into the problem how unmarked nodes first reach maximal probability of the seeds.

Due to the selection of initial seeds is manual. This may be inconvenient for the application of tongue image segmentation. And the spatial information in the image is not fully utilized. Most of all, the effects of tongue image segmentation may not be okay, when utilizing traditional random walk algorithm. Based on the considerations above, we suggest a kind of improved random walk image segmentation algorithm, in which the seeds are selected fully automatic and the spatial information is also fully utilized. Now, let's discuss the improved random walk image segmentation algorithm in detail.

5. Improved Random Walk Image Segmentation Algorithm

The improved random walk image segmentation algorithm is composed of 4 steps. Firstly, improved toboggan algorithm is applied to get initial regions. Secondly, the weighted-graph is built according to the initial regions. Thirdly, apply random walk algorithm to make final segmentation using newly-built weight function. Fourthly, mathematical morphology operations, i. e. inflations and erosions are carried out on the segmentation result of the third step, so as to fill small holes on the tongue region.

5.1. Toboggan Algorithm

In 1990, Fairfield introduced toboggan algorithm to be applied in the field of image segmentation. Its basic thinking is that we can specify the movement directions by finding the minimal grads in the neighbourhoods of the pixels and divide those pixels with minimal grads into one group, so as to segment images. Because grayscale information (i. e. intensity information) is not enough for the segmentation of tongue image, so we will utilize both hue and intensity to describe the differences between 2 pixels. The improved toboggan algorithm can be described as following.

Step 1: Scan original image to find a seed which is a non-zero pixel.

Step 2: Add the seed pixel to object region, push the seed pixel into the stack and remove the seed pixel from the original image.

Step 3: Repeat following step 4 and step 5 until the stack is empty.

Step 4: Pop up a seed pixel from stack.

Step 5: Considering the neighbourhoods of the seed pixel, if the differences of intensity and hue between the seed pixel and the neighbourhood pixel are lower than a certain thresholds, we add the neighbourhood pixel to object region, push the neighbourhood pixel into the stack and remove the neighbourhood pixel from the original image.

Step 6: Repeat step 1 to step 5 until there are no non-zero pixels in the original image.

5.2. Construction of Weighted-Graph

After original image is segmented into initial regions, we can construct the weighted-graph according to the initial regions. The weight function is no more composed of intensity, but the combination of intensity and hue, which conforms to the principles of human vision of color. The weight function is defined as following:

$$W_{ij} = \alpha\left(1 - \frac{|I_i - I_j|}{255}\right) + \beta\left(1 - \frac{|H_i - H_j|}{360}\right) \quad (3)$$

Herein, α and β are weight coefficients, $\alpha \in [0,1]$, $\beta \in [0,1]$, $\alpha + \beta = 1$, I_i and I_j are intensity values of pixel i and pixel j, and H_i and H_j are hue values of pixel i and pixel j.

In the construction of weighted-graph, to fully utilize the spatial information of images, we only permit those initial regions which are adjacent to each other are connected with a certain weight value. This rule is more practical than that of traditional random walk algorithm, which can transform the weighted-graph into a sparse network, can reduce the work of random walk, and can achieve much better segmentation effects. Just because the weighted-graph is a sparse network, we adopt adjacency list to denote the weighted-graph, which can reduce the space of the data structure. The algorithm to construct the weighted-graph can be described as following.

Step 1: Create an array of heads of linked lists, each element of which represents an initial region.

Step 2: If region a and region b are neighbourhoods, run following step 3 to step 7.

Step 3: Create a new edge node which is from region a to region b.

Step 4: Set the identifier of the new edge node to b.

Step 5: Calculate the weight between region a and region b according to formula (3), set the weight value of the new edge node and set the successor of the new edge node to null.

Step 6: Link the new edge node to the tail of linked list of region a.

Step 7: Do the same as from step 3 to step 6 to create a new edge node from region b to region a.

5.3. Automatic Selection of the Initial Seed

To apply random walk algorithm to tongue image segmentation, we first need to specify the initial seed where the segmentation starts. Here, we suggest a kind of automatic selection of the seed. Generally speaking, the tongue region usually lies in the middle of the original image. Therefore, we take the maximal region as the seed in which the average of the distances of pixels is closest to the center of the original image.

5.4. Description of Random Walk Algorithm

When weighted-graph is built, we can apply random walk algorithm to final segmentation. The basic thinking of random walk algorithm is to make clustering of regions with similar features or small differences and the features and differences are described by the weight values among regions nodes. That is to say, if the weight value between 2 region nodes are smaller than a certain threshold, we can expand the target region from the one region to the other one. The description of random walk algorithm is shown as following.

Step 1: Find the initial seed in the original image using the method described in previous section.

Step 2: Initialize the elements of visit array to all false.

Step 3: If current seed is not visited, continue the following steps.

Step 4: Set the visit tag of current seed to true.

Step 5: Record current seed region and add this seed region to target region.

Step 6: For all adjacent nodes of current seed, if the weight between current seed and adjacent node is smaller than a certain threshold, execute step 3 to step 6 recursively.

6. Experiment Results and Analyses

In the experiment, we utilize Visual C++ to implement our improved random walk algorithm mentioned above and the traditional random walk algorithm. And we utilize both our improved random walk algorithm which contains 4 steps and traditional random walk algorithm which takes intensity as main segmentation factor to segment the tongue images. The experiment data are five typical tongue images the colors of which are light red, light white, red, deep red and purple red respectively. The colors of these five tongue images include all the typical types of tongues. So the results of the experiment can be persuasive. The results of the experiment are shown as Figure 8.

As we can see from the results of tongue image segmentation, our method achieves basically ideal segmentation effects in the 5 segmentation tests. The edges of our segmentation result images basically conform to the edges of the tongues. Nevertheless, traditional random walk algorithm makes a mess. As the Figure 8(d) and Figure 8(h) show, the segmentation result images of light red tongue and light white tongue are smaller than the actual size of the tongues. These results owe much to that the traditional method takes only intensity as the segmentation factor. As the Figure 8(l) shows, the segmentation result image of red tongue is quite wrong, which contains non-tongue parts of the image, such as mouth and face. The reason why the segmentation result image contains non-tongue parts may be that the intensity of the tongue and that of mouth and face are quite similar. And as the Figure 8(t) shows, even if we apply mathematical morphology operations to the target image, the big hollow in the tongue region is still difficult to fill in. The cause of this result may be that the intensity values in the center of the purple red tongue are quite different from the surroundings of the tongue.

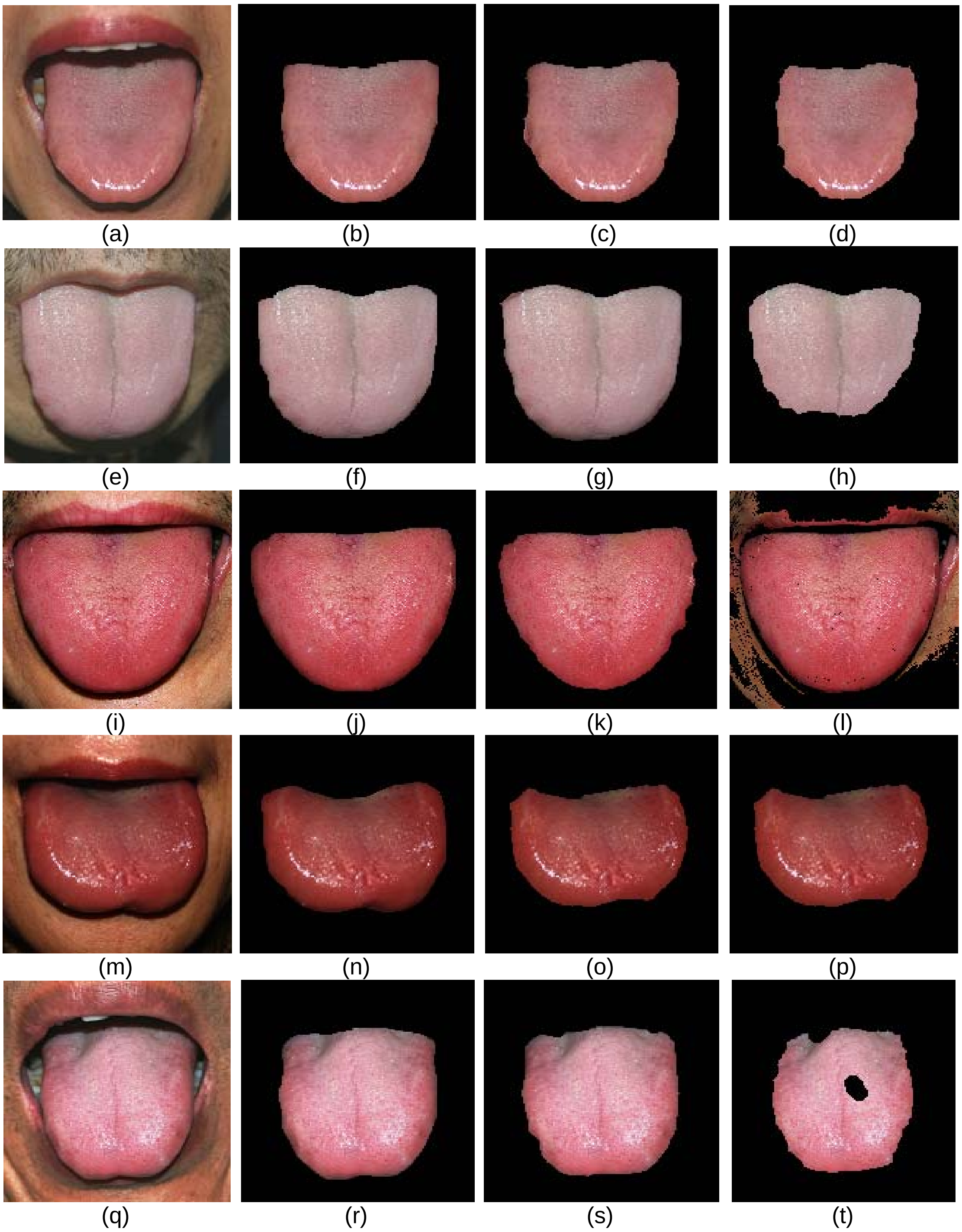


Figure 8. Results of Tongue Image Segmentation (a) light red tongue, (b) light red tongue manual segmentation result, (c) light red tongue segmentation result by our method, (d) light red tongue segmentation result by traditional method, (e) light white tongue, (f) light white tongue manual segmentation result, (g) light white tongue segmentation result by our method, (h) light white tongue segmentation result by traditional method, (i) red tongue, (j) red tongue manual segmentation result, (k) red tongue segmentation result by our method, (l) red tongue segmentation result by traditional method, (m) deep red tongue, (n) deep red tongue manual segmentation result, (o) deep red tongue segmentation result by our method, (p) deep red tongue segmentation result by traditional method, (q) purple red tongue, (r) purple red tongue manual segmentation result, (s) purple red tongue segmentation result by our method, (t) purple red tongue segmentation result by traditional method.

To evaluate the effects of the results of both our improved random walk method and traditional random walk method objectively and quantitively. We introduces 2 measurement values. One is recognition rate and the other is error rate. The recognition rate η and error rate ε can be denote as following:

$$\eta = \frac{TP}{TP + FN} \tag{4}$$

$$\varepsilon = \frac{FP}{FP + TP} \tag{5}$$

Herein, TP is the number of pixels which are correctly recognized as tongue pixels, FN is the number of pixels which are tongue pixels but incorrectly recognized as background pixels and FP is the number of pixels which are background pixels but incorrectly recognized as ongue pixels. The recognition rates and error rates of image segmentation tests are shown as Table 1.

Table 1. The Recognition Rates and Error Rates of Image Segmentation Tests

Metho \ Tongue		Light red tongue	Light white tongue	Red tongue	Deep red tongue	Purple red tongue
Our method	Recognition rates	96.98%	99.90%	94.68%	87.45%	95.89%
	Error rates	0.99%	2.98%	0.29%	1.21%	0.86%
Traditional method	Recognition rates	87.98%	80.19%	99.99%	87.45%	82.28%
	Error rates	0.03%	0.24%	28.80%	1.23%	0.03%

As Table 1 shows, most of the recognition rates of our method are much higher than those of traditional method and the error rates of our method are quite low. When it comes to red tongue segmentation test, although the recognition rate of traditional method is a little higher than that of our method, the error rate of the traditional method is much larger than that of our method. Therefore, the segmentation effects of our method are more accurate than those of the traditional method.

7. Conclusion

In this paper, an improved random walk algorithm for color tongue image segmentation is introduced. The improved algorithm contains 4 steps to segment tongue images. We adopt a kind of improved toboggan algorithm to make initial segmentation and produce initial regions. Then we construct a weighted-graph where only those adjacent regions are connected with weights. Further more, a method for automatic selection of the initial seed is proposed. In the end, we adopt random walk algorithm to make final segmentation of tongue image based on the compound weight function of intensity and hue. In the experiment, we utilize our improved algorithm and traditional algorithm to process 5 typical kinds of tongue images. As the experiment results show, our method achieves basically ideal segmentation results, but the traditional method makes a mess.

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