Firefly Optimization Based Multilevel Segmentation of Tongue Images

1Rakoth Kandan S, 2Jayapriya D and 3Sasikala J

1Research Scholar, Computer Science and Engineering, Annamalai University, INDIA.
2Technology Education Team Lead, Accenture Solutions Pvt. Ltd., Chennai, INDIA.
3Assistant Professor, Information Technology, Annamalai University, INDIA.

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ABSTRACT
Background: Multilevel segmentation is an important task in the analysis, interpretation and understanding of images, and widely applied for classification and object recognition in many applications. Objective: The prime objective of the paper is to build Firefly Optimization (FFO), inspired by social flashing behavior of fireflies, based method for performing multilevel segmentation of tongue images. Results: The proposed method is applied on two tongue images and the results are compared with that of the existing method. Conclusion: The proposed method is able to offer better segmented results than that of the existing method.

KEYWORDS: Image processing Segmentation Tongue images Firefly optimization

INTRODUCTION

Tongue diagnosis is a simple and non-invasive way to identify the body condition / state and symptoms of the patient in traditional Chinese medicine (TCM) for determining the actual disease or deficiency in the patient where a physician visually examines the color and other properties of the substance and coating of the tongue through listening, smelling, inquiry and palpation [1-4].

In TCM, the tongue can be partitioned into five regions as indicated in Fig. 1. Each divided regions acts like a mirror of different organs of the human body as listed in Table 1 [4, 5]. For instance, the pathological changes of the bowel can reflect in the root (R1) region of the tongue. Rapid change can be observed in these regions with the development of the diseases.

The large variations in the color of different tongue regions and the coatings indicate the various diseases of the concerned organs. The diagnosis through observing the tongue regions’ colour and coating is usually based on the physician’s vision and his years of experience [6-10]. The surrounding illuminations may also affect the visual observation of the tongue. However, ambiguity and subjectivity are associated with the diagnostic results that may be fuzzy and uncertain.

There is thus a need to build computer aided diagnostic tool that acquires true-color tongue images that are invariant to illumination changes and performs automatic analysis of tongue properties [4,8,11] through segmentation, feature extraction and disease classification with a view of eliminating these qualitative aspects and minimizing the physical harm inflicted to patients unlike the diagnostic procedures in western medicine.

Recently, various tongue diagnostic systems have been developed to support acquisition, processing, analysis, storage and retrieval of tongue images [5,4, 12-15]. They include: a vision-based tongue diagnosis system using the local RGB color mean metric [13]; a tongue diagnosis supporting system based on quantized color class labels [14]; a computerized tongue examination system using a color relaxation approach with...
decision boundaries in HSV color space [5]; and a digital tongue inspection system based on RGB color histogram approach [15].

![Partition of a tongue](image)

**Fig. 1:** Partition of a tongue

**Table 1:** Various region of tongue linked to different organs

<table>
<thead>
<tr>
<th>Region</th>
<th>Organs</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 (root)</td>
<td>stomach</td>
</tr>
<tr>
<td>R2 (middle / center)</td>
<td>spleen</td>
</tr>
<tr>
<td>R3 (tip)</td>
<td>heart and lungs</td>
</tr>
<tr>
<td>R4 (right side)</td>
<td>liver</td>
</tr>
<tr>
<td>R5 (left side)</td>
<td>gall bladder</td>
</tr>
</tbody>
</table>

An approach to automatically recognize tongue shapes based on seven geometry features that includes length, area, and angle extracted from tongue images has been suggested in [16]. The approach uses a support decision tool to weight the relative influences of the geometry features and classify tongue image into one of six tongue shapes, namely, hammer, rectangle, acute triangle, obtuse triangle, square, and round. The shape of a human tongue and its relation to a patients’ state, either healthy or diseased has been quantitatively analyzed using geometry features by means of computerized methods in [17]. The method extracts thirteen geometry features based on measurements, distances, areas, and their ratios from tongue images and classifies the tongue shapes into rectangle, acute and obtuse triangles, square, and circle.

It is well known fact that the segmentation of color image demonstrates to be more useful than the segmentation of gray scale image, because color image expresses much more image features than gray scale image. In fact, each pixel is characterized by a great number of combination of R, G, B chromatic components. The segmentation of tongue images would have been more effective, if segmentation is performed considering the rich chromatic information in all the three color channels of tongue images. However, it requires the computational cost considerably higher than that needed for gray scale image, but it is no longer a major problem with the increasing speed of computation. In fact, there has been a remarkable growth of techniques for the segmentation of color images in this decade [18, 19]. A dragonfly optimization (DFO), a population based meta-heuristic optimization algorithm that simulates the static and dynamic swarming behaviors of dragonflies, has been applied for performing multilevel segmentation of gray scale images [20].

Recently, firefly optimization (FFO), inspired by the light attenuation over the distance and fireflies’ mutual attraction rather than the phenomenon of the fireflies’ light flashing, has been suggested for solving optimization problems [21,22], and found to yield satisfactory results on engineering optimization problems [23-25]. The goal of this paper is to build a multilevel thresholding based method for segmenting the tongue images in RGB colour space by modifying the DFO based gray scaled segmentation method [20]. The paper is organized with four sections containing introduction, proposed method (PM), results and discussions, and conclusion.

**Proposed Method:**

This section describes a FFO based multilevel segmentation method for tongue images. The PM is an extension of the segmentation method suggested by the authors in [16] with a view of processing the R, G, B
chromatic components of tongue images. It involves representation of decision variables and formation of a fitness function.

Each chromatic channel of RGB tongue image is divided into $nc$ number of classes by $nc-1$ number of thresholds of $\{T_1, T_2, \ldots, T_{nc-1}\}$. These thresholds act as separators between the consecutive classes of $\{C_1, C_2, \ldots, C_{nc}\}$ in the range of threshold values of $\{0, \ldots, T_1, \ldots, T_2, \ldots, [T_{nc-1}+1, \ldots, L]\}$ for each chromatic channel, where $L$ is the maximum pixel intensity value of the digital image. In the PM, each $i$-th firefly $f_i$ is defined to denote the threshold levels of all the three colour spaces as decision variables as

$$f_i = \{f_i^1, f_i^2, \ldots, f_i^{3(nc-1)}\} = \left\{T_1^R, T_2^R, \ldots, T_{nc-1}^R; T_1^G, T_2^G, \ldots, T_{nc-1}^G; T_1^B, T_2^B, \ldots, T_{nc-1}^B\right\}$$

(1)

The search space is limited by the following inequality

$$0 \leq f_i^k \leq 255 : k = 1, 2, \ldots, 3(nc - 1) \quad (2)$$

Initially, the positions of the $i$-th firefly are generated from a uniform distribution using the following equation

$$f_i^k = 255 \times \text{rand} : k = 1, 2, \ldots, 3(nc - 1) \quad (3)$$

Here, $\text{rand}$ is a random number between 0 and 1, taken from a uniform distribution. Eq. (3) generates random values from a uniform distribution within the prescribed range defined by Eq. (2).

The light intensity of the $i$-th firefly, $LI_i$, is written based on Kapur’s entropy as

$$\text{Maximize } LI_i = \sum_{\text{colour}\in\{R,G,B\}} \left\{ \sum_{k=1}^{nc} H_k^{\text{colour}} \right\} \quad (4)$$

Where $H_k^{\text{colour}}$ represents $k$-th entropy of the selected colour channel of RGB tongue image and is evaluated by

$$H_1^{\text{colour}} = \sum_{j=0}^{T_1^{\text{colour}}} p_j^{\text{colour}} \ln\left(\frac{p_j^{\text{colour}}}{\chi_1}\right) \quad ; \quad \chi_1 = \sum_{j=0}^{T_1^{\text{colour}}} p_j^{\text{colour}}$$

$$H_2^{\text{colour}} = \sum_{j=T_1^{\text{colour}}+1}^{T_2^{\text{colour}}} p_j^{\text{colour}} \ln\left(\frac{p_j^{\text{colour}}}{\chi_2}\right) \quad ; \quad \chi_2 = \sum_{j=T_1^{\text{colour}}+1}^{T_2^{\text{colour}}} p_j^{\text{colour}}$$

$$H_{nc}^{\text{colour}} = \sum_{j=T_{nc-1}^{\text{colour}}+1}^{L} p_j^{\text{colour}} \ln\left(\frac{p_j^{\text{colour}}}{\chi_{nc}}\right) \quad ; \quad \chi_{nc} = \sum_{j=T_{nc-1}^{\text{colour}}+1}^{L} p_j^{\text{colour}}$$

$$colour \in \{R,G,B\}$$

(5)

$p_j^{\text{colour}}$ represents probability distribution at $j$-th intensity level of the selected chromatic channel of RGB tongue image and is calculated by

$$p_j^{\text{colour}} = \frac{h_j^{\text{colour}}}{np} \quad ; \quad j \in \{0,1,\ldots,L\} ; \quad colour \in \{R,G,B\}$$

$h_j^{\text{colour}}$ indicates number of pixels that corresponds to $j$-th intensity level of the selected chromatic channel of R, G and B.

$np$ is the total number of pixels in the image.

$\chi_j$ denotes the probability of set $C_j$.
The attractiveness between the $i$-th and $j$-th firefly, $\beta_{i,j}$, is given by

$$\beta_{i,j} = \beta_o \exp\left(-\gamma r_{i,j}^2\right)$$

(7)

Where $r_{i,j}$ is the Cartesian distance between $i$-th and $j$-th firefly

$$r_{i,j} = \sqrt{\sum_{k=1}^{nd} (f_{i,k} - f_{j,k})^2}$$

(8)

$\beta_o$ is a constant taken to be 1. $\gamma$ is another constant whose value is related to the dynamic range of the solution space. The position of firefly is updated in each iterative step. If the light intensity of $j$-th firefly is larger than the intensity of the $i$-th firefly, then the $i$-th firefly moves towards the $j$-th firefly and its motion at $t$-th iteration is denoted by the following equation:

$$f_i(t) = f_i(t-1) + \beta_{i,j}(f_j(t-1) - f_i(t-1)) + \alpha(rand - 0.5)$$

(9)

$\alpha$ is a random movement factor, whose value depends on the dynamic range of the solution space. At each iterative step, the intensity and the attractiveness of each firefly is calculated. The intensity of each firefly is compared with all other fireflies and the positions of the fireflies are updated using Eq. (9). After a sufficient number of iterations, all the fireflies converge to the same position in the search space and the global optimum is achieved. The algorithm of the PM is outlined below.

Read the tongue image
Choose the FFO parameters such as number of fireflies, $nf$, in the population
Generate the initial population of fireflies, as represented by Eqs. (1-3).
Set the iteration counter $t = 0$
while (termination requirements are not met) do
   for $i = 1:nf$
      Evaluate $L_I$ using Eq. (4)
      for $j = 1:nf$
         Evaluate $L_J$ using Eq. (4)
         if $L_I > L_J$
            Compute $r_{ij}$ using Eq. (8)
            Evaluate $\beta_{ij}$ using Eq. (7)
            Move $j$-th firefly towards $i$-th firefly through Eq. (9)
         end-(if)
      end-(j)
   end-(i)
Rank the fireflies and find the current best.
end-(while)

RESULTS AND DISCUSSIONS

Two tongue images have been considered for testing the PM. The images are resized to have a width of 512 pixels with the height proportionally adjusted so as to have the true shape of the original image. The results of the two tongue images for segmented levels of 2, 3, 4, 5 and 6 have been obtained by the existing method (EM) explained in [20] in addition to the PM with a view of comparing the results. The results of both the methods have been presented in Table 2 and 3 for image 1 and 2 respectively.
Table 1: Results for Tongue Image-1

<table>
<thead>
<tr>
<th>Level</th>
<th>Threshold values</th>
<th>Segmented Colour Image</th>
<th>Segmented Colour Image in Gray Scale</th>
<th>Threshold values</th>
<th>Segmented Gray Scale Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>115 84 197</td>
<td></td>
<td></td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>84 178 66 145 58 135</td>
<td></td>
<td></td>
<td>68 148</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>59 134 196 50 112 166 43 102 153</td>
<td></td>
<td></td>
<td>55 123 175</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>40 99 159 204 43 99 142 189 18 108 116 128</td>
<td></td>
<td></td>
<td>37 90 138 181</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>31 76 127 171 209 29 74 116 151 194 31 74 109 140 173</td>
<td></td>
<td></td>
<td>32 79 125 161 197</td>
<td></td>
</tr>
</tbody>
</table>

These table also include the original RGB and gray scale converted tongue images. The threshold values for the PM are given in second column of the tables, while for the EM, they are given in the fifth column of the tables. It can be observed that the segmented colour image, given in third column of the table, conveys more accurate information than that of the segmented gray image given in the last column of the table. The segmented colour images are also converted into gray scale images and presented in fourth column of the tables. The visual comparison of gray scale images of the PM with those of the EM also ensures that the PM is able to make better segmentation. The visual analysis of these results clearly indicate that the segmented results are better with more number of threshold levels.
Table 2: Results for Tongue Image-2

<table>
<thead>
<tr>
<th>Level</th>
<th>Threshold values</th>
<th>Segmented Colour Image</th>
<th>Threshold values</th>
<th>Segmented Grey Scale Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>151 112 22</td>
<td></td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>107 178 69 130 77 145</td>
<td></td>
<td>86 150</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>88 157 200 58 107 147 66 122 164</td>
<td></td>
<td>69 123 163</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>67 129 172 207 50 94 124 158 42 93 130 168</td>
<td></td>
<td>50 101 136 170</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60 116 155 184 212 36 77 105 131 163 35 82 116 144 177</td>
<td></td>
<td>44 91 123 148 178</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion:
FFO is a meta-heuristic optimization technique imitated from the social flashing behaviour of fireflies. An elegant FFO based methodology for performing multilevel segmentation of colour tongue images has been presented. The multilevel segmentation problem has been tailored as an optimization problem and solved using the FFO. The method has been applied on two tongue images with a view of demonstrating the superiority of the developed method. It has been found from the results that the PM effectively yields better segmented results than that of performing segmentation after converting the image into gray scale. The method can be modified to classify various diseases from the features of segmented tongue results.
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REFERENCES