A Color Image Segmentation Approach Based on Fuzzy Similarity Measure

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Abstract - In this paper, we proposed a new image segmentation scheme based on fuzzy color similarity measure to segment out meaningful objects in an image according to human perception. The proposed method first defines a set of fuzzy colors based on the HLS color coordinate space. Each pixel in an image is represented by a set of fuzzy colors that are the most similar colors in the color palette selected by human. Then, a fuzzy similarity measure is developed for evaluating the similarity of fuzzy colors between two pixels. We recursively merge adjacent pixels to form meaningful objects by the fuzzy similarity measure until there is no similar color between adjacent pixels. The experiments demonstrate that the proposed method can extract meaningful objects from images effectively.

Keywords: image segmentation, fuzzy colors, fuzzy similarity measure

1. INTRODUCTION

Image segmentation is one of the important and preliminary processes in many applications of images, such as content-based image retrieval, image understanding, and pattern recognitions. Image segmentation is a process of partitioning an image into regions such that each region is homogeneous and stands for a meaningful object for users. However, it is a rather difficult problem to perform a perfect segmentation in a color image. Although many color image segmentation algorithms have been proposed in the past few decades [1, 2, 3, 4], the results are still not ideal enough for human visual perception.

A color image is usually represented by the RGB color coordinate system, and most of the traditional segmentation algorithms for color images use Minkowski’s r-metric [7], e.g. Euclidean distance, to compute the similarity of colors in the process of segmentation. However, the RGB color coordinate system and Euclidean metric cannot model human visual perception on colors. That is the reason why the segmented results of traditional segmentation algorithms are usually far from human visual perception and unable to capture high-level concepts of real objects appropriately.

In this paper, we propose a color image segmentation approach based on the HLS color coordinate system. We first design a set of fuzzy colors based on the HLS color coordinate system. A set of membership functions including hue, lightness and saturation are defined and used to form fuzzy colors. Each pixel in an image is represented by a set of fuzzy colors that is defined in the color palette selected by the user. Then, a fuzzy similarity measure is developed to evaluate the degree of similarity between two fuzzy colors of pixels. Based on the fuzzy color similarity measure, the adjacent pixels are merged recursively and the meaningful objects will be segmented out from an image. The experimental results show that our method can extract meaningful objects from images effectively.

This paper is organized as follows. We will review some important related researches in Section 2. In Section 3, we briefly introduce the HLS color coordinate system. Section 4 depicts the fuzzy color membership functions used in this paper and similarity measure of fuzzy colors. Section 5 gives the detailed algorithm of image segmentation based on the fuzzy color similarity measure. The experimental results are shown in Section 6. At last, we make a summary and outline the future work.

2. REVIEW OF RELATED RESEARCHES

In the past few years, many color image segmentation techniques have been developed. We summarize some important researches in this section and show their problems in common.

Zhong et al. [2] proposed a color image segmentation method based on fuzzy clustering. They segment color images by color space analysis and fuzzy c-means. We summarize their approaches as follows:

Step 1: Computing a proper number of colors in the RGB coordinate system.
Step 2: Estimating initial center positions of the clusters.
Step 3: Using fuzzy c-means algorithm to refine the center positions of the clusters obtained in Step 2 optimally.
Step 4: According to clusters obtained in Step 3, input color image can be segmented into sub-images thus color segmentation achieved.

In this method, before using fuzzy c-means algorithm to refine the center positions of the clusters, this method applies pyramid method and low-pass filter to reduce the number of color space objects to be less than seven. Then, the fuzzy c-means algorithm based on Euclidean distance is used to refine centers of clusters optimally. It is not appropriate for an image containing more than seven objects to do segmentation by this method. Because an image will never be segmented to be more than seven color
Another color image segmentation method proposed by Deng et al. [3] is called JSEG. The key steps of their method are summarized as follows:

Step 1: Quantizing colors in an image to several representative classes.

Step 2: Assigning a representative class label to each image pixel and building a class-map of the source image.

Step 3: Using class-map to obtain possible region boundaries and region centers.

Step 4: Region growing to segment the image.

Step 5: Using agglomerate method to merge the regions due to over segmentation.

This method defined a measure, called measure J, to measure the distances between different classes. The measure J is Euclidean distance based. In the process of merging regions, this method uses Euclidean distance again to calculate the distances between two neighboring regions. This method needs high cost of computation time if an image contains a large number of regions.

The other effective method proposed by Chang et al. [4] uses block-based color segmentation approach [5] to segment out the significant objects in an image. We summarize their method as follows:

Step 1: Quantizing images to lower resolution blocks.

Step 2: Assigning a representative color to each block, which is the mean color value of all pixels falling in the block.

Step 3: Using stepwise-optimal agglomerative clustering algorithm to merge regions iteratively until a single region is reached.

Step 4: Determining the best number of regions.

Step 5: Merging adjacent blocks recursively into regions until the best number of regions in Step 4 is reached.

This method based on Euclidean distance of the RGB color space to segment input color images. The results of segmentation are the regions having similar color values of RGB, but not real objects.

The common characteristics of above approaches are that they use the RGB color coordinate system and Euclidean distance to be the fundamental of image processing. However, the RGB color coordinate system and Euclidean distance cannot model human visual perception on color. Thus, the segmentation results are not satisfied by visual perception.

3. THE HLS COLOR COORDINATE SYSTEM

Color images are usually represented in the RGB color coordinate format. However, the RGB color coordinate system does not model the human perception on color. The human recognize color by hue, lightness, and saturation. In measuring similarity of color, a color coordinate system described by hue, lightness, and saturation is more appropriate than the RGB color coordinate system. In this paper, the color coordinate system we used for measuring similarity of colors is the HLS [6]. In our proposed fuzzy based segmentation system, tone plane for all hue is the same and is triangular form, we will slightly modify the transformation from RGB color coordinate system to HLS color coordinate system.

For a given color \((R, G, B)\) represented by the RGB color coordinate system, the values of \(R, G, \) and \(B\) are all integers in the range of \([0, 255]\) and represent the values of red, green and blue, respectively. We define the relative intensity value \((r, g, b)\) of \((R, G, B)\) to be:

\[
\begin{align*}
    r &= \frac{R}{255}, \\
    g &= \frac{G}{255}, \\
    b &= \frac{B}{255}.
\end{align*}
\]

Let \(I_{\text{max}} = \max \{r, g, b\}\) and \(I_{\text{min}} = \min \{r, g, b\}\). The values of hue\((H)\), lightness\((L)\) and saturation \((S)\) can be transformed from the values of \(R, G\) and \(B\) by the following formulas:

\[
\begin{align*}
    H &= \begin{cases} 
    60\left(\frac{g - b}{I_{\text{max}} - I_{\text{min}}}\right) & \text{if } r = I_{\text{max}} \\
    60\left(2 + \frac{b - r}{I_{\text{max}} - I_{\text{min}}}\right) & \text{if } g = I_{\text{max}} \\
    60\left(4 + \frac{r - g}{I_{\text{max}} - I_{\text{min}}}\right) & \text{if } b = I_{\text{max}} \\
    \text{undefined} & \text{if } I_{\text{max}} = I_{\text{min}}
    \end{cases} \\
    L &= \max \left\{I_r, I_g, I_b\right\} \\
    S &= \max \left\{I_r - I_{\text{min}}, I_b - I_{\text{min}}, I_g - I_{\text{min}}\right\}.
\end{align*}
\]

\[
\begin{align*}
    H &= H + 360 \quad \text{if } H < 0 \\
    L &= \max \left\{\frac{L_{\text{max}} + L_{\text{min}}}{2} \right\} \\
    L^* &= \begin{cases} 
    0 & \text{if } L_{\text{max}} = L_{\text{min}} \\
    \frac{L - 0.5}{0.5} & \text{if } L \leq 0.5 \\
    \frac{1 - L_{\text{max}} - L_{\text{min}}}{2} & \text{if } L_{\text{max}} = L_{\text{min}} \\
    L^* & \text{otherwise}
    \end{cases}
\end{align*}
\]

4. THE ANALYSIS OF FUZZY COLORS

Kawamura et al. [9] utilized color attributes hue and tone to design a fuzzy based approach for color specification. Sugano [8] made use of color attributes including hue and tone to design expression model of subjective color impressions. The usage of color attributes hue and tone to reflect human’s subjectivity is easier than the RGB color space system. Hence, we define fuzzy colors based on the combination of hue and tone to construct fuzzy colors.

In our proposed system, fuzzy colors are composed by hue and tone. Tone is constructed by lightness and saturation. Given a specified color we use triangular membership functions to calculate membership grades according to the pre-defined fuzzy set of hue. Triangular membership functions are also applied to calculate membership grades.
relative to the fuzzy sets of lightness and saturation. Then we combine fuzzy sets of lightness and saturation into the fuzzy set of tone. After that, the fuzzy set of hue is combined with the fuzzy set of tone to construct fuzzy colors. We also design a fuzzy similarity measure to compute the similarity between two fuzzy colors. The fuzzy similarity measure will be presented in sub-section 4.4.

4.1 THE FUZZY SET OF HUE

Let \( H = \{H_i \mid i = 1, 2, ..., h\} \) be the set of predefined hues given by users. For a hue \( H_i \), the fuzzy set of \( \tilde{H} \) is represented as

\[
\tilde{H} = \sum_{i=1}^{h} \mu_{Hi}(x) / H_i,
\]

where \( x \) is the value of the hue \( H \) defined in (1) and (2). The membership degree of the fuzzy hue for a specified \( H_i \) is characterized by the function \( \mu_{Hi} \) with two parameters, \( a_i \) and \( p_i \), as follows

\[
\mu_{Hi}(x) = \begin{cases} 
\frac{1}{p} \left| \frac{x - a_i}{p} \right| & \text{if } a_i - p_i \leq x \leq a_i + p_i; \\
0 & \text{otherwise},
\end{cases}
\]

as shown in Figure 1.

4.2 THE FUZZY SET OF TONE

In the proposed fuzzy color system, since tone is constructed by lightness and saturation, we first define the fuzzy sets of lightness and saturation and then combine the two fuzzy sets to be the fuzzy set of tone.

Let \( L = \{L_i \mid i = 1, 2, ..., l\} \) be the set of predefined lightnesses. For a lightness \( L_i \), the fuzzy set of \( \tilde{L} \) is represented as

\[
\tilde{L} = \sum_{i=1}^{l} \mu_{Li}(y) / L_i,
\]

where \( y \) is the value of the lightness \( L \) defined in (3). The membership degree of the fuzzy lightness for a specified \( L_i \) is characterized by the function \( \mu_{Li} \) with two parameters, \( b_i \) and \( q_i \), as follows

\[
\mu_{Li}(y) = \begin{cases} 
1 - \left| \frac{y - b_i}{q_i} \right| & \text{if } b_i - q_i \leq y \leq b_i + q_i; \\
0 & \text{otherwise},
\end{cases}
\]

Let \( S = \{S_i \mid i = 1, 2, ..., s\} \) be the set of predefined saturations. For a saturation \( S_i \), the fuzzy set \( \tilde{S} \) is represented as

\[
\tilde{S} = \sum_{i=1}^{s} \mu_{Si}(z) / S_i,
\]

where \( z \) is the value of saturation \( S \) defined in (4). The membership degree of the fuzzy saturation for a specified \( S_i \) is characterized by the function \( \mu_{Si} \) with two parameters, \( c_i \) and \( r_i \), as follows

\[
\mu_{Si}(z) = \begin{cases} 
\frac{1}{r_i} |z - c_i| & \text{if } c_i - r_i \leq z \leq c_i + r_i; \\
0 & \text{otherwise}.
\end{cases}
\]

4.2.1 THE FUZZY SIMILARITY MEASURE

The fuzzy similarity measure to compute the similarity between two fuzzy colors. We also design a fuzzy similarity measure to compute the similarity between two fuzzy colors. The fuzzy similarity measure will be presented in sub-section 4.4.

After the fuzzy set of lightness and saturation are defined, we use the two fuzzy sets to compose the fuzzy set of tone. We observe that the definition of saturation in equation (4) is dependent on lightness.

The composite result of \( S \) and \( L \) will be located inside a triangular area instead of crossed rectangle on the tone plane. The outside area of the triangular tone plane will never appear in this color system. We first granulate the saturation and lightness space using the fuzzy sets defined in equations (7) and (9). For the corresponding of saturation variable \( S_i, 1 \leq i \leq s \), in the fuzzy set \( \mu_S \), each \( S_i \) is separated by the fuzzy set of lightness \( \mu_L \) into several tone regions. Owing to the dependent relationships between saturation and lightness, the separations will decrease in number when the value of saturation \( S \) is getting larger, as shown in Figure 2.

Assume that the tone plane is divided into several tone regions by fuzzy sets \( L \) and \( S \). Let \( T_{ij} \) be the region composed by \( L_i \) and \( S_j \) inside the triangular tone plane. The fuzzy set of tone \( \tilde{T} \) is represented as

\[
\tilde{T} = \sum_{T_{ij} \text{ are Tone regions}} \mu_{T_{ij}}(y, z) / T_{ij}
\]

We further define the membership functions for the fuzzy
set of tone as the product of the membership grade of lightness and the membership grade of saturation.

\[ \mu_{y_j}(y, z) = \mu_{L_j}(y) \cdot \mu_{S_j}(z) \]  

where \( y \) and \( z \) as defined in equations (3) and (4), respectively. \( \mu_{S_j} \) and \( \mu_{y_j} \) are the membership functions defined in equations (8) and (10), respectively.

For example, as in Figure 2, we can generate 17 fuzzy tones by the definitions of five fuzzy lightness \( L_1, \ldots, L_5 \) and five fuzzy saturation \( S_1, \ldots, S_5 \). The fuzzy saturation \( S_1 \) and \( S_2 \) are separated into 5 fuzzy tones, respectively, including \( T_{11}, T_{12}, T_{13}, T_{14}, T_{15} \) and \( T_{21}, T_{22}, T_{23}, T_{24}, T_{25} \). Similarly, \( S_3 \) and \( S_4 \) are separated into 3 fuzzy tones by \( L_2, L_3, L_4 \), respectively, and \( S_5 \) can only join with \( L_1 \) to be \( T_{53} \). We will have the following fuzzy set of tone.

\[ \tilde{T} = \{ \mu_{T_{11}}(y, z)T_{11} + \mu_{T_{12}}(y, z)T_{12} + \mu_{T_{13}}(y, z)T_{13} + \mu_{T_{14}}(y, z)T_{14} + \mu_{T_{15}}(y, z)T_{15} + \mu_{T_{21}}(y, z)T_{21} + \mu_{T_{22}}(y, z)T_{22} + \mu_{T_{23}}(y, z)T_{23} + \mu_{T_{24}}(y, z)T_{24} + \mu_{T_{25}}(y, z)T_{25} + \mu_{T_{31}}(y, z)T_{31} + \mu_{T_{32}}(y, z)T_{32} + \mu_{T_{33}}(y, z)T_{33} + \mu_{T_{34}}(y, z)T_{34} + \mu_{T_{43}}(y, z)T_{43} + \mu_{T_{44}}(y, z)T_{44} + \mu_{T_{53}}(y, z)T_{53} \} \]

4.3 FUZZY COLORS

In sub-section 4.1 and 4.2, the membership degree of hue and tone have been defined. In this section, we will use fuzzy set of hue and tone to compose of fuzzy colors.

In our proposed system, a fuzzy color is constructed using a hue and a tone modifier. Assume that there are \( h \) hues and \( t \) tones. Let \( C = C_{ij} \) \( 1 \leq i \leq h \) and \( 1 \leq j \leq t \) be the set of fuzzy colors constructed by the \( h \) hues and \( t \) tones. The fuzzy set of fuzzy color \( \tilde{C} \) is represented as

\[ \tilde{C} = \sum_{i=1}^{h} \sum_{j=1}^{t} \mu_{C_{ij}}(x, y, z) / C_{ij} \]  

The membership degree for the fuzzy color are defined as follows

\[ \mu_{C_{ij}}(x, y, z) = \mu_{H_{ij}}(x) \cdot \mu_{T_{ij}}(y, z) \]  

where \( x \) is defined in equation (1) and (2). \( y \) and \( z \) are defined in equation (3) and (4), respectively. \( \mu_{H_{ij}} \) is defined in equation (6) and \( \mu_{T_{ij}} \) is defined in equation (12).

4.4 FUZZY COLOR SIMILARITY MEASURE

In our proposed system we designed a fuzzy similarity measure to calculate similarity between two fuzzy colors in an image. The fuzzy similarity measure is based on the membership grades of fuzzy color. For two given specified color \( \text{Color}_{1} = (R_1, G_1, B_1) \) and \( \text{Color}_{2} = (R_2, G_2, B_2) \), following the sub-section 4.1 the correspondence HLS coordination can be computed as \( C_1 = (h_1, l_1, s_1) \) and \( C_2 = (h_2, l_2, s_2) \) respectively.

From equations (13) and (14) the membership degrees of fuzzy color \( \tilde{C}_1 \) and \( \tilde{C}_2 \) are

\[ \tilde{C}_1 = \sum_{i=1}^{h} \sum_{j=1}^{t} \mu_{C_{ij}}(h_1, l_1, s_1) / C_{ij} \]

Then, the fuzzy similarity measure is defined as follow

\[ \text{Sim}(\tilde{C}_1, \tilde{C}_2) = \sum_{i=1}^{h} \sum_{j=1}^{t} \min(\mu_{C_{ij}}(h_1, l_1, s_1), \mu_{C_{ij}}(h_2, l_2, s_2)) \]

\[ \sum_{i=1}^{h} \sum_{j=1}^{t} \max(\mu_{C_{ij}}(h_1, l_1, s_1), \mu_{C_{ij}}(h_2, l_2, s_2)) \]

The value of \( \text{Sim}(\tilde{C}_1, \tilde{C}_2) \) is in the range of \([0, 1]\).

4.5 AN EXAMPLE

Assuming our fuzzy-based segmentation system selected color palette and tone modifier as Figure 3 and Figure 4 respectively. Table 1, 2 and 3 show the relative parameters. Given two specified color \( \text{Color}_1 = \text{RGB}(77, 255, 51) \) and \( \text{Color}_2 = \text{RGB}(51, 255, 26) \). We calculate color similarity using our selected color palette in the following.

The values of \((r, g, b)\) of colors \( \text{Color}_1 \) and \( \text{Color}_2 \) are computed as follows:

\((r_1, g_1, b_1) = (77, 255, 255, 51, 255) = (0.3, 1, 0.2)\)

\((r_2, g_2, b_2) = (51, 255, 255, 26, 255) = (0.2, 1, 0.1)\)

According to equations (1) and (2), the hues of \( \text{Color}_1 \) and \( \text{Color}_2 \) are computed as follows:

Hue of \( \text{Color}_1 = 112.5 \) Hue of \( \text{Color}_2 = 113.3 \)

The values of lightness of colors \( \text{Color}_1 \) and \( \text{Color}_2 \), according to equation (3), are computed as follows:

Lightness of \( \text{Color}_1 = 0.6 \) Lightness of \( \text{Color}_2 = 0.55 \)

The values of saturation of colors \( \text{Color}_1 \) and \( \text{Color}_2 \), according to equation (4), are computed as follows:

Saturation of \( \text{Color}_1 = 0.8 \) Saturation of \( \text{Color}_2 = 0.9 \)

Hence, the corresponding HLS color coordination of \( \text{Color}_1 \) and \( \text{Color}_2 \) are as follows:

\( \text{Color}_1 = (h_1, l_1, s_1) = (112.5, 0.6, 0.8) \)

\( \text{Color}_2 = (h_2, l_2, s_2) = (113.3, 0.55, 0.9) \)

From equations (5) and (6):

\( \tilde{H}_{h_1} = (0.25 / \text{YG} + 0.75 / \text{G}) \)

\( \tilde{H}_{h_2} = (0.223 / \text{YG} + 0.777 / \text{G}) \)

According to equations (7) and (8):

\( \tilde{L}_{l_1} = (0.6 / \text{L}_{l_1} + 0.4 / \text{L}_{l_4}) \)

\( \tilde{L}_{l_2} = (0.8 / \text{L}_{l_3} + 0.2 / \text{L}_{l_4}) \)

According to equations (9) and (10):

\( \tilde{S}_{s_1} = (0.8 / \text{S}_{s_4} + 0.2 / \text{S}_{s_3}) \)

\( \tilde{S}_{s_2} = (0.4 / \text{S}_{s_4} + 0.6 / \text{S}_{s_3}) \)

From equations (11) and (12):

\( \tilde{T}_{c_1} = (0.48 / \text{Hue} + 0.32 / \text{Br} + 0.12 / \text{Vi}) \)

\( \tilde{T}_{c_2} = (0.32 / \text{Hue} + 0.08 / \text{Br} + 0.48 / \text{Vi}) \)

From equations (13) and (14):

\( \tilde{C}_{c_1} = (0.12 / \text{YG, Hue} + 0.08 / \text{YB, Br} + 0.03 / \text{YB, Vi}) \)+ 0.36 / (G, Hue) + 0.24 / (G, Br) + 0.09 / (G, Vi))

\( \tilde{C}_{c_2} = (0.071 / \text{YG, Hue} + 0.018 / \text{YB, Br} + 0.107 / \text{YB, Vi}) \)+ 0.249 / (G, Hue) + 0.062 / (G, Br) + 0.373 / (G, Vi)) \)
Hence, according equation (15), the similarity between \textit{Color1} and \textit{Color2} is

$$\text{Sim}(\tilde{C}_1, \tilde{C}_2) = 0.071 + 0.018 + 0.03 + 0.249 + 0.062 + 0.09 = 0.406.$$ 

TABLE 1. PARAMETERS FOR SELECTED HUES

<table>
<thead>
<tr>
<th>Alias</th>
<th>Hue Name</th>
<th>Hue Angle</th>
<th>$p_i$</th>
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<tbody>
<tr>
<td>(H_1)</td>
<td>R</td>
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</tr>
<tr>
<td>(H_2)</td>
<td>RY</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>(H_3)</td>
<td>Y</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>(H_4)</td>
<td>YG</td>
<td>90</td>
<td>30</td>
</tr>
<tr>
<td>(H_5)</td>
<td>G</td>
<td>120</td>
<td>30</td>
</tr>
<tr>
<td>(H_6)</td>
<td>GC</td>
<td>150</td>
<td>30</td>
</tr>
<tr>
<td>(H_7)</td>
<td>C</td>
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<td>30</td>
</tr>
<tr>
<td>(H_8)</td>
<td>CB</td>
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<td>30</td>
</tr>
<tr>
<td>(H_9)</td>
<td>B</td>
<td>240</td>
<td>30</td>
</tr>
<tr>
<td>(H_{10})</td>
<td>BM</td>
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<td>30</td>
</tr>
<tr>
<td>(H_{11})</td>
<td>M</td>
<td>300</td>
<td>30</td>
</tr>
<tr>
<td>(H_{12})</td>
<td>MR</td>
<td>330</td>
<td>30</td>
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TABLE 2. PARAMETERS FOR SELECTED TONE MODIFIERS

<table>
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<th>Name</th>
<th>Abbreviation</th>
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<td>Block</td>
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<td>(T_{II})</td>
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<td>Dark Gray</td>
<td>DG</td>
<td>(T_{I})</td>
</tr>
<tr>
<td>Gray</td>
<td>Gr</td>
<td>(T_{II})</td>
</tr>
<tr>
<td>Light Gray</td>
<td>LG</td>
<td>(T_{III})</td>
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<td>Wh</td>
<td>(T_{V})</td>
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<tr>
<td>Very Dark</td>
<td>VD</td>
<td>(T_{V})</td>
</tr>
<tr>
<td>Dark Grayish</td>
<td>DI</td>
<td>(T_{VI})</td>
</tr>
<tr>
<td>Grayish</td>
<td>Gi</td>
<td>(T_{VII})</td>
</tr>
<tr>
<td>Light Grayish</td>
<td>LI</td>
<td>(T_{VIII})</td>
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<tr>
<td>Very Pale</td>
<td>VP</td>
<td>(T_{IX})</td>
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<tr>
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<td>(T_{X})</td>
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<td>(T_{XII})</td>
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<td>Deep</td>
<td>Dr</td>
<td>(T_{XIII})</td>
</tr>
<tr>
<td>Hue</td>
<td>Hue</td>
<td>(T_{XIV})</td>
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<tr>
<td>Bright</td>
<td>Br</td>
<td>(T_{XV})</td>
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<tr>
<td>Vivid</td>
<td>Vr</td>
<td>(T_{XVI})</td>
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TABLE 3. PARAMETERS FOR LIGHTNESS AND SATURATION

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<thead>
<tr>
<th>Granulations</th>
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<th>$c_i$ or $r_i$</th>
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<td>(S_2)</td>
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<td>0.25</td>
</tr>
<tr>
<td>(S_3)</td>
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<td>0.25</td>
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<tr>
<td>(L_0)</td>
<td>0</td>
<td>0.25</td>
</tr>
<tr>
<td>(L_1)</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>(L_2)</td>
<td>0.5</td>
<td>0.25</td>
</tr>
<tr>
<td>(L_3)</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td>(L_4)</td>
<td>1</td>
<td>0.25</td>
</tr>
</tbody>
</table>

5. THE COLOR IMAGE SEGMENTATION ALGORITHM

In sub-section 4.1 to 4.2, a set of membership functions including hue, lightness, saturation, and tone were defined. In sub-section 4.4, fuzzy color similarity measure was designed. After define fuzzy color similarity measure, we can utilize the defined membership functions and fuzzy color similarity measure to design our segmentation algorithm. The designed algorithm was a automatic segmentation algorithm. Let \(I_m\) be the input image. The proposed segmentation algorithm can be detailed as following:

\textbf{Algorithm: color image segmentation algorithm}

\textbf{Input}: a color image \(I_m\)

\textbf{Output}: A segmented image

1. Defining a set of fuzzy colors based on the HLS color coordinate space.
2. \(RGB(I_m) \rightarrow HLS(I_m)\)
3. for \(h←1\) to \(height(I_m)\)
4. \{ for \(w←1\) to \(width(I_m)\)
5. \{ for \(w′←1\) to \(width(I_m)\)
6. \{ for \(h′←1\) to \(height(I_m)\)
7. \{ Compute \(\text{Sim}\), equation (15), of pixels \(I_m(w, h)\) correspondence to its eight adjacency pixels.
8.  \} If \(\text{Sim} > 0\) then
9.  \{ Assign the same region id to \(I_m(w, h)\) and its correspondence adjacency pixel.
10. \} for \(h′←1\) to \(height(I_m)\)
11. \} for \(w←1\) to \(width(I_m)\)
12. \} for \(w′←1\) to \(width(I_m)\)
13. \}
14. \}

Figure 3. Example of hue angle.

Figure 4. Tone modifier.
In line 2, we transform colors of each pixel in input image $I_m$ from RGB color coordinate system to HLS color coordinate space. When line 3 to 9 are completed, each pixel in input image will be represented by a fuzzy color and has color attribute hue, lightness, and saturation. The fuzzy similarity measure is based on these color attributes.

Initially, each pixel in input image $I_m$ is regarded as a region. In line 14 we use the fuzzy similarity measurement, $Sim \in [0,1]$, for finding two adjacent regions with similarity color. Line 16 assigns the same region id to these two regions. Then, repeat line 10 to 18 to automatically segment out meaningful objects in input image.

6. EXPERIMENTAL RESULTS

The proposed method was implemented in C++ language on a personal computer with Intel Pentium 350 CPU and 128M RAM.

First, we selected twelve hues and seventeen tone modifiers, as shown in Figure 3 and Figure 4 respectively, to construct fuzzy color. Hue angle of red, denoted by $R$, is 0 degree and each other hues are 30 degrees apart. The experimental results are shown in Figure 5. In Figure 5, original images are shown in first and third columns and our experimental results are shown in second and fourth columns. Secondly, we selected six hues (red, yellow, green, cyan, red, magenta) and seventeen tone modifiers. Hue angle of red is 0 degree and each other hues are 60 degrees apart. Seventeen tone modifiers as shown in Figure 4. The experimental results are shown in Figure 6.

In this experimental, we attempt to select different hue set for different image applications. Because, the used colors of natural scene images are different from that of satellite images. The experimental results show that our method can extract meaningful objects from images effectively.

7. CONCLUSIONS

In this paper, we proposed a fuzzy-based approach for color image segmentation. Because of the RGB color coordinate system and Euclidean distance cannot model human perception on color. The proposed fuzzy model according the fact that the human recognizes color by hue, lightness, and saturation to design the system.

Our future work will extend this prototype system to image retrieval system. Then, focus on including other features such as shape, spatial relation, and texture.

REFERENCES


