Color Segmentation based on Human Perception Using Fuzzy Logic

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Abstract. Color segmentation is important in the field of remote sensing and Geographic Information System (GIS). Most of the color vision systems need to classify pixel color in a given image. Human perception-based approach to pixel color segmentation is done by fuzzy logic. Fuzzy sets are defined on the H, S and V components of the HSV color space. Three values (H, S and V), the fuzzy logic model has three antecedent variables (Hue, Saturation and Value) and one consequent variable, which is a color class ID are fuzzified with Triangular Fuzzy Numbering Method. Fuzzy Rules are constructed according to the linguistic fuzzy sets. One of Discrete Defuzzification method based on zero-order takagi-Sugeno model is used for color segmentation. To define the output color value, Fuzzy reasoning with zero order Takagi-Sugeno model is used for assigning the color of the given images.

Keywords: Color segmentation, Fuzzy Logic. Takagi-Sugeno model

1. Introduction

This research is the importance of the color segmentation in vision system. It also explains general structure of Color Segmentation System. Moreover, it shows that how to convert the RGB value of color image to HSV color space for further processing. The identification of the fuzzy set ranges for inputs and outputs of the system. This system is the first part of the computer vision system. It can be extended the color object detection application. And also sixteen output colors are used to define for color classification. For getting more accurate color classification, the system can extend to define more output colors. In this system, the machines task more challenging than human eye classify colors in the spectrum visible. This research is based on fuzzy logic modeling to segment an image via color space and the human intuition of color classification using HSV color space.

2. Color Segmentation System

Color is one of the major features in identifying objects, and color vision has been the most intensively studied sensory process in human vision. In machine vision, color has recently received attention as a useful property for image segmentation and object recognition. The purpose of color vision is to extract aspects of the spectral property of object surfaces, while at the same time discounting various illuminations in order to provide useful information in image analysis. The most notable applications include recognition and identification of colored objects and image segmentation [13].

3. Converting RGB to HSV

It is based on segmentation of the HSV color space using a fuzzy logic model that follows a human intuition of color classification. It predefines the segments using a fuzzy logic model, and divides the color space into segments based on linguistic terms. So the input RGB color space is required to convert to HSV model. RGB to HSV conversion formula is as in the following procedure: Firstly, the *R*, *G*, *B* values are divided by 255 to change the range from 0.255 to 0.1. And then *R*', *G*', *B*' are computed as following.

$$R' = R/255,\ G' = G/255,\ B' = B/255 \tag{1.1}$$

After that, maximum and minimum values among them are extracted as C_{max} and C_{min}.

$$C_{max} = \max(R', G', B') \tag{1.2}$$

$$C_{min} = \min(R', G', B') \tag{1.3}$$

The difference between C_{max} and C_{min} are computed as delta value for further processing.

$$\Delta = C_{max} - C_{min} \tag{1.4}$$

After finished calculating of these above parameters, Hue, Saturation and Value are defined as in equation 1.5, 1.6, and 1.7.

Hue calculation:

$$H\begin{cases} 60°\times\left(\frac{G'-B'}{\Delta} mod\, 6\right), Cmax=R' \\ 60°\times\left(\frac{B'-R'}{\Delta}+2\right), Cmax=G' \\ 60°\times\left(\frac{R'-G'}{\Delta}+4\right), Cmax=B' \end{cases} \quad (1.5)$$

Saturation calculation: $S = \Delta / C_{max}$ (1.6)

Value calculation: $V = C_{max}$ (1.7)

3.1 Fuzzy Color Identification

In this system, HSV color space each color is defined by three values (H, S and V), the fuzzy logic model has three antecedent variables (Hue, Saturation and Value) and one consequent variable, which is a color class ID. The domain of the variables Hue, Saturation and Value is the interval (0,240). The domain of the consequent variables discrete, and depends on the number of the predefined color classes.

There are 10 fuzzy sets for Hue, 5 fuzzy sets for Saturation and 4 fuzzy sets for Value. All membership functions are in the form of a triangular function. The fuzzy sets of the antecedent fuzzy variable Hue are defined based on 10 basic hues distributed over the 0 – 240 spectrum. The hues are Red, Dark Orange, Light Orange, Yellow, Light Green, Dark Green, Aqua, Blue, Dark Purple, Light purple. Saturation is defined using the five fuzzy sets Gray, Almost Gray, Medium, Almost Clear, and Clear. Value is defined using the four fuzzy sets Dark, Medium Dark, Medium Bright and Bright.

The fuzzy rules in this model are defined based on human observations. Since this model has 10 fuzzy sets for Hue, 5 for Saturation and 4 for Value, the total number of rules required for this model is 10 5 4=200.The reasoning procedure is based on a zero-order Takagi-Sugeno model, so that the consequent part or the output color of each fuzzy rule is a crisp discrete value of the set Black, White, Red, Orange, Yellow, Dark Gray, Light Gray, Pink, Light Brown, Dark Brown, Aqua, Blue, Olive, Light Green, Dark Green, and Purple.

3.2 Sugeno-Type Fuzzy Inference System

The fuzzy inference process that is referring to so far is known as Mamdani's fuzzy inference method, the most common methodology. In this section, it discusses the socalled Sugeno , or Takagi-Sugeno-Kang, method offuzzy inference. It is similar to the Mamdani method in many respects. The first two parts of the fuzzy inference process, fuzzifying the inputs and applying the fuzzy operator, are exactly the same. The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant [19].

A typical rule in a Sugeno fuzzy model has the form of

If Input 1 = x and Input 2 = y, then Output is z = ax + by + c

For a zero-order Sugeno model, the output level z is a constant (a = b = 0).

The output level z_i of each rule is weighted by the firing strength w_i of the rule. For example, for an AND rule with Input 1 = x and Input 2 = y, the firing strength is

$$w_i = \text{And Method}\,(F_1(x), F_2(y))$$

Where F1, 2 (.) are the membership functions for Inputs 1 and 2. The final output of the system is the weighted average of all rule outputs, computed as

$$FinalOutput = \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i}$$

4. Implementation

Input to the system is RGB image but HSV color space is used for further computing. Firstly, the RGB value from the given image is extracted pixel by pixel basic. In second stage, the extracted RGB value of each pixel is required to convert to HSV color space. In the third stage, the HSV values are fuzzified using Triangular Fuzzy Numbering for computing crisp value to fuzzy value. Fuzzy rules are predefined for further processing. According to the fuzzy values of HSV, the respective fuzzy rules for each pixel are achieved. In the fourth stage, Zero-order Takagi-Sugeno model [19, 20] is used for defuzzification. After that, the color of each pixel is assigned as last step as in Figure 1 .The procedure works iteratively and it is done for all pixel of the given image.

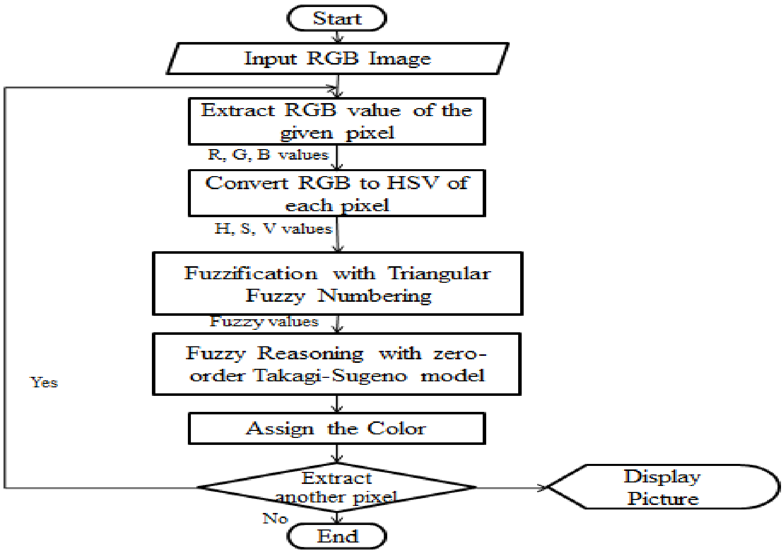


Fig. 1 System flow diagram

5. Results and Discussion

In this research, the color classification system defines the color of the input image based on pixel by pixel. The detail implementation of the system such as converting RGB to HSV color space, fuzzification of HSV value, and extraction of the color output from the consequences of fuzzy rules. The implementation is very simple and the input to the system is color image. After the input image is loaded as in Figure 1, RGB values from each pixel are extracted [3] .The extracted RGB values are converted to HSV value as in Table 1.

Table 1. RGB Value and HSV Value of Each Pixel of the Input Image

Pixel	R	G	B	H	S	V
0x0	255	209	61	45.773	76.078	100
0x1	255	209	61	45.773	76.078	100
0x2	255	209	61	45.773	76.078	100
0x3	255	209	61	45.773	76.078	100
0x4	255	209	61	45.773	76.078	100
0x5	255	209	61	45.773	76.078	100
0x6	254	210	59	46.462	76.772	99.608
0x7	254	210	59	46.462	76.772	99.608
0x8	252	211	59	47.254	76.587	98.824
0x9	252	211	59	47.254	76.587	98.824

0x10	251	211	61	47.254	76.587	98.824

5.1 Fuzzy Membership function

There are three inputs H, S and V, so it has at most six fuzzy set and at least three fuzzy set. For each fuzzy set, it has the value of fuzzy value. As an example, Table 2 mentions the 'Hue' value and its respective fuzzy values. Table 3 mentions the 'Situation' value and its respective fuzzy values. Table 4 mentions the 'Value' value and its respective fuzzy values.

Table 2. 'Hue' value and its respective fuzzy values

Pixel	Hue Fuzzy Vaue1	Hue Fuzzy Set1	Hue FuzzyVaue2	Hue Fuzzy Set2
0x0	0.711	Light Purple	0.218	Red
0x1	0.811	Light Purple	0.189	Red
0x2	0.968	Light Purple	0.32	Red
0x3	0.013	Dark Purple	0.987	Light Purple
0x4	0.052	Dark Purple	0.948	Light Purple
0x5	0.04	Dark Purple	0.96	Light Purple
0x6	0.973	Light Purple	0.027	Red
0x7	0.032	Dark Purple	0.968	Light Purple
0x8	1	Light Purple	0	Red
0x9	0.914	Light Purple	0.086	Red
0x10	0.043	Dark Purple	0.957	Light Purple

Table 3. 'Situation' value and its respective fuzzy values

Pixel	Saturation Fuzzy Value1	Saturation Fuzzy Set1	Saturation Fuzzy Value2	Saturation Fuzzy Set2
0x0	0.25	Almost Gray	0.75	Medium
0x1	0.25	Almost Gray	0.75	Medium
0x2	0.266	Almost Gray	0.734	Medium
0x3	0.518	Almost Gray	0.482	Medium
0x4	0.492	Almost Gray	0.508	Medium
0x5	0.25	Almost Gray	0.75	Medium
0x6	0.258	Almost Gray	0.742	Medium
0x7	0.25	Almost Gray	0.75	Medium
0x8	0.25	Almost Gray	0.75	Medium

0x9	0.25	Almost Gray	0.75	Medium
0x10	0.361	Almost Gray	0.639	Medium

Table 4. 'Value' value and its respective fuzzy values

Pixel	Value Fuzzy Value1	Value Fuzzy Set1	Value Fuzzy Set2	Value Fuzzy Value2
0x0	0.513	Dark	0.487	Blue
0x1	0.516	Dark	0.484	Blue
0x2	0.974	Dark	0.026	Blue
0x3	0.719	Dark	0.281	Blue
0x4	0.752	Dark	0.248	Blue
0x5	0.51	Dark	0.49	Blue
0x6	0.513	Dark	0.487	Blue
0x7	0.993	Dark	0.007	Blue
0x8	0.5	Dark	0.5	Blue
0x9	0.507	Dark	0.493	Blue
0x10	0.824	Dark	0.176	Blue

HSV value of each pixel may extract at most eight rules. The maximum strength of rules is the output color. The rules and the respective output color for each pixel are shown as follow.

If Hue = Red (0.019) and Saturation = Almost Gray (0.266) and Value = Dark (0.484) then Output = Black (0.019)

If Hue = Red (0.019) and Saturation = Almost Gray (0.266) and Value =Medium Dark (0.033) then Output = Dark Brown (0.019)

If Hue = Red (0.019) and Saturation = Almost Gray (0.266) and Value = Dark (0.484) then Output = Dark Brown (0.019)

If Hue = Red (0.019) and Saturation = Medium (0.734175) and Value = Medium Dark (0.033) then Output = Dark Brown(0.019)

If Hue = light purple (0.981) and Saturation = Almost Gray (0.266) and Value = Dark (0.484) then Output = Blue (0.266)

If Hue = light purple (0.981) and Saturation = Almost Gray (0.266) and Value = Medium Dark (0.033) then Output = Blue (0.033)

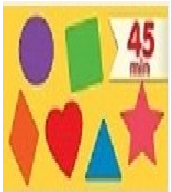
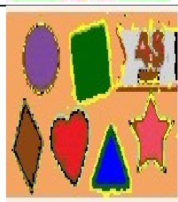
If Hue = light purple (0.981) and Saturation = Medium (0.734175) and Value = Dark (0.484) then Output = Blue (0.484)

If Hue = light purple (0.981) and Saturation = Medium (0.734175) and Value = Medium Dark (0.033) then Output = Blue (0.033)

The output color is Blue (0.848).

5.2 Experimental Results

The output color from fuzzy rule based system of each pixel are updated at each pixel. Experiments are performed on Intel i5 CPU at 1.80GHz and 4GB of RAM. The following results are obtained when the system is experimented. The output color segmented image is as shown in the figure.

No	**Input Image**	**Output Image**	**Dimensions and Size(KB)**	**Computation Time (seconds)**
1.			150 x 85 5.9	608
2.			66 x 50 10.7	87
3			150 x 84 6.3	446

6. CONCLUSION

This research is a model based on the human perception of colors by using fuzzy logic. HSV color space is used for getting near the human vision color. Fuzzy logic based color segmentation model used in many real-life application. Triangular Fuzzy Numbering and Fuzzy Rule based on Zero Order Takagi _ Sugeno Method are used to classify the output color of each pixel. The output color of each pixel needs to calculate. So the computation time is relatively high according to the size of image. Getting the right human perceptual output color depend the fuzzy rule. This system is just only the first part of the computer vision system. It can extend color object detection. And also sixteen output colors (Black , White , Red , Orange , Yellow, Dark Gray, Light Gray, Pink , Light Brown , Dark Brown , Aqua , Blue , Olive , Light Green and Dark Green) are used to define for color classification. For getting more accurate color classification, the system can extend to define more output colors. Sample image and its color segmented image can be seen in Appendix.

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