A Harness Line Color Recognition Method Based on Fuzzy Similarity Measure

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Abstract

Conventional methods for color separation in computer-based machine vision has weak performance because of the environmental dependency like light source, camera sensitivity, etc. In this paper, we propose an improved color separation method using RGB, HLS, color coordination space and fuzzy similarity measure. RGB that consists of red, green, blue is light's three primary colors. HLS that includes hue, light, saturation is human's color recognition elements. A fuzzy similarity measure is employed for evaluating the similarity among fuzzy colors with six features in RGB and HLS. Color recognition system for the harness line is designed and implemented as a testbed to evaluate the physical performance. The proposed color separation algorithm is tested with different kind of harness lines.

Keywords: color recognition, fuzzy entropy, fuzzy measure

1. Introduction

By the development of high efficiency computer recently, image processing algorithm and improvement of image devices helped test systems to improve the performance. What is called, it is given a name field that is artificial vision. Artificial vision is not concept of conventional contact-based sensor but concept of information-based sensor that comes from videotex in short or long distance using camera. The status of target is recognized through suitable digital image processing algorithm or numerical solution.

Many parts of several functions in the artificial vision are implemented and used for industrial equipments. But, the part of color recognition has still many problems to be solved. One of the underlying problems is the subject measurements that come from several values according to strength, direction, and color temperature of light and quality of the material of product. We normally try to recognize and represent an object as one color but the object consists of many color elements which is called natural color.

If a red color electric line in harness line is captured from camera, we recognize the line as a red color but the information of the pixels includes variable colors such as brown, black, etc. Because of these problems, the conventional color recognition methods in natural color image has many restricts. Many intelligent methods have been developed to overcome these problems. Several intelligent approaches for color recognition are:

- Fuzzy colors
- Neural networks
- Fuzzy similarity measure

But, intelligence methods generally require too many arithmetic operations to handle complicated algorithm.

In this paper, we propose a simple algorithm for natural color recognition with low computational burden. First, the HLS color coordination system that converted from RGB information is introduced. The HLS color coordinate system is similar to the human's color recognition system. Second, fuzzy memberships based upon the RGB and HLS information is represented. Third, fuzzy similarity measure of each color are computed and compared for the color recognition. Finally, the proposed algorithm is applied to the harness line color recognition system and the performance is discussed.

2. RGB and HLS Color Coordination

2.1 RGB

RGB coordinate of reflex gives us information about three dimensional spaces that consist of red (R), green color (G) and blue color (B). Three dimensional spaces are represented as a color cube. Here, the origin of the cube displays and means pure black. Color density is increased as the value in the each axis of coordinates is receded from origin. Image device that follows NTSC rules basically shows the RGB information. Image processing based on RGB information has an advantage in time aspect because the pretreatment process is not necessary. For these reasons, RGB color coordinate system is more popular than other color coordinate systems in image processing until present.

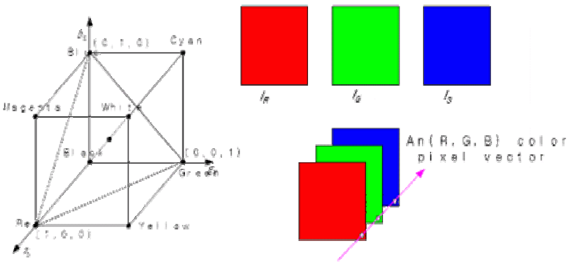

Fig. 1 RGB color cube.

2.2 HLS

The coordination of human's color recognition for an object is based upon the HLS color coordination (hue, light and saturation) [2]. Alternative method to express color information consists of hue, saturation and light. The hue marks color frequency that is represented as chromaticity graph as shown in Fig. 2. The saturation mixing with white and density expresses luminance of object or realized brightness. Structure of this coordinate is cone style. Distance is density from cone top and position of archetype. Cross section of cone is hue and distance from origin to outside is saturation. The hue is put according to order of spectrum (on right from observer red and left blue, green). HLS is color space that marks brightness to specified frequency fastest.

Proved that more correct recognition is possible than RGB in color recognition by H. Palus, D. Bereska. For these reason, HLS information through HLS conversion of RGB is utilized by means of color awareness along with RGB information.

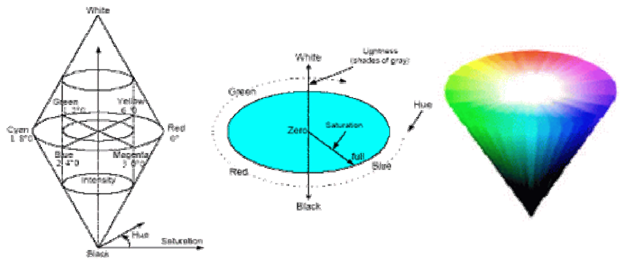

Fig 2 HLS Graph.

2.3 HLS Conversion Using RGB Information

HLS can be easily converted from RGB information by the following arithmetic expressions.

$$r = \frac{R}{255},\ g = \frac{G}{255},\ B = \frac{B}{255} \qquad (1)$$

$$I_{\max} = \max(r, g, b),\ I_{\min} = \min(r, g, b)$$

$$H = \begin{cases} 60 * \left(\frac{g-b}{I_{\max} - I_{\min}} \right) & if\ \ r = I_{\max} \\ 60 * \left(2 + \frac{g-b}{I_{\max} - I_{\min}} \right) & if\ \ g = I_{\max} \\ 60 * \left(4 + \frac{g-b}{I_{\max} - I_{\min}} \right) & if\ \ b = I_{\max} \\ 0 & if\ \ I_{\max} = I_{\min} \end{cases} \qquad (2)$$

$$H = H + 360 \quad if\ \ H < 0$$

$$L = \frac{I_{\max} - I_{\min}}{2} \qquad if\ \ H < 0 \qquad (3)$$

$$L^{'} = 1 - \frac{|L - 0.5|}{0.5}$$

$$S = \begin{cases} 0 & if\ \ I_{\max} = I_{\min} \\ \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} * L^{'} & if\ \ L < 0.5 \\ \frac{I_{\max} - I_{\min}}{2 - (I_{\max} + I_{\min})} * L^{'} & otherwise \end{cases} \qquad (4)$$

3. Fuzzy Similarity Measure

In this section, we introduce some preliminary results of fuzzy measures. Measure of fuzziness is an interesting topic in the fields of pattern recognition or decision theory. Measure of crisp set can be determined by classical mathematical study, whereas the concepts of fuzzy measures and fuzzy integrals had been proposed by Sugeno[8]. Recently, Liu suggested three axiomatic definitions of fuzzy entropy, distance measure and similarity measure as Definitions [9]. Among these definitions, we used fuzzy similarity's concept for color recognition.

Definition 1 [9] A real function $s: F^2 \rightarrow R^+$ is called a similarity measure on $F(X)$ if d satisfied the following properties:

(S1) $s(A,B) = s(B,A),\ \ \forall A,B \in F(X)$

(S2) $s(A, A^c) = 0\ \ \forall A \in F(X)$

(S3) $s(D,D) = \max_{A,B \in F} s(A,B),\ \ \forall D \in P(X),$
$\forall A,B \in F(X)$

(S4) $\forall A,B,C \in F(X), if\ A \subset B \subset C, then\ s(A,B)$
$\leq s(A,C)\ and\ s(B,C) < s(A,C)$.

Above definitions are the axiomatic, Liu also pointed out that there is an one-to-one relation between all distance measure and all similarity measures, $d + s = 1$.

We used a mathematical expression in equation (5) as a similarity measure that satisfies definition 1.

$$s(M_1, M_2) = \frac{\sum_{i=1}^{n} \min(\mu_{M_1}(i), \mu_{M_2}(i))}{\sum_{i=1}^{n} \max(\mu_{M_1}(i), \mu_{M_2}(i))} \qquad (5)$$

4. Experimental Results

4.1 Color Recognition Using Fuzzy Similarity Measure

We verify, in this section, the proposed color recognition algorithm and demonstrate experiment result that uses fuzzy similarity measure. First we make color fuzzy membership functions for RGB and HLS. 100 samples are acquired from color information for each color in image to make color distribution. We make distribution of acquired RGB and HLS information that converted from RGB information.

The prepared data use to generate membership information through the following calculation:

$$\mu_M(i) = \frac{n}{N} \qquad i = 0,1,\cdots 255 \quad ,if\ R,G,B,L,S \quad (6)$$

Where μ_M are membership values, n is number of member data and N is the number of whole data. But a hue is different from the other data, discontinuous data. Because of this reason we don't make hue membership information.

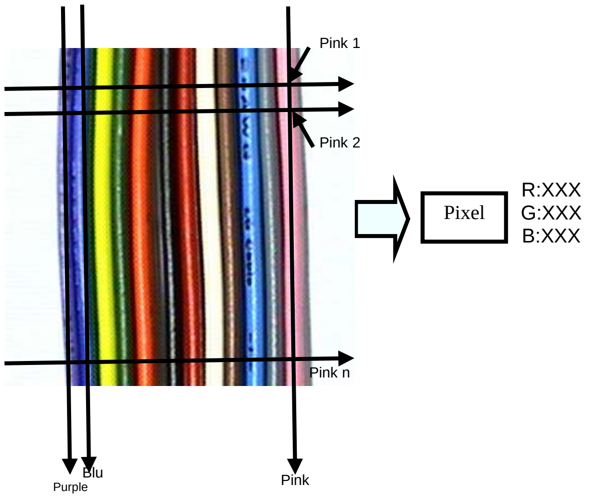

Fig 3 Gathering color information.

In this research, our sample of color information acquired from harness image of twelve different colored lines. The following among line of other colors, red line's color information will R, G, B, L and S distributions of each line.

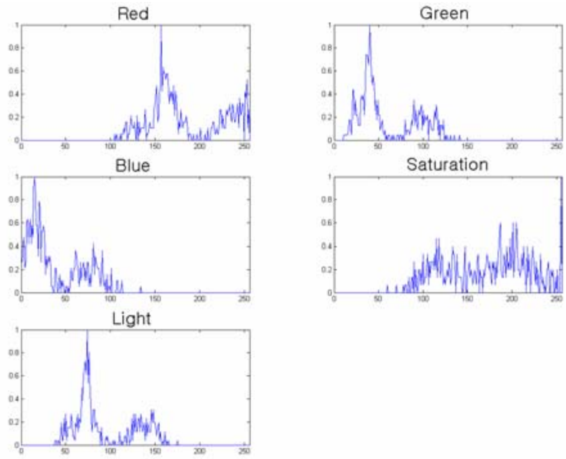

Fig. 4.2 Distribution graph of R, G, B, L, S (red line).

Figure 4.2 is non-convex form. It doesn't treat to fuzzy set. Also, connect out-line of this distribution chart apply concept to compensate information that was lost by digitizing and then changed in form of fuzzy membership.

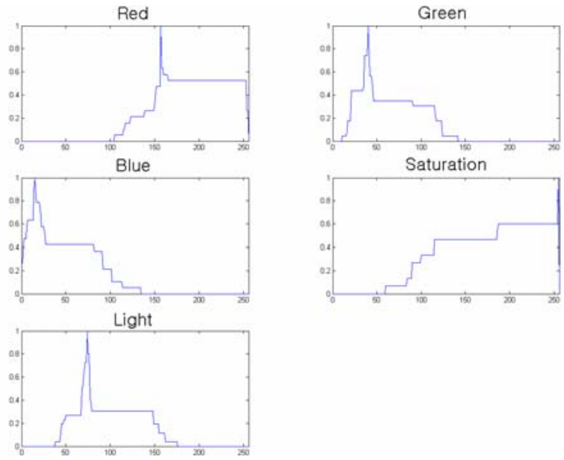

Fig. 4.3 Fuzzification of color distribution (red line).

Color of Harness line that used by this research has pink, blue, white, black, violet, blue, green, yellow, orange, red, brown and gray of 12 colors.

After data of a set that consist of 12 colors makes membership by prior method, compare template fuzzy membership to unknown fuzzy membership in each color.

In table 1, you can see distribution special quality of each color Hue values. Various Hue values appear in achromatic color, but chromatic color has only one hue value. It can gain advantage that may not do comparison calculation between unnecessary each membership except achromatic color using this nature.

Table 1 Color distribution by hue value

Hue value	Colors
0 value (Red like)	BROUN, RED, ORANGE, PINK
120 value (Green like)	GREEN
240 value (Blue like)	BLUE, SKY-BLUE
Uniformly distributed	BLACK, YELLOW, PURPLE, GRAY, WHITE

After consider this Hue condition, we can recognize the color using fuzzy similarity measure method and we have displayed red and gray color recognition result of algorithm.

Table 2 Results of color recognition (red line)

Input data	Red line, Hue values are all 0.				
Comparison (Red like)	**R.**	**G.**	**B.**	**S.**	**L.**
Brown	0.2084	0	0.0219	0.0329	0.0635
Red	0.2344	0.4468	0.4624	0.5773	0.3813
Orange	0.0044	0.0152	0.2181	0.5549	0.0223
Pink	0.0630	0	0	0	0.0016
Max value	0.2344	0.4468	0.4624	0.5773	0.3813
Result	Red	Red	Red	Red	Red

Table 3 Results of color recognition (blue line)

Input data	Blue line, Hue values are all 240.				
Comparison (Blue like)	**R.**	**G.**	**B.**	**S.**	**L.**
Blue	0.4461	0.2980	0.6661	0.5961	0.4786
Sky Blue	0.4439	0.1788	0.0975	0.3427	0.1972
Max value	0.4461	0.2980	0.6661	0.5961	0.4786
Result	Blue	Blue	Blue	Blue	Blue

Table 4 Results of color recognition (gray line)

Input data	Gray line, Hue values are uniformly distribute				
Comparison (Red like)	**R.**	**G.**	**B.**	**S.**	**L.**
Black	0.0082	0.0055	0.0081	0.0092	0.1188
Yellow	0.0361	0.0105	0	0.3073	0
Gray	0.2609	0.2921	0.3252	0.5952	0.3063
Purple	0.1338	0.0995	0.6525	0.3144	0.0855
White	0.0038	0.0056	0.2633	0.0460	0.3243
Max value	0.2609	0.2921	0.6525	0.5952	0.3243
Result	Gray	Gray	Purple	Gray	Gray

4.2 Color Recognition Using Fuzzy Similarity

We manufacture the harness line color recognition system on the basis of algorithm that introduced in session 4.1 and verified performance. Fig 4.2 shows this system and tested harness. System of Fig 4.2 can recognize harness's line color and distinguishes whether order of line is right.

Fig 4.2 Test system and picture of harness.

We confirmed the recognition rate of actuality Harness's line color using this system. Harness that used in experiment has 12 colors (order of black, brown, red, ash color, blue, green color, blue color, yellow, orange, pink, violet and white). Result of an experiment appeared to Table 5. An experiment has 10th trial and show the 100% recognition rate.

5. Conclusion

Color recognition which use color information of a pixel or mean value of neighbor pixels that is method that is accomplishing main current in existent research had limit. In this paper, we did so that can analyze color distribution of objects that describe person's index process to a these alternative method and color recognition is more exactly.

Table 5 Results of harness's line order recognition

Tested harness's line order: BK BR RD GY SB GR BL YL OR PK PP WH												
No.	Test Result (Order of Harness's line color)											
1	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
2	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
3	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
4	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
5	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
6	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
7	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
8	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
9	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH
10	BK	BR	RD	GY	SB	GR	BL	YL	OR	PK	PP	WH

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