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Developing a New Color Model for Image Analysis and Processing

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Abstract. The theoretical outcomes and experimental results of new color model implemented in algorithms and software of image processing are presented in the paper. This model, as it will be shown below, may be used in modern real time video processing applications such as radar tracking and communication systems. The developed model allows carrying out the image process with the least time delays (i.e. it speeding up image processing). The proposed model can be used to solve the problem of true color object identification. Experimental results show that the time spent during RGI color model conversion may approximately four times less than the time spent during other similar models.

1. Introduction

Digital image processing is a new and promptly developing field which finds more and more application in various information and technical systems such as: radar-tracking, communications, television, astronomy, etc. [1]. There are numerous methods of digital image processing techniques such as: histogram processing, local enhancement, smoothing and sharpening, color segmentation, a digital image filtration and edge detection. Initially, theses methods were designed specially for gray scale image processing [2, 3]. The RGB color model is standard design of computer graphics systems is not ideal for all of its applications. The red, green, and blue color components are highly correlated. This makes it is difficult to execute the image processing algorithms. Many processing techniques work on the intensity component of an image only. These processes are standard implemented using the HSI color model.

The main target of this paper is to develop a new color model can be used in modern real time video processing applications. Achieving such a goal requires presenting this paper which is organized from five sections. In section two, we describe some type of color model that is used in image processing dedicated to work on the intensity component of an image only. Section three deals with developing a new methodology for object recognition.

In section four, we develop an advanced approach for image processing that satisfies the target of this paper. Results and conclusion are shown in section five and six correspondently.

2. Description of HSI Model

The HSI color model (abbreviation of hue, saturation and intensity), as it was mentioned before, is standard of color image processing. The idea of this model implementation is not so easy; usually this standard can be represented graphically in hue, saturation, and intensity in 3 dimensional space [3, 4] as shown in Fig.1.

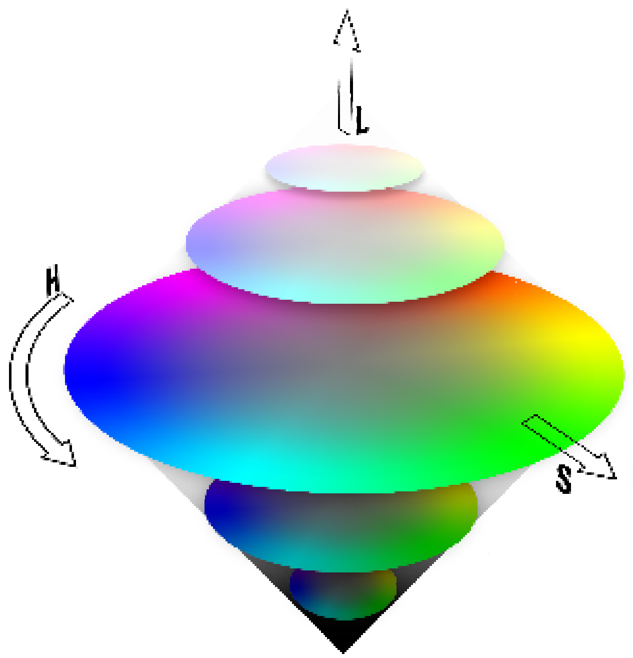

Fig.1 Double Cone Model of HSI Color Space

The following formulas show how to convert from RGB space to HSI:

$$I = \frac{1}{3}(R + G + B) \quad (1)$$

$$S = 1 - \frac{3}{(R+G+B)}[\min(R,G,B)] \quad (2)$$

$$H = \cos^{-1}\left\{\frac{0.5[((R-G)+(R-B]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right\} \quad (3)$$

If B is greater than *G*, then $H = 360^0$ - H (4)

Where: R, G and B are three color component of source RGB image. H, S and I it's components of hardware independent on HSI format.

As we can see, conversion from RGB to HSI is not easy with regard to computing algorithm complexity because it's regarding minimum from three searching (expression 1, as minimum two operators of condition), long cosine function, square root, square computation, additional operation of condition (expression 4) during one pixel conversion. More difficulty to convert from HSI color space back to standard RGB, where the process depends on which color sector H lies in. For the RG sector ($0^0 \le H \le 120^0$), we have the following equations to convert RGB to HSI format:

$$B = I(1-S) \quad (5)$$

$$R = I\left[1 + \frac{S\cos H}{\cos(60^0 - H)}\right] \quad (6)$$

$$G = 3I - (R+B) \quad (7)$$

For the *GB* sector ($120^0 \le H \le 240^0$):

$$H = H - 120^0 \quad (8)$$

$$R = I(1-S) \quad (9)$$

$$G = I\left[1 + \frac{S\cos H}{\cos(60^0 - H)}\right] \quad (10)$$

$$B = 3I - (R+G) \quad (11)$$

For the BR sector ($240^0 \le H \le 360^0$):

$$H = H - 240^0 \quad (12)$$

$$G = I(1 - S) \tag{13}$$

$$B = I\left[1 + \frac{S\cos H}{\cos(60^0 - H)}\right] \tag{14}$$

$$R = 3I - (G + B) \tag{15}$$

So, twelve formulas are required for conversion and as a result there is too long time delay spent for color conversion; here it is important to reduce computation complexity for real time image processing. There are some other color models among which possible to emphasize the [2, 3] HSV space (hue, saturation, value), HSL space (hue, lightness, saturation), the CMY color space and YCbCr color model [5-8].

3. Development of a New Methodology for Object Recognition

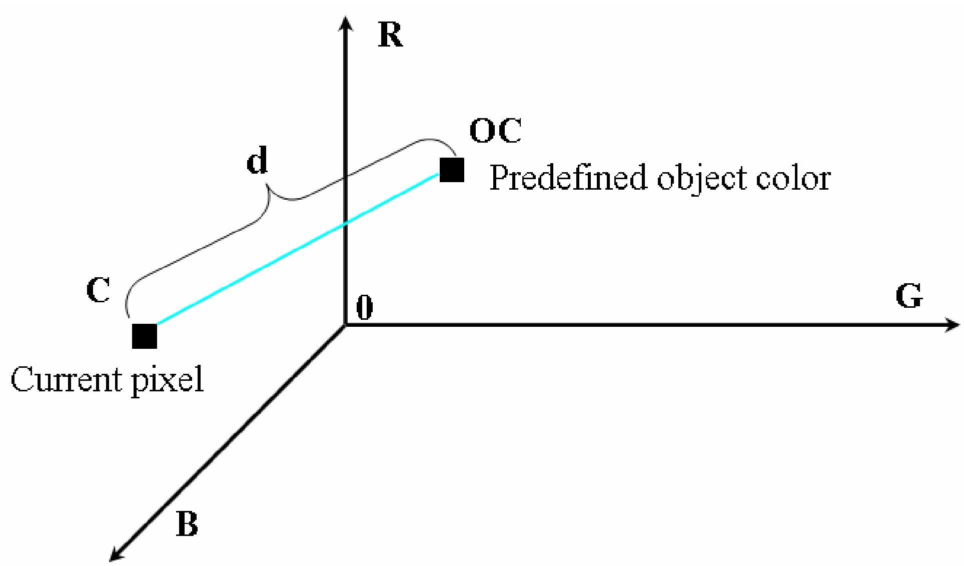

Fig. 2 the direct comparing of RGB colors

During design the software of optical topographer [14], we use the direct true color comparing which is comparing of current image pixel with predefined (during system learning) color. Let us designate as OC the predefined color and ac C current pixel color. Taking into account the fact that any pixel color represented in system as composition of R, G and B color components direct color comparing able by using 3D RGB color space, as shown in Fig. 2.

In Fig.2 shown above, the distance between current pixel color and predefined object color is d. Small value of distance meaning that visually two pixels looking like similar color. Also, it can be shown mathematically that:

$$d = \sqrt{(\mathrm{OC.r - C.r})^2 + (\mathrm{OC.g - C.g})^2 + (\mathrm{OC.b - C.b})^2} \quad (16)$$

The decision about belonging of current pixel color to the color of predefined object can be accepted when d less then some parameter e and as our investigation show, in standard RGB color model steady object detection reached when we use the e factor according to the e formula given in Eq.17:

$$e = \sqrt{10\%(\max \mathrm{R})^2 + 10\%(\max \mathrm{G})^2 + 10\%(\max \mathrm{B})^2} \quad (17)$$

Where: max R, max G, max B are the maximum values of the color components (in standard systems it is 255; so $e = \sqrt{(25)^2 + (25)^2 + (25)^2} = 42$).

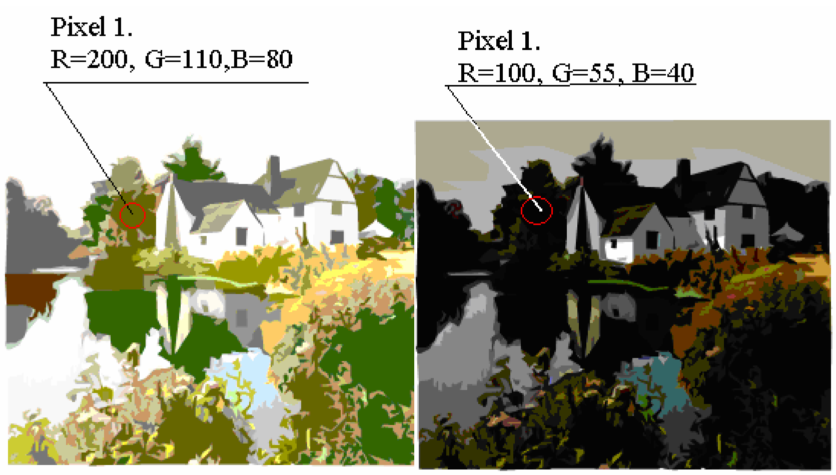

Fig. 3 Two RGB images: a) acquired during day and sunlight b) During evening and values of pixel components

Color image can be obtained in different brightness, like photo registered during day and evening as shown in Fig. 3.

Just for example, we got only one pixel. So, pixel in image **2.a** will be recognized as object color. But pixel in image **2.b** is same pixel; just brightness of image is less. But it cannot be recognized as object. So, directly color comparing can produce mistake according to brightness of image. To avoid mistakes during object identification, we try to use normalized colors according to the following formulas:

The original colors are:

C.r;

C.g

C.b

The normalized colors are:

$$C^{'}_{r} = \frac{C.r}{C.r + C.g + C.b} \cdot 100\% \qquad (18)$$

$$C^{'}_{g} = \frac{C.g}{C.r + C.g + C.b} \cdot 100\% \qquad (19)$$

$$C^{'}_{b} = \frac{C.b}{C.r + C.g + C.b} \cdot 100\% \qquad (20)$$

Where C.r, C.g, C.b are the original colors; C'.r, C'.g, C'.b are the normalized colors. These colors show how much each components contained in color (in %). According to the example shown above, we can show that for image shown in Fig.3.a:

R'= (200/390)*100=51%, G'= (110/390)*100=28%, B'= 80/390)*100=20%;

While for example shown in Fig.3. b:

R= (100/195)*100=51%, G= (55/195)*100=28%, B= 40/195)*100=20%.

As we can see from the above $R^{'}$, R Equations, 2 images, one obtained during day, second during evening, having the same normalized color, so this methodology is better to be applied in object detection systems because system is not sensible to image brightness. Our investigations show that variability of parameter e for steady object detection can be around ten times less to comparing with direct colors comparing.

4. Development of a New Approach for Image Processing

The development of a new method caused by necessity to decrease the time of image processing and to provide the possibility of real video processing techniques is very important. It is known that majority methods of image processing working only with intensity part of color model [9-11]. The color model must be in full basis, it mean that model must allow to transform image to new color model, use the intensity component for image processing then return image back to RGB after processing [12,13]. The method must be as minimum few times faster to comparing with standard HSI transformation. As we can see above, formulas 18-20 produced normalized colors of image and Cr'+Cg'+Cb'=100; so, in new model we can exclude some component, Cb' for example and add component of intensity to return model to full basis. So, the formulas to convert RGB image to R'G'I color model can be produced according to the formulas 18-20:

$$\mathrm{R}^{'} = \frac{\mathrm{R}}{\mathrm{R}+\mathrm{G}+\mathrm{B}} \qquad (18)$$

$$\mathrm{G}^{'} = \frac{\mathrm{G}}{\mathrm{R}+\mathrm{G}+\mathrm{B}} \qquad (19)$$

$$\mathrm{I} = \frac{\mathrm{R}+\mathrm{G}+\mathrm{B}}{3} \qquad (20)$$

Where R,G,B is source RGB components of current pixel, R',G',I are three components of same pixel in new color model. Let's here and in future denote this color model as RGI.

Inverse transform to return R'G'I color model to RGB standard possible to obtain according with formulas 21-23:

$$\mathrm{R} = 3 \cdot R' \cdot I \qquad (21)$$

$$\mathrm{G} = 3 \cdot G' \cdot I \qquad (22)$$

$$\mathrm{B} = 3 \cdot (1 - R' - G') \cdot I \qquad (23)$$

The graphical representation of R'G'I color model can be shown as cube in 3D color space as shown in Fig. 4.

Let's explain the idea implementation in real example: lets suppose that there is color pixel in some x,y position of image and color components of this pixels are R=15, G=50, B=100. Lets provide any simple image processing operation on this pixel, brightness increment in 50 for example. So, first operation is conversion from RGB color space to RGI according with equation 18: R'=0.09, G'=0.3, I=55; second operation is image processing, brightening 50, new intensity component become I=I+50=105; and the last one operation is inverse conversion to return the pixel to standard RGB model, according with equations 21-23 we can calculate that new pixel color is R=28, G=95, B=192.

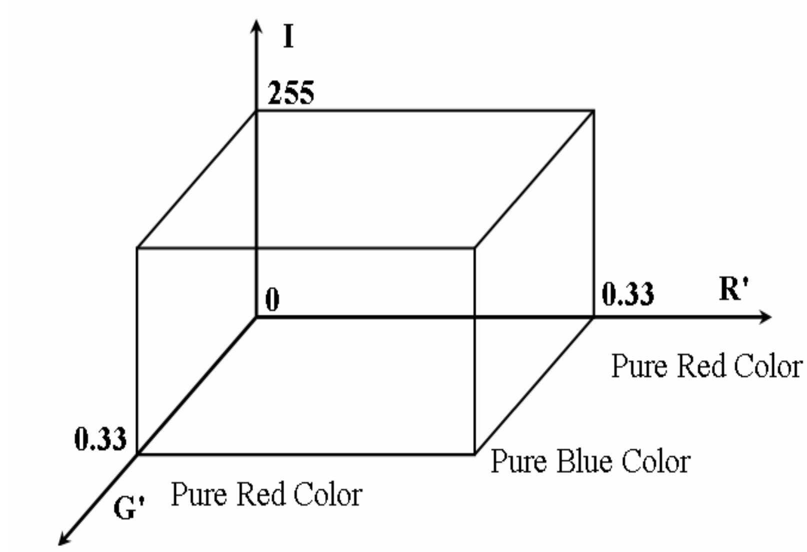

Fig.4 Graphical Representation of R'G'I Color Space

5. Results

Designed method of object detection explained in chapter 5 with using normalized colors was implemented using software of optical topographer, especially designed for diagnosis of support-locomotion system diseases [14]. The leaded researches has shown that normalized colors practically not sensitively to light exposure changing, the normalized values of color components practically is the same, and method provides steady allocation of image required area.

To study the practical approaches of new color model especially in image processing field the program implemented a RGI model and standard HSI model (for comparing) has been created with using Borland Delphi 6.0 compiler[15,16]]. The graphical user interface of program, that we created illustrated in Fig. 5.

Produced by Borland International, Delphi is a powerful development environment used primarily to build client/server applications for Microsoft Windows, with an emphasis on databases. Based on Object Pascal, it is object-oriented and was designed to give developers the ability to build applications easily, with minimal coding required. As we can see from the figure, the program of image processing was created using both methods of conversion: HSI and RGI. The program implemented such method of image processing as brightening, contrast stretching and histogram equalization, it's enough because our aim was evaluation of new model advantages. The result of image processing showed in the figure 6.

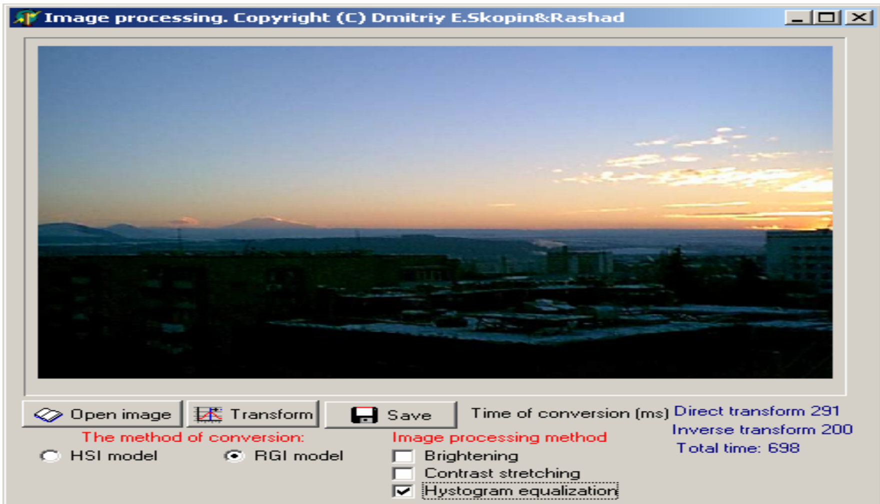

Fig.5 Graphical User Interface of the developed program

(d)  (e) 

Fig. 6. a) The source Image, b) the result image after histogram equalization with using HSI color model, c) the result image after histogram equalization with using RGI model, (d) the result of brightening with using HSI model, (e) the result of brightening with using RGI color model.

As we can see both methods standard and designed produce the same results. To estimate a time of image conversion, we create the test image represented as array (500X2500 pixels), and filled with random function. After that, the time for conversion was measured. The test result is shown in the table 1.

Table 1. Measured time of conversion

Number of test	Method of conversion	Time of conversion (ms)
1.	RGB to HSI	1024
2.	HSI to RGB	939
3.	RGB to R'G'I	291
4.	R'G'I to RGB	200
5.	Total time of image processing (brightening) with using HSI (standard) method of conversion	2170
6.	Total time of image processing (brightening) with using RGI (suggested) method of conversion	698
7.	Total time of image processing (contrast stretching) with using HSI (standard) method of conversion	2265
8.	Total time of image processing (contrast stretching) with using RGI (suggested) method of conversion	791
9.	Total time of image processing (histogram equalization) with using HSI (standard) method of conversion	1096
10.	Total time of image processing	2568

	(histogram equalization) with using RGI (suggested) method of conversion	

The same result but expressed in the percentage of acceleration (as quotient of HSI conversion time over RGI conversion time) shown in the figure 7.

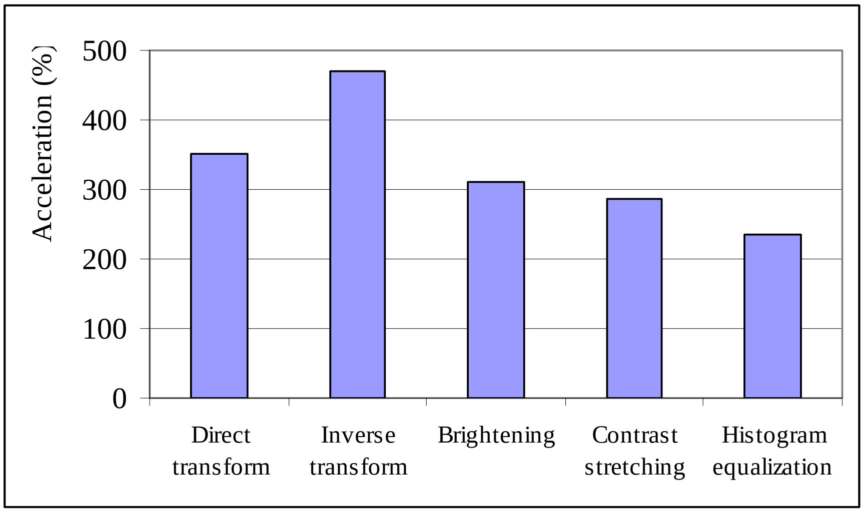

Fig.7 HIS conversion time over RGI conversion time

6. Conclusion

In this article we offer of new color model that can be used in color image processing techniques as well as in image recognition aims. The results of the test show that the time spent during HSI conversion method was approximately 4 times more to comparing with RGI color model conversion. Carried out experimental results of RGI color model for image recognizing and image processing show their efficiency that allows recommending including developed method in software of modern digital image processing systems.

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