Color Image Edge Detection Method Based on Interval Type-2 Fuzzy Systems

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Abstract Edge detection is one of the most commonly used operations in computer vision, image processing and pattern recognition. The efficiency of these applications depends in many cases on the quality of detected edges. A color image edge detection method based on Sobel and Interval type-2 fuzzy system IT2FSs is presented in this paper. Color images provide more information than grayscale images. Thus, more edge information is expected from a color edge detector than a grayscale edge detector. The proposed method is applied over a database of color images that include synthetic and real images. The performance of the proposed method is compared with other edge detection algorithms such as Sobel combined with type-1 fuzzy systems T1FSs and the traditional Sobel operator.

1 Introduction

Edge detection in color images is a far more difficult task than gray scale images but the color images provide more information than grayscale images; this can be vital in some computer vision applications [1]. Additionally, human perception of color images is more enriched than an achromatic picture [2]. Several color models are present such as RGB color model, YUV model, CMY color model, CMYK color model, HIS color model [3, 4].

This paper describes the application of the color image edge detection based on Sobel and interval type-2 fuzzy systems, which is performed using the RGB color model. The algorithm is tested on synthetic and real images and the results are

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compared with the results of color edge image edge detection based on Type-1 fuzzy systems and the Sobel Operator.

The paper is organized as follows: In Sect. 2 the representation of a color image is defined. Section 3 presents the Color image detector using Sobel operator. Section 4 shows the color image edge detector based on type-1 and interval type-2 fuzzy systems. In Sect. 5 the simulation results are described. Finally, Sect. 6 shows the Conclusions.

2 Representation of a Color Image

Color images are of great importance in daily life and for the representation of images in the digital world. Color perception is very important but a complicated phenomenon. There are different models to represent color images, such as the RGB color model, YUV model, CMY color model, CMYK color model and HIS color model. In this paper the RGB model is applied, which is defined as follows [3].

2.1 RGB Model

The RGB color model is based on the combination of the primary colors: red (R), green (G), and blue (B). The origin of this model is in the technology of television and can be considered as the fundamental color representation in computers, digital cameras and scanners. Most programs for image processing and graphical representation are using this model for the internal representation of color.

An RGB color image is an M × N × 3 array of color pixels, where each color pixel is a triplet corresponding to the red, green, and blue components of an RGB image at a specific location.

A color image can be considered as a related group of images of intensity $I_R(x, y)$, $I_G(x, y)$, $I_B(x, y)$ where the RGB value of a pixel of the color image I is obtained by accessing each of the arrays that constitute the combination of the shape [3]. The RGB color image composition is shown is Fig. 1.

3 Color Image Edge Detector Using the Sobel Operator

The edges can be considered as points in an image in which the intensity in a given direction changes dramatically. Depending on the change in intensity is the edge value to that point in the image [5].

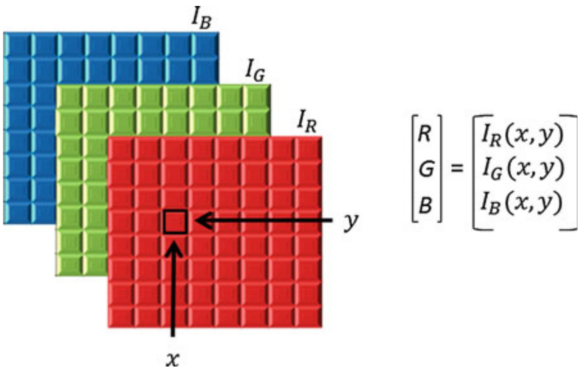


Fig. 1 Composition of a color image RGB

The Sobel operator is one of the most used methods for edge detection. This operator uses a filter defined by 3 × 3 coefficients matrices which are expressed by

$$Sobelx = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \tag{1}$$

$$Sobely = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{2}$$

The matrices *Sobelx* in (1) and *Sobely* in (2) are separately applied on the input image (*I*) to obtain two gradient components *gx* in (3) and *gy* in (4) in the horizontal and vertical orientations respectively [5, 6].

The size and direction of the gradients gx and *gy* are calculated by

$$gx = Sobelx * I \tag{3}$$

$$gy = Sobely * I \tag{4}$$

On a grayscale digital image, the magnitude of the edge or output edge is defined as the magnitude of the gradient *G*, which is defined by

$$G = \sqrt{g_x^2 + g_y^2} \tag{5}$$

The RGB color image can be considered as a related group of images of intensity $I_R(x, y)$, $I_G(x, y)$, $I_B(x, y)$. To apply the Sobel Operator in color image we need calculated the magnitude of the gradient (5) for each dimension of the color image I_R (Red), I_G (Green) and I_B (Blue).

The magnitude of the $\boldsymbol{G_R}$ gradient for the Red dimension is defined by

$$Rg_x = Sobelx * I_R \tag{6}$$

$$Rg_y = Sobely * I_R \tag{7}$$

$$G_R = \sqrt{Rg_x^2 + Rg_y^2} \tag{8}$$

For the Green dimension, the magnitude of the $\boldsymbol{G_G}$ gradient is expressed by

$$Gg_x = Sobelx * I_G \tag{9}$$

$$Gg_y = Sobely * I_G \tag{10}$$

$$G_G = \sqrt{Gg_x^2 + Gg_y^2} \tag{11}$$

An finally the magnitude of the $\boldsymbol{G_B}$ gradient, for the Blue dimension is defined by

$$Bg_x = Sobelx * I_B \tag{12}$$

$$Bg_y = Sobely * I_B \tag{13}$$

$$G_B = \sqrt{Bg_x^2 + Bg_y^2} \tag{14}$$

The result of the edge detector based on the Sobel operator applied on color images is shown in Fig. 2.

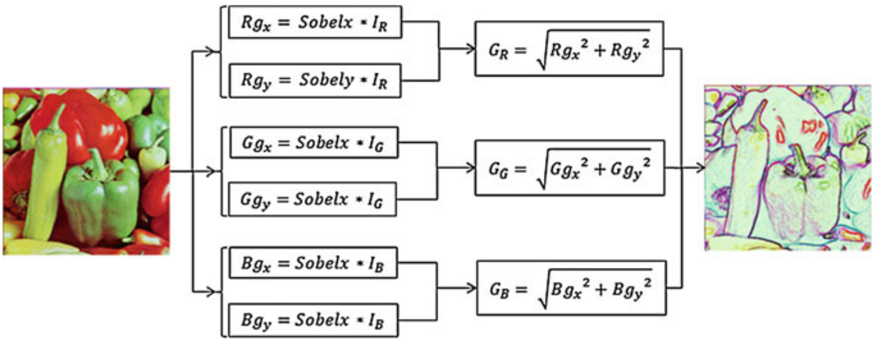


Fig. 2 Color image edge detector using the Sobel operator

4 Color Image Edge Detector Based on Fuzzy Logic

In the last years we have witnessed a rapid growth in a number of applications of fuzzy logic [7–10]. Fuzzy logic techniques have been used in many image recognition problems [11, 12], digital image processing, such as the detection edges [13–15], noise filter [16, 17], feature extraction [18], signal estimation, classification and clustering [2]. Fuzzy logic techniques represent a powerful alternative to design smart engineering systems. There are many advantages to using fuzzy inference systems [19]. Fuzzy systems are linguistic, not numerical, making it similar to the way humans think [20, 21].

In this section, an application on digital image processing using fuzzy logic is presented. The idea is to develop a color image edge detector based on Sobel operator combined with fuzzy logic; for this case study the edge detector is performed using type-1 fuzzy systems and interval type-2 fuzzy systems.

4.1 Fuzzy Inference System for Color Image Edge Detection

To apply the fuzzy approach for color image edge detection based on the Sobel combined type-1 and interval type-2 fuzzy inference system six inputs are required.

The six inputs are the gradients with respect to *x-axis* and *y-axis* for the each color image dimension (Red, Green and Blue); these gradients are calculated with (6), (7), (9), (10), (12) and (13). In Fig. 3, the type-2 fuzzy inference system for edge detection in a color image is shown. The three outputs of the model presented in Fig. 3, represent the magnitude of the gradient for the color image dimension.

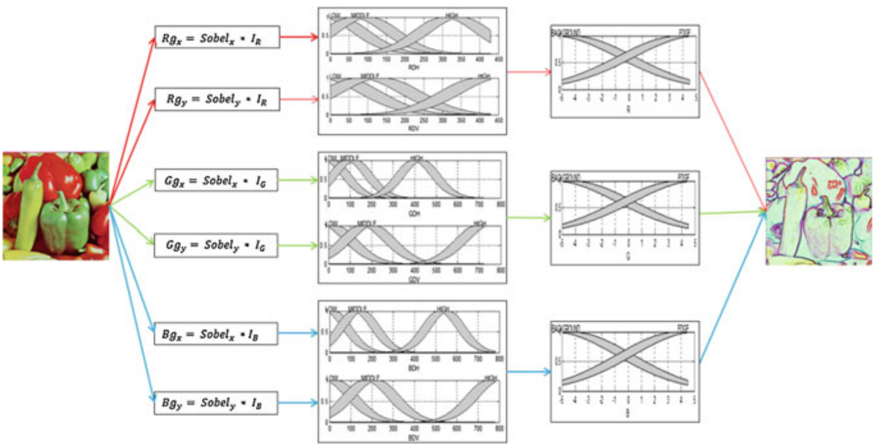


Fig. 3 Color image edge detector using Sobel combined with type-2 fuzzy systems

The two models (Sobel + T1FSs and Sobel + ITFSs) are developed under the same conditions, which are required to be able to make a comparison of both results.

4.2 Fuzzy Inference Rules

The fuzzy inference system is designed considering different groups of rules. These fuzzy rules are obtained based on the knowledge of an expert in image processing and combined with a series of tests, to achieve good results with a minimum number of rules. The rules used in the experiments are presented as follows

1. If (RDH is HIGH) or (RDV is HIGH) then (R is EDGE)
2. If (RDH is MIDDLE) or (RDV is MIDDLE) then (R is EDGE)
3. If (RDH is LOW) and (RDV is LOW) then (R is BACKGROUND)
4. If (GDH is HIGH) or (GDV is HIGH) then (R is EDGE)
5. If (GDH is MIDDLE) or (GDV is MIDDLE) then (R is EDGE)
6. If (GDH is LOW) and (GDV is LOW) then (R is BACKGROUND)
7. If (BDH is HIGH) or (BDV is HIGH) then (R is EDGE)
8. If (BDH is MIDDLE) or (BDV is MIDDLE) then (R is EDGE)
9. If (BDH is LOW) and (BDV is LOW) then (R is BACKGROUND)

5 Simulation Results

In this section we present the results of the proposed image color edge detection based on Sobel and Fuzzy Systems (T1FSs and IT2Fs). For the simulation results we used a color image database of synthetic and real images, and these images are presented in Table 1.

In the first test, the traditional Sobel operator was applied, and for this experiment we used the methodology presented in Sect. 3. The results for this edge detector are shown in Tables 2 and 3.

In another test, the proposed edge detector based on type-1 and type-2 fuzzy systems is now applied to the same color images of Table 1. These methods (Sobel + T1FSs and Sobel + IT2FSs) are designed with the structure described in Sect. 4; both methods use the same inputs, outputs and number of fuzzy rules. The edge detection obtained with these methodologies is presented in Tables 2 and 3.

The visual edge detections for the Sobel, Sobel + T1FSs, Sobel + IT2-FSs, are shown in Tables 2 and 3. Graphically, we can clearly note that the edges detected in the Sobel operator are smaller in number than those detected by Sobel + T1FLS and Sobel + IT2-FLS. On the other hand; visually, we cannot appreciate the difference in the detected edges between Sobel + T1FLS and Sobel + IT2-FLS.

Table 1 Color images database

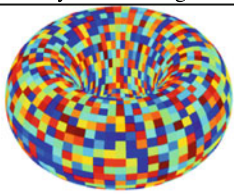
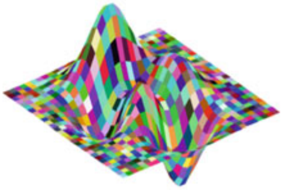
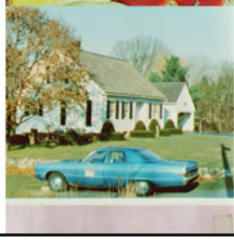
Synthetic Image	Real images
	
	
	

Table 2 Edge detection in color synthetic images

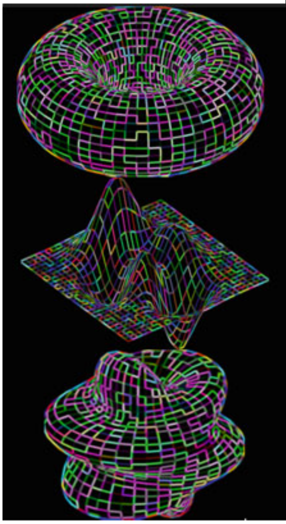
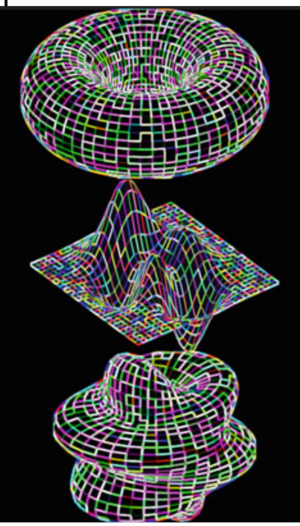
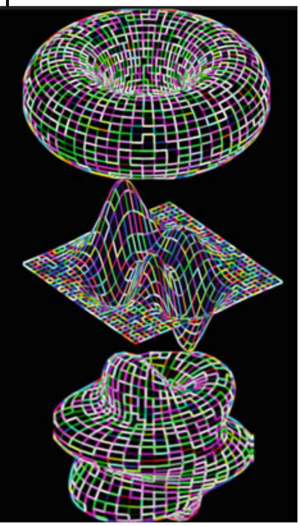
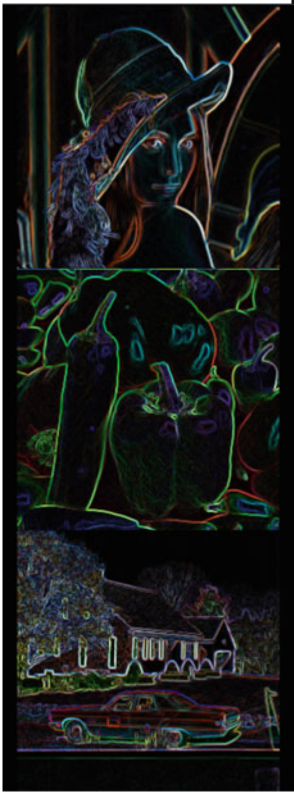
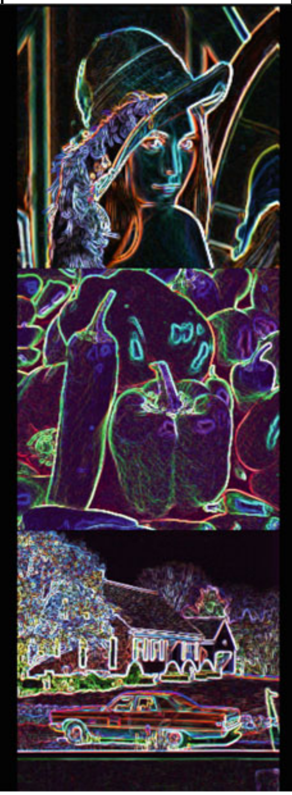
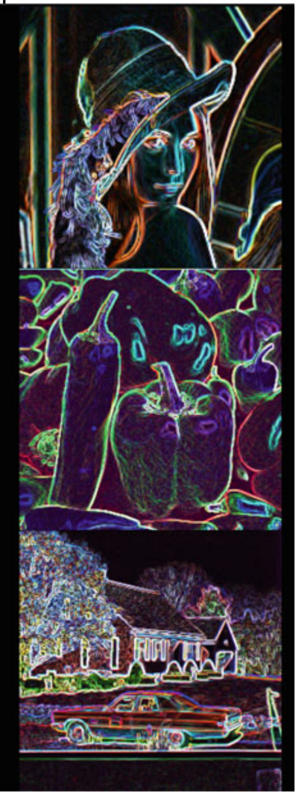
Sobel	Sobel + T1FSS	Sobel + IT2FSS
		

Table 3 Edge detection in color real images

Sobel	Sobel + T1FSS	Sobel + IT2FSS
		

6 Conclusions

A new method based on Type-1 and Type-2 fuzzy systems has been proposed in this paper for extracting edges from color images. On Tables 2 and 3, we can appreciate that the proposed fuzzy edge detectors are better that the traditional Sobel operator; however, we cannot appreciate clearly the difference between T1FSs and T2FSs. In future work we can apply some metric to measure the differences in the detected edges.

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