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An Improved Method of Color Image Edge Detection Based on One Order Gradient Operator

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Abstract

In order to research the problem of the gray edge and leaving out some edges during detecting the color edges, the color contrast enhancement algorithm is designed that it dependences on decomposing the interrelated color component of the color images based on RGB color model. And the edge detection improved method is proposed based on the above algorithm. Namely, the components edges are computed by the gradient operators after the components are enhanced and the color image edges are composed. The experimental results show that the color edges are detected through the proposed method and the algorithm has the advantage of keeping the more edge details than the other ways. Because the algorithm is an improved method of pixel processing based on three components of RGB color model, it needn't transform one color model to the other color model, so it is a more simple method than the other methods.

Keywords: *Image enhancement; Contrast intensity; Color edge; Edge detection; Gradient operator*

1. Introduction

Image segmentation is an important link of digital image processing and is the basis of image analysis, recognition and understanding. Edge detection is an essential prerequisite for image segmentation and the result of edge detection determines the correctness of subsequent image processing. So it is an important research content [1].

Usually the image edge is mutation of the local pixel values, so image edge detection is usually implemented by calculating local differential operator. Edge detection of color image is mainly implemented based on gray image edge detection. The key step is firstly to transform color image to gray image. Then gray edge is detected by local differential operator. Because edge information lost its color information, this affects the degree of color image understanding. And this makes the subsequent processing of color image to be inevitably affected. Therefore the problem of color edge detection is a problem to be solved [2].

According to the main lost edge problems of gray edge detection, the color contrast enhancement is the premise

2. Research Basis

2.1 A Method of Contrast Enhancement Based on Pixel Operation

Suppose $f(i,j)(0\le i\le M\text{-}1, 0\le j\le N\text{-}1)$ is gray image to be enhanced, pixel value is expressed by n bit, then $0\le f(i,j)\le 2^n\text{-}1$,$g(i,j)$ is enhanced gray image, F is neighbor operation of pixel

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(i,j),then $g(i,j)= F(f(i,j))$. If F is defined on every pixel (i,j),F is called pixel operation. If F is defined on a neighbor of pixel(i,j),F is called neighbor operation. The function types of pixel operations are linear function and nonlinear function, common linear transform mathematical expressions are written as:

$$g(i,j)=\begin{cases} \dfrac{t_1}{s_1} f(i,j) & 0 \le f(i,j) \le s_1 \\ \dfrac{t_2-t_1}{s_2-s_1}[f(i,j)-s_1]+t_1 & s_1 < f(i,j) \le s_2 \\ \cdots & \\ \dfrac{2^n-1-t_{l-1}}{2^n-1-s_{l-1}}[f(i,j)-s_{l-1}]+t_{l-1} & s_{l-1} < f(i,j) \le 2^n-1 \end{cases} \quad (1)$$

Where the pixel value set of the original image can be writen as:

$$[0,s_1] \cup (s_1,s_2) \cup [s_2,2^n-1] = [0,2^{n-1}] \quad (2)$$

the pixel value set of the enhanced image can be writen as:

$$[0,t_1] \cup (t_1,t_2] \cup,...,(t_{l-2},t_{l-1}] \cup [t_{l-1},2^n-1] \quad (3)$$

Contrast degree is enhanced or reduced by above linear function, in other words, image detail gray level to be needed will be stretched, the image detail gray level to be not needed will be shrinked [3].

2.2 Edge Detection Algorithm

Classical edge detection algorithm has four steps as follows [3]:

Step 1: Image filtering. Noisy image edge detection usually has some wrong edge information because the derivative calculation is very sensitive to noise pixel. Most filters can decrease noise degree and lose some edge degree. So the moderate noise reduction can guarantee to detect more edge.

Step 2: Image enhancement. The basis of edge enhancement is to determine change image of each point neighborhood strength values. And edge enhancement is usually accomplished by calculating the gradient amplitude.

Step 3: Edge detection. There are many pixels of a big gradient amplitude in the image. These pixels are not all edge pixels. The gradient amplitude threshold is applied to determine which pixels are edge pixels.

Step 4: Edge location. Edge position and direction may be estimated on sub_pixel resolution ratio during some employing environment.

The color image edge detection depends on the color model, and the process based on color component decomposition is listed below:

Step1: Decompose color image to three components

Step 2: Detect the edge of three components

Step 3: Compose the component edge to color image edge.

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For example, the color image edge detection process based on HSI is given as follows:

Step1: Transform RGB model to HSI model and decompose color image to Component H, Component S and Component I.

Step 2: Detect the edge of the three components.

Step 3: Compose the component edge to color image edge.

Step 4: Transform HSI model to RGB model.

2.3 Edge Detection Results of Image Formation and Evaluation Criterion

The edge detection results of image formation have five methods. The formulas of image edge result can be written as [3]:

$$g_1(i, j) = G(i, j) \tag{5}$$

$$g_2(i, j) = \begin{cases} G(i, j) & G(i, j) \geq T \\ f(i, j) & G(i, j) < T \end{cases} \tag{6}$$

Where T is a non negative threshold

$$g_3(i, j) = \begin{cases} L_G & G(i, j) \geq T \\ f(i, j) & G(i, j) < T \end{cases} \tag{7}$$

Where LG is a specified edge gray value

$$g_4(i, j) = \begin{cases} G(i, j) & G(i, j) \geq T \\ L_B & G(i, j) < T \end{cases} \tag{8}$$

Where LB is a specified background gray value

$$g_5(i, j) = \begin{cases} L_G & G(i, j) \geq T \\ L_B & G(i, j) < T \end{cases} \tag{9}$$

A good edge detection algorithm usually should meet three basic requirements. The first is good detection result of low wrong detection ratios. The second is good edge accuracy of edge position image as close as possible to the real edge pixel position. The third is to have low response times on the same edge pixel.

3. Improved Color Image Edge Detection Method

3.1. Kernel Idea

According to the component relation of color model, there are component correlation color model and component not to be related color model. Color model RGB is a typical color model with three related components. Color model HSI is a typical color model with three components not to be related. In general, the edge detection method of color image is implemented by applying grayscale image edge detection method to the color image components. The first step is to decompose the color model to the three components. And the second step is to detect the three component edges. At last the three component edges are composed to the color image edge.

During the course of the gray image edge detection, the strong contrast intensity is the key

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of gray edge to be detected. So color image edge detection also mainly depends on the color edge color contrast intensity [4]. Color edge should have the continuous character. Color edge is often the target boundary with different color features. In the case of low color brightness, there are some color edges not to be detected. So the contrast enhancement operation is the precondition of color image edge detection.

3.2 HSI Model Color Image Edge Detection Method

The kernel idea of color image edge detection method based on HSI model is to enhance the contrast of Component I. Color component contrast enhancement method is based on color model [5].The color image edge detection process based on HSI model is given as follows [6]:

Step 1: Color model transformation. Transform RGB model to HSI model and compute Component H, Component I and Component S. The transform formulae can be written as [3,5]:

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

$$S = 1 - \frac{3}{(R+G+B)}[\min(R,G,B)] \quad (10)$$

$$H = \begin{cases} \theta & G \geq B \\ 2\pi - \theta & G < B \end{cases}$$

$$\theta = \arccos\left\{ \frac{[(R-G)+(R-B)]/2}{[(R-G)^2+(R-B)(G-B)]^{1/2}} \right\} \quad (11)$$

Step 2: Component I enhancement. Apply Component I values regulation or histogram modification technology to enhance the contrast of Component I and Component H and Component S remain unchanged.

Step 3: Component edge detection. Compose the color image edge after detecting three component edges.

Step 4: Color model transformation. Transform HIS model to RGB model. The transform formulae can be written as [3, 5]:

If 0º≤H<120º,then

$$B = I(1-S) \quad (12)$$

$$R = I[1 + \frac{S\cos(H)}{\cos(60° - H)}] \quad (13)$$

$$G = 3I - (B+R) \quad (14)$$

If 120º≤H < 240º,then

$$R = I(1-S) \quad (15)$$

$$G = I[1 + \frac{S\cos(H-120°)}{\cos(180° - H)}] \quad (16)$$

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$$B = 3I - (R + G) \quad (17)$$

If 240º≤H < 360º,then

$$G = I(1 - S) \quad (18)$$

$$B = I[1 + \frac{S\cos(H - 240°)}{\cos(300° - H)}] \quad (19)$$

$$R = 3I - (G + B) \quad (20)$$

The color type pertinence of the method is not strong and the method is applied to all color types of contrast enhancement. Because color model transformation is needed before edge detecting and inverse transformation is needed after edge detecting. The time complexity and space complexity of the algorithm are very high.

3.3 RGB Model Color Image Edge Detection Method

This section presents color image contrast enhancement method based on the color model with three components not to be related [7]. Its precondition is to obtain RGB color value and its color table. The kernel idea is to pixel operation by creating non lineal function. The first step is to get the red component value *r*, the green component value *g*, and the blue component value *b*. The difference of the maximum value *MAX*（*r*,*g*,*b*）and the minimum value *MIN*（*r*,*g*,*b*）is *D*. The median value *M*, the maximum value *MAX*（*r*,g,*b*）and the normalized gray value *GRAY*（*r*,*g*,*b*）are computed. The formula can be written as:

$$GRAY(r,g,b) = a1 \times r + a2 \times g + a3 \times b \quad (21)$$

Where $0 < a1, a2, a3 < 1$ and $a1+a2+a3=1$

The enhancement coefficient *K* is supposed, the formula can be written as:

$$R1 = K \times r,\ G1 = K \times g,\ B1 = K \times b \quad (22)$$

Where $K=GRAY(r,g,b)/M$

If $K \times MAX(r,g,b) > 2^n - 1$, the enhancement coefficient K isnot reasonable. The enhancement coefficient *K* must be supposed again, *MAX*(*r*,*g*,*b*) is the maximum of *r*,*g*,*b*, then the red component value *r*, the green component value *g*, and the blue component value *b* are updated:

$$R1 = K \times r,\ G1 = K \times g,\ B1 = K \times b \quad (23)$$

Component contrast enhancement algorithm is given as follows:

Algorithm *R*1*G*1*B*1=color_enhance(*RGB*)

Input : *RGB* image(every color component is expressed by *n* bit, then the color value is in the range of $[0, 2^n-1]$)

Output: *RGB* image *R*1G1B1 of contrast enhancement

Step 1: Initialization. Suppose contrast coefficient *K*=1, suppose the difference of the maximum value *MAX*（*r*,*g*,*b*）and the minimum value *MIN*（*r*,*g*,*b*）is *D*.

Step 2: Get the red component value *r*, the green component value *g*, and the blue

component value *b* of any pixel P in a given order.

Step 3: If $MAX(r,g,b)- MIN(r,g,b)<D$, then M is the median value $M=MEDIAN(r,g,b)$, K is the normalized gray value $GRAY(r,g,b)$ of p,and the median value coeffcient of proportionality of r,g,b $K=GRAY(r,g,b)/M$,otherwise,go to step 5.

Step 4: if $K\times MAX(r,g,b)>255$, the component maximum can be written as:

$$MAX(r,g,b),\ K=GRAY(M)/MAX(r,g,b),\ R1=K\times r,\ G1=K\times g,\ B1=K\times b. \quad (24)$$

Step 5: If p is last pixel, then go to step 6,otherwise go to step 2.

Step 6: Output the result image $R1G1B1$.

The process of the improved color image edge detection based on RGB color model is given as follows:

Step 1: Decompose the color image to Component R, Component G, and Component B.

Step 2: Call Algorithm color_enhance.

Step 3: Detect the component edge according to the gradient operator.

Step 4: Compose the color edge.

4. Experiment Results

4.1. Experiment Results of Edge Detection Based on HSI Color Model

The experiments are performed on a Pentium 4 2.4GHZ PC running Windows XP, with 2.0GB memory and one 120 GB hard disk. The below results are got in MATLAB 7.0 environment through editing M files and user defined functions.

The experiment image is a true color image with 384×512 pixels and 256^3 kinds of color in this section. At first the RGB color model are transformed to the HSI color model. Suppose p is any pixel, p has three component value H,S and I. In this experiment Component I is only enhanced.

The formula of enhancing Component I can be written as:

$$I_1=\begin{cases}1 & I\geq 0.3 and I+0.3\geq 1\\ I+0.3 & I\geq 0.3 and I+0.3<1\\ I-0.2 & I<0.3 and I-0.3\geq 0\\ 0 & I<0.3 and I-0.3<0\end{cases} \quad (25)$$

The execution time of component I enhancement is 0.5310 seconds.

The image results are shown in Figure 1. Image (1) is the original image based on RGB model, image (2) is the original image based on HSI model, image (3) is enhancement image based on HSI model and image (4) shows that the brightness of RGB image is lower. The edge detection of I component is implemented by Robert operator and Prewitt operator. And H component and I component keep unchanged. The three components are composed to the color image based on HSI color model. It is transformed to RGB image. Image (5) is Prewitt operator edge of original image, image (6) is enhancement image edge by Prewitt operator. The execution time of Prewitt operator edge detection is 1.2970 seconds. Image (7) is Robert operator edge of original image, image (8) is enhancement image edge by Robert operator.

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The execution time of Robert operator edge detection is 2.3440 seconds.

Apparently, edge image of Component I by Robert operator and Prewitt operator is color edge. But there is no obvious difference in the two color edge. Its shortcoming is to lose part of the edge details. Therefore, edge detection method only by enhancement I component grayscale contrast is not ideal.

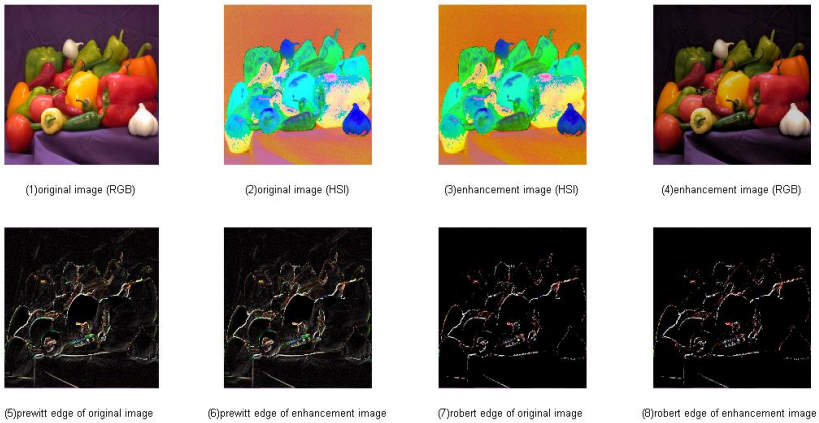

Figure 1. Edge Detection Results of Original Image and Image Enhancement

4.2 Experiment Results of Edge Detection Based on RGB Color Model

The experiment process of color image edge detection based on RGB color model is shown in this section. The first is to decompose RGB image to Component R, Component G and Component B. Component R, Component G and Component B are enhanced by color_enhance algorithm in this paper.

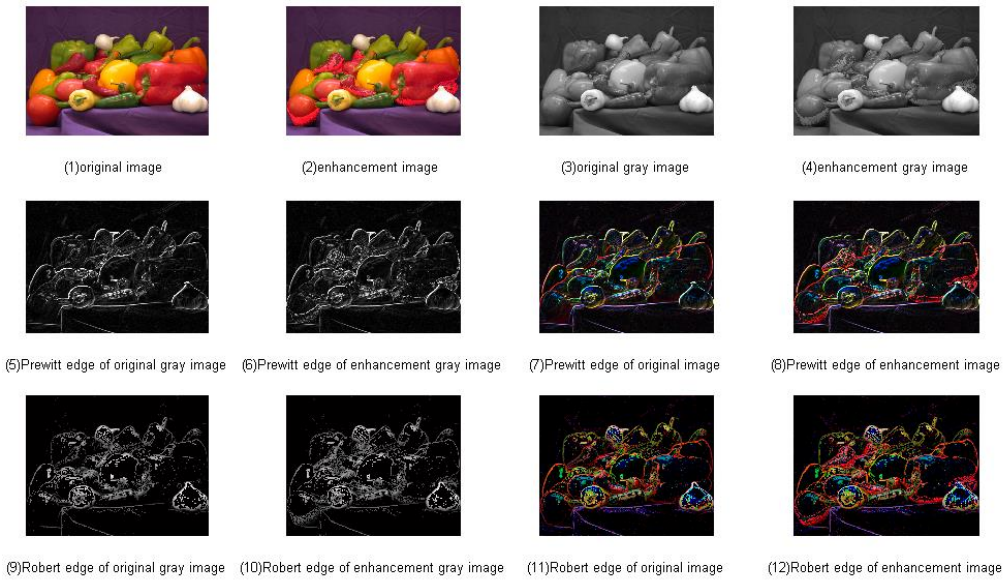

Figure 2. Edge Detection Results of Original Image and Image Enhancement Based on RGB Color Model

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In the algorithm, n=8,D=128,the grayscale $GRAY(r,g,b)$ can be written as:

$$GRAY(r,g,b) = 0.299 \times r + 0.587 \times g + 0.114 \times b \quad (26)$$

Then edge detection results of Component R, Component G and Component B are calculated by gradient operators. The color edges are composed by the three component edges.

Detection results are shown in Figure 2. Image (1) is original image, image (2) is the enhanced image through the algorithm in this paper, image (3) is the gray image, and image (4) is gray enhanced image. Image (5) is edge result of original gray image by Operator prewitt, image (6) is edge result of enhanced gray image by Operator prewitt, image (7) is edge result of original image by Operator robert, and image (8) is edge result of enhanced image by Operator robert. Image (9) is edge result of original gray image by Operator robert, image (10) is edge result of enhanced gray image by Operator robert, image (11) is edge result of original image by Operator robert, and image (12) is edge result of enhanced image by Operator robert.

From Figure 2 and Figure 3, edge detection effect of the enhanced gray image and the enhanced color image is differently superior to the original color image and the original gray image. Threshold of Robert operator is 10. In the method, the execution time of the enhancement algorithm is 10.0320 seconds. The edge detection time of the three components by Operator prewitt is about 1.1400 seconds. The edge detection time of the three components by Operator robert is about 1.3590 seconds. Due to the first scanning processing by pixel , the enhanced algorithm needs some times. The experimental data show that the enhanced algorithm's time is about 10 times to detect the edge of time. Therefore, it is necessary to study the rapid enhancement algorithm.

4.3 Comparison of Edge Detection Based on HSI and RGB Color Model

The experiment process of color image edge detection based on RGB color model is shown in this section. The first is to decompose RGB image to Component R, Component G and Component B. Component R, Component G and Component B are enhanced by algorithm in this paper. Then edge detection results of Component R, Component G and Component B are calculated by gradient operators. The color edges are composed by the three component edges. The experiment image is true color image with 533×1024 pixels and 256^3 kinds of color in this section. Detection results are shown in Figure 3 and Figure 4.

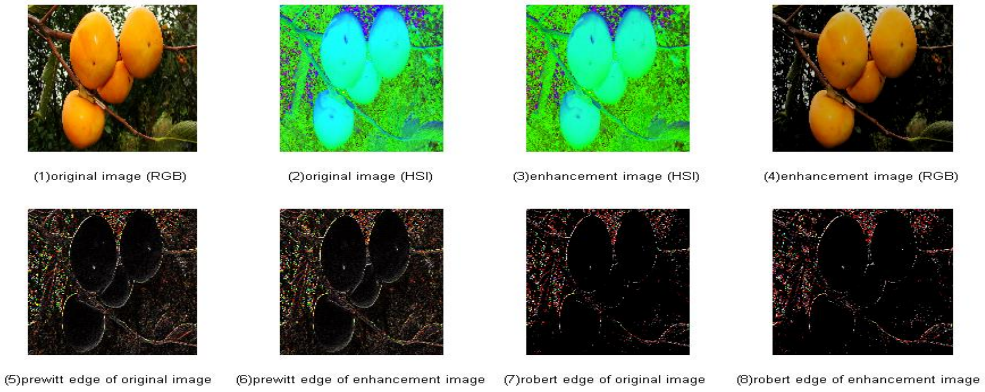

Figure 3. Edge Detection Results of Original Image and Image Enhancement

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The image results are shown in Figure 3. Image (1) is the original image based on RGB model, image (2) is the original image based on HSI model, image (3) is enhancement image based on HSI model and image (4) shows that the brightness of RGB image is lower. The edge detection of I component is implemented by Robert operator and Prewitt operator. And H component and I component keep unchanged. The three components are composed to the color image based on HSI color model. It is transformed to RGB image. Image (5) is Prewitt operator edge of original image, image (6) is enhancement image edge by Prewitt operator. The execution time of Prewitt operator edge detection is 1.2970 seconds. Image (7) is Robert operator edge of original image, image (8) is enhancement image edge by Robert operator.

The image edge results are shown in Figure 4. Image (1) is original image, image (2) is the enhanced image through the algorithm in this paper, image (3) is the gray image, and image (4) is gray enhanced image. Image (5) is edge result of original gray image by Operator prewitt, image (6) is edge result of enhanced gray image by Operator prewitt, image (7) is edge result of original image by Operator robert, and image (8) is edge result of enhanced image by Operator robert. Image (9) is edge result of original gray image by Operator robert, image (10) is edge result of enhanced gray image by Operator robert, image (11) is edge result of original image by Operator robert, and image (12) is edge result of enhanced image by Operator robert.

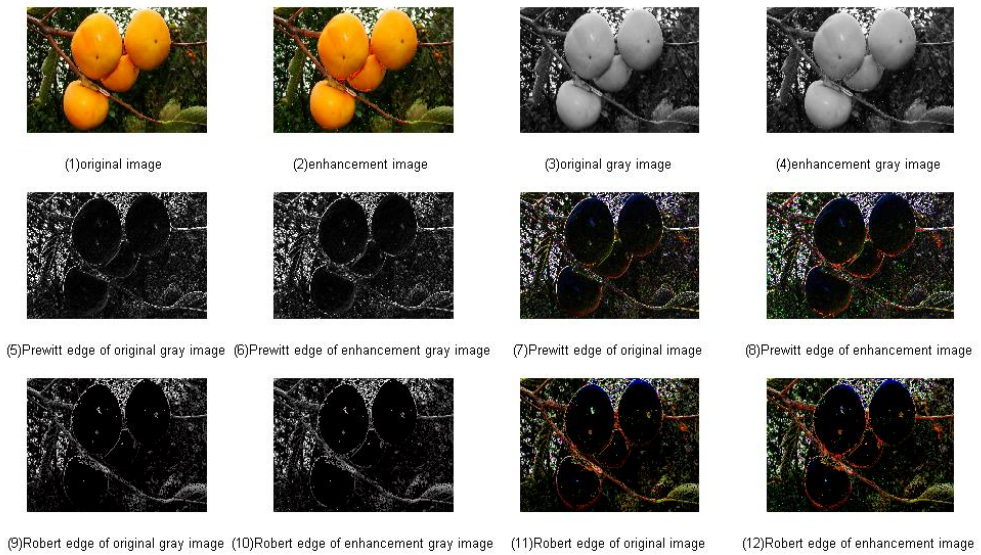

Figure 4. Edge Detection Results of Original Image and Image Enhancement Based on RGB Color Model

In the method, the execution time of the enhancement algorithm is 28.875 seconds. The edge detection time of the three components by Operator prewitt is about 2.9370 seconds. The edge detection time of the three components by Operator robert is about 3.250 seconds. Edge detection effect of the enhanced gray image and the enhanced color image is differently superior to the original color image and the original gray image.

The experiment image is true color image with 586×1024 pixels and 256^3 kinds of color in this section. Detection results are shown in Figure 5 and Figure 6. In the method, the execution time of the enhancement algorithm is 35.281 seconds. The edge detection time of the three components by Operator prewitt is about 3.781 seconds. The edge detection time of the three components by Operator robert is about 3.725 seconds. Edge detection effect of the

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enhanced gray image and the enhanced color image is differently superior to the original color image and the original gray image.

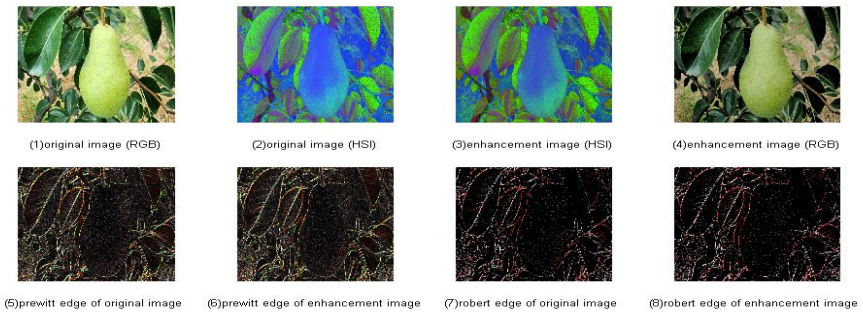

Figure 5. Edge Detection Results of Original Image and Image Enhancement

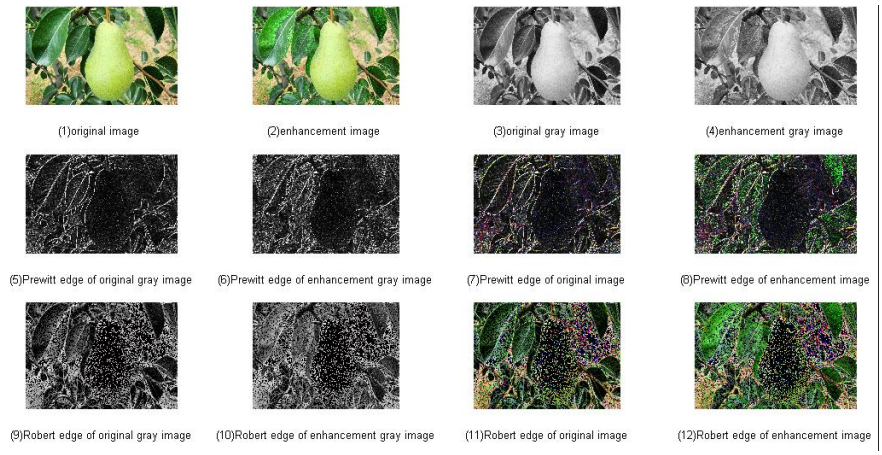

Figure 6. Edge Results of Original Image and Image Enhancement Based on RGB Color Model

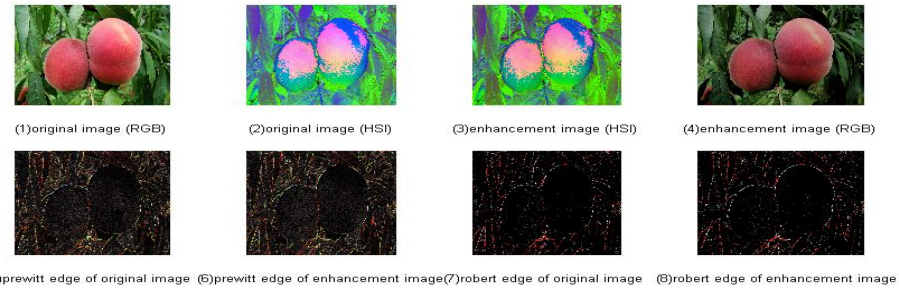

Figure 7. Edge Detection Results of Original Image and Image Enhancement

The experiment image is a true color image with 535×1024 pixels and 256^3 kinds of color in this section. Detection results are shown in Figure 7 and Figure 8. In the method, the execution time of the enhancement algorithm is 29.797 seconds. The edge detection time of the three components by Operator prewitt is about 3.500 seconds. The edge detection time of the three components by Operator robert is about 3.485 seconds. Edge detection effect of the enhanced gray image and the enhanced color image is differently superior to the original color image and the original gray image.

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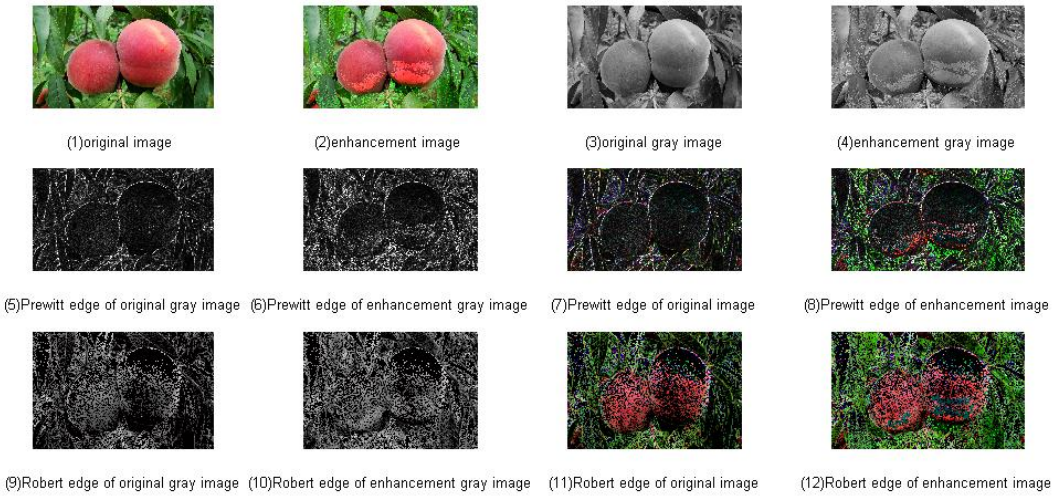

Figure 8. Edge Results of Original Image and Image Enhancement Based on RGB Color Model

5. Conclusion

This paper studies the color contrast enhancement of color image and the color edge detection method. Compared with the gray edge detection operator, the extraction of color edge is implemented. Compared with directly component edge extraction of the original color image, it has the advantages of more edge information, without leakage phenomenon.

Color_enhance Algorithm in Section 3 is a pixel-wise processing, and needs some time. Experimental data in Section 4 show that the time of the enhancement algorithm is about 10 times to the time of detecting the gray edge. Namely, it needs some time of preprocessing thecolor image. Therefore, further research should focus on the rich edge region in the color image. How to determine the rich area with color edges is the key problem. So the rapid implementation of the enhanced algorithm is also necessary.

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