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The Application of Local Operator of Edge Detecting in the Extraction of Waxberry Contour

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Abstract—It is a crucial point for the auto-picking robots how to extract the fruit's contour in their growing environment. The paper explores the extraction of waxberry contour by way of local operator of edge detecting, compares the detection effects of different operators, summarizes the application field of variant detection operators, and analyzes the advantages and disadvantages of edge detecting by these operators and the factors influencing the detection results. Hence the paper aims to make a little contribution to image preprocessing for the vision system of waxberry-picking robots.

Keywords- edge detecting; operator; grads

1. Introduction

Edge detecting is the basis and precondition of image recognition, which aims to extract the information of contours in different regions of an image. If these regions have the same color and brightness, that means they are one object or one part of the object[1]. In edge detecting, the data of extracting information is much less than that of the original image[3], but it is closely related with module of the machine vision system. The paper detects the waxberry image by local operator of edge detecting, compares the results, and makes a little contribution to image preprocessing for the vision system of waxberry-picking robots.

2. Image preprocessing

First of all, a waxberry image is acquired by a digital camera, which is a 24-bit RGB and with 640×480 pixels. Because of the large amount of data in a 24-bit RGB image and JPG compressed format, the colored image is first processed into a format of 256×256 bitmap (bmp) by the tool software (eg. Photoshop, ACDSee, and so on), and then is transformed into a grayscale one, in order to lessen the amount of information by image processing and improve the image processing speed.

2.1. The storage format of 24-bit RGB bitmap

The storage format of 24-bit RGB bitmap are successively: one file header, one info header and bitmap array. The bitmap array is expression part of pixel, every point of which is composed by three-byte data. They successively show R-red, G-Green, B-Blue, all of which are called tricolor. The different combinations of the three colors become the various real colors.

2.2. The storage format of grayscale bitmap

The storage format of grayscale bitmap is basically the same as the one of 24-bit RGB bitmap. The only difference is that grayscale bitmap has one more color index segment because one byte means one pixel in

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grayscale bitmap. Therefore the pixel array is one third smaller. When a real color image is transformed into a grayscale image, the following formula can be used:

$$Gray(x, y) = 0.28\, Red(x, y) + 0.60\, Green(x, y) + 0.12\, Blue(x, y) \quad (1)$$

where Gray (x , y)is grayscale value at point(x , y) in the transformed image.

The image transformed can be illustrated as Fig.1 and Fig.2:

Fig.1. 24-bit RGB original bitmap

Fig.2. 8-bit grayscale bitmap

3. Local operator of edge detecting

The edge of an image usually corresponds to the mutation of grayscale. The detecting method is to examine the change of every pixel in a certain region. Using the first or second derivative changing rule of edge contiguity to detect edges is usually called the method of local operator of edge detecting. The common first derivative operators are Robert operator, Sobel operator, Prewitt operator and the second derivative operators are Laplacian operator, LOG operator. Now the extraction of the contour of a waxberry can be realized by using these local operator.

3.1. Grads

Edges are the points of image function change. Because an image is two-dimensional function, the grads $\nabla f(x, y)$ of an image function must be calculated to find these points. The grads of a two-dimensional function is two-dimensional vector, whose weight is the partial derivatives of image functions along the orthogonal direction.

The grayscale value function z = f(x , y)of a two-dimensional image , x and y are respectively the coordinates of the image pixel. If there are edges in x and y, the direction toward which it changes rapidly can be calculated by way of the changing rate of x and y directions in f(x, y), which is the direction of grads. The grad vector, including the sizes and directions can be shown as follows:

$$\nabla f(x, y) = [G_x, G_y]^T = \left[\frac{\partial f}{\partial x} \; \frac{\partial f}{\partial y}\right]^T \quad (2)$$

the range of grads:

$$mag(\nabla f) = \left[G_x^2 + G_y^2\right]^{\frac{1}{2}} \quad (3)$$

the phase of grads:

$$\varphi = \arctan\left(\frac{G_y}{G_x}\right) \quad (4)$$

In the above formula, the Euclidean distance is adopted to calculate the grad ranges. In calculation, evolution is used. On the other hand other distance formula can be used in order to increase its speed. For instance:

$$mag(\nabla f) = |G_x| + |G_y| \quad (5)$$

or

$$mag(\nabla f) = \max(|G_x|, |G_y|) \quad (6)$$

Choose proper threshold value. If $mag(\nabla f) \geqslant T$, (x,y) is the edge point and f(x, y) is the edge image.

Because the digital image is discrete, the partial derivatives can be replaced by one order difference in image derivatives. The formula as follows:

$$f_x(x,y) = f(x,y) - f(x-1,y)$$
$$f_y(x,y) = f(x,y) - f(x,y-1) \quad (7)$$

3.2. The first derivative operator

1) Roberts operator

Roberts operator is the simplest one, which uses the difference between two adjacent pixels of diagonal direction that is close to the grad range value to detect edges. The effect to detect the vertical edge is better than the oblique edge. Roberts operator has high precision in orientation and is sensitive to noise. It is a 2*2 model as follows:

x direction y direction

$$\begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \quad \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad (8)$$

The following formula can be got by multiplying and adding of pixels and elements corresponded by the model while calculating Roberts operator.

$$Gx(x,y) = f(x+1,y) - f(x,y+1)$$
$$Gy(x,y) = f(x,y) - f(x+1,y+1) \quad (9)$$

2) Prewitt operator

Prewitt operator uses the difference of grayscale between the upper and lower points, and between left and right points of pixel to detect extremum of edges. Its principle is to use neighborhood convolution between the model of two orientation in the image space and the image. The model used as follows:

horizontal vertical

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad (10)$$

As far as the digital image f (x, y) is concerned, the definition of Prewitt operator is as follows:

$$G_x(x,y) = f(x+1,y-1) + f(x+1,y) + f(x+1,y+1) - f(x-1,y-1) - f(x-1,y) - f(x-1,y+1)$$
$$G_y(x,y) = f(x-1,y+1) + f(x,y+1) + f(x+1,y+1) - f(x-1,y-1) - f(x,y-1) - f(x+1,y-1) \quad (11)$$

$$mag(\nabla f) = \max(|G_x|,|G_y|) \quad (12)$$

3) Sobel operator

Sobel operator is a method which combines difference operations and local averages. Like Prewitt operator, the influence of pixel neighborhood on the present pixel is equivalent. But the difference is the elements between two operator models. Sobel operator has different weight according to the distance between neighboring pixel and present pixel. Usually the farther the distance is, the smaller the weight is. Its model can be seen as follows:

horizontal vertical

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (13)$$

As far as the digital image f (x, y) is concerned, Sobel operator can be defined as follows:

$$G_x(x,y) = f(x+1,y-1) + f(x+1,y) + f(x+1,y+1) - f(x-1,y-1) - f(x-1,y) - f(x-1,y+1)$$
$$G_y(x,y) = f(x-1,y+1) + f(x,y+1) + f(x+1,y+1) - f(x-1,y-1) - f(x,y-1) - f(x+1,y-1) \quad (14)$$

3.3. The second derivative operator

The second derivative is the derivative of first derivative, that is the difference of the difference.

1) Laplacian operator

Laplacian operator is an edge detecting operator defined by $\nabla^2 f(x,y) = \frac{\partial^2 f}{\partial^2 x} + \frac{\partial^2 f}{\partial^2 y}$, the second partial derivative in the direction of x and y according to the image f (x, y). Because there is a great change in the grayscale of the image edge, the first partial derivative of the image in the edges has its local maximum and minimum values. In this way the second partial derivative goes through point zero in the edges. To detect the edges by way of f (x, y) is to estimate and calculate the output of Laplacian operator, thus the position of point zero can be found out. The model can be used as follows:

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \tag{15}$$

In the digital image f (x, y), the classical Laplacian operator can be defined as follows:

$$\nabla^2 f(x,y) \approx f(x,y-1) + f(x,y+1) + f(x-1,y) + f(x+1,y) - 4f(x,y) \tag{16}$$

choose proper threshold value. If $mag(\nabla f) \geqslant$T, (x,y) is the edge point and f(x, y) is the edge image.

Because the digital image is discrete, the partial derivatives can be replaced by one order difference in image derivatives.

$$\begin{aligned} f_x(x,y) &= f(x,y) - f(x-1,y) \\ f_y(x,y) &= f(x,y) - f(x,y-1) \end{aligned} \tag{17}$$

2) LOG operator

LOG is the short form of Laplacian of Gaussian operator. Because Laplacian operator is highly sensitive to the noises, some people proposed that Gaussian filter be combined with Laplacian edge detecting to form LOG algorithm. That is firstly, to make the smoothest process of the original image with Gaussian lowpass filter in order to restrain the noises to a maximum extent, then get the edges of the smooth images. The response function of two-dimensional Gaussian filter is:

$$Gauss(x,y) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2} \tag{18}$$

Supposing that f (x, y) is the grayscale image function and the output function of LOG operator is H (x, y), the following can be got according to the interchangeability of convolution and difference in linearity system.

$$H(x,y) = \nabla^2 [Gauss(x,y) \cdot f(x,y)] = [\nabla^2 Gauss(x,y)] \cdot f(x,y) \tag{19}$$

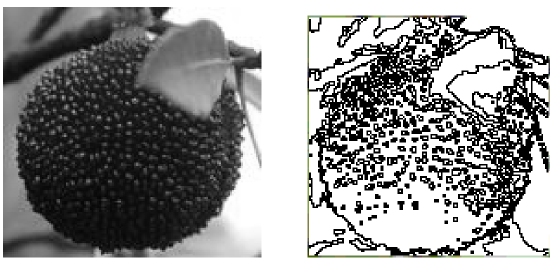
$$\nabla^2 Gauss(x,y) = \left[\frac{x^2 + y^2 - 2\sigma^2}{\sigma^4}\right] \cdot e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{20}$$

its model as follows:

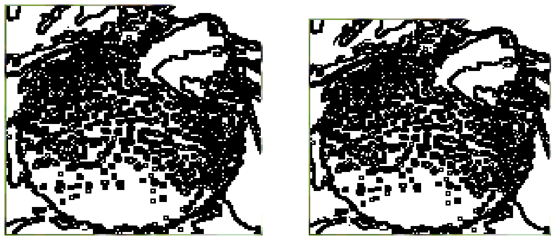
$$\begin{bmatrix} -2 & -4 & -4 & -4 & -2 \\ -4 & 0 & 8 & 0 & -4 \\ -4 & 8 & 24 & 8 & -4 \\ -4 & 0 & 8 & 0 & -4 \\ -2 & -4 & -4 & -4 & -2 \end{bmatrix} \tag{21}$$

4. Analysis of the experiment results

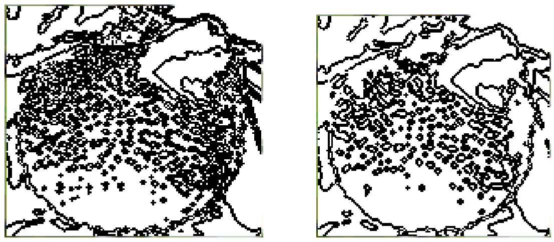
The results of extracting the edge features of the waxberry image can be shown as Fig.3 according to the above edge detecting operator.



(a)original (b)Roberts



(c)Prewitt (d)Sobel



(e)Laplacian (f)LOG

Fig.3. the results of edge detecting

By comparing the processed results of the above edge detecting local operator, we can draw the following conclusion:

In picture(b)the resolution of Roberts operator is better, but it is very sensitive to noises. So there appear some isolated points and incompleteness in the very edge. Its effect to detect the vertical edge is better than the oblique edge.

The detecting result of Prewitt operator in picture(c) is very close to that of Sobel operator in picture(d). While detecting the contour of the waxberry, the contour of the background including the leaves and the stalks can be detected at the same time. Because these operators can both process using difference and filter, and the only difference is the different weights in the smooth part, both can restrain noises in a certain degree. But it can't eliminate the false edges in the detecting results. Sobel operator is more sensitive to diagonal edges than to horizontal and vertical edges, whereas Prewitt operator is evenly sensitive to horizontal and vertical edges. Both these operators can better process the grayscale changes and much noises of an image. When the precision requirement is not very high, this is an often commonly use edge detecting method.

The detecting result of Laplacian operator in picture (e) is very unclear and the edge line is incomplete. Because Laplacian operator is a second order difference operator, it has no orientations which loses part of information of edge orientation although it is very precise for the orientation of step edge points in the image. This leads to some incontinuous edge detecting and the poor noise resistance. And sometimes the edges of double pixels can be easily detected. This operator is suit for ridge edge detection.

When LOG operator is compared with the above methods, the detecting result is very clear. Most parts of the edges can be seen with few false edges. This better solves the conflict between space optimization and frequency domain optimization with a simple calculating method. In addition, the operator has the feature of isotropy when going through point zero, which contributes to the completeness of the edge, hence a better edge detecting result can be achieved.

So far as the edge detecting method, there are a number of methods besides the above classical ones, for example Facet model, Hough transform, multi-scale space filter, wavelet transform, fuzzy reasoning, artificial neural network. But these methods are not as simple as the classical ones. For these methods, it is either difficult to get a reasonable computational complexity and to realize with the hardware, or in need of various parameters adjusted manually. Sometimes it is pretty difficult for real-time operation.

5. Conclusion

Although LOG operator has been widely acknowledged for many years and its application results have been good, there is still room for improving its orientation precision. We must admit the conflict between the edge orientation precision and the edge completeness can never objectively compromised optimally. Especially the natural environment in which waxberry grows, its light conditions, the changes of the planting areas and the image noise all have an adverse influence on the results of edge detecting. Besides the particularity of waxberry surface which is rough and uneven makes its texture contour detected as a part of the detecting results to a certain degree. To solve all these problems, a further research of the edge detecting method is needed to realize effectively and easily use the hardware.

In conclusion, on the way to seek for the edge detecting method, there is no best way but the better one. How to achieve a precise and unique automatic detecting method which also meets the requirement is a pretty long way to go.

6. References

[1] Xiang Bai, Xingwei Yang, Longin Jan Latecki. Detection and recognition of contour parts based on shape similarity, Pattern Recognition. 2008, pp 2189-2199.

[2] Cosmin Grigorescu, Nicolai Petkov. Michel A. Westenberg, Contour and boundary detection improved by surround suppression of texture edges, Image and Vision Computing. 2004, pp 609-622.

[3] Qiling Tang, Nong Sang, Tianxu Zhang.Contour detection based on contextual influences, Image and Vision Computing. 2007, pp 1282-1290.

[4] Konrad Schindler, David Suter. Object detection by global contour shape, Pattern Recognition. 2008, pp 3736-3748.

[5] V. Gemignani, M. Paterni, A. Benassi, M. Demi. Real time contour tracking with a new edge detector. Real-Time Imaging. Volume 10, Issue 2, April 2004, pp 103-116.