ALGORITHM AND TECHNIQUE ON VARIOUS EDGE DETECTION: A SURVEY

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ABSTRACT

An edge may be defined as a set of connected pixels that forms a boundary between two disjoints regions. Edge detection is basically, a method of segmenting an image into regions of discontinuity. Edge detection plays an important role in digital image processing and practical aspects of our life. .In this paper we studied various edge detection techniques as Prewitt, Robert, Sobel, Marr Hildrith and Canny operators. On comparing them we can see that canny edge detector performs better than all other edge detectors on various aspects such as it is adaptive in nature, performs better for noisy image, gives sharp edges , low probability of detecting false edges etc.

KEYWORDS

Edges, Edge detection, Canny edge detection.

1. INTRODUCTION

Digital image processing is meant for processing digital computer. It is the use of computer algorithm to perform image processing on digital images. It is a technology widely used for digital image operations like feature extraction, pattern recognition, segmentation, image morphology etc. Edge detection is a well developed field on its own within image processing. Edge detection is basically image segmentation technique, divides spatial domain, on which the image is defined, into meaningful parts or regions. Edges characterize boundaries and are therefore a problem of fundamental importance in image processing. Edges typically occur on the boundary between two different regions in an image. Edge detection allows user to observe those features of an image where there is a more or less abrupt change in gray level or texture indicating the end of one region in the image and the beginning of another. It finds practical applications in medical imaging, computer guided surgery diagnosis, locate object in satellite images, face recognition, and finger print recognition ,automatic traffic controlling systems, study of anatomical structure etc. Many edge detection techniques have been developed for extracting edges from digital images .Gradient based classical operators like Robert, Prewitt, Sobel were initially used for edge detection but they did not give sharp edges and were highly sensitive to noise image .Laplacian based Marr Hildrith operators also suffers from two limitations : high probability of detecting false edges and the localization error may be severe at curved edges but

DOI : 10.5121/sipij.2013.4306

algorithm proposed by John F. Canny in 1986 is considered as the ideal edge detection algorithm for images that are corrupted with noise. Canny's aim was to discover the optimal edge detection algorithm which reduces the probability of detecting false edge, and gives sharp edges.[1][2][3][4][5].

1.1 Edge detection

Edge detection is a basic tool used in image processing, basically for feature detection and extraction, which aim to identify points in a digital image where brightness of image changes sharply and find discontinuities. The purpose of edge detection is significantly reducing the amount of data in an image and preserves the structural properties for further image processing. In a grey level image the edge is a local feature that, with in a neighborhood separates regions in each of which the gray level is more or less uniform with in different values on the two sides of the edge**.** For a noisy image it is difficult to detect edges as both edge and noise contains high frequency contents which results in blurred and distorted result.

1.2 Different edge detection methodologies [1]

Edge detection makes use of differential operators to detect changes in the gradients of the grey levels. It is divided into two main categories:

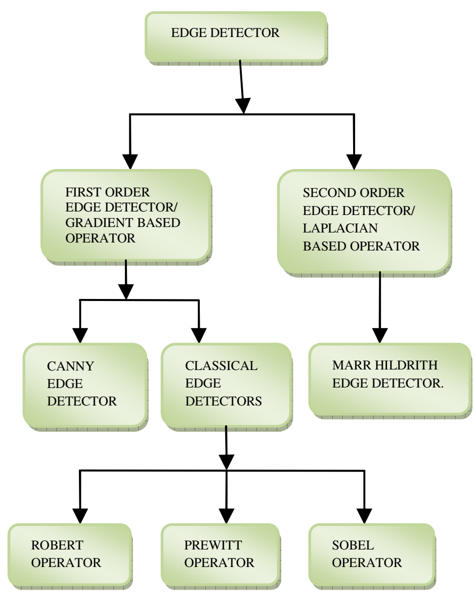

Figure 1 Types of edge detector

2. FIRST ORDER EDGE DETECTION OR GRADIENT BASED EDGE OPERATOR: [1]

It is based on the use of a first order derivative, or can say gradient based. If I (i , j) be the input image, then image gradient is given by following formula

$$\nabla I(i,j) = \hat{\imath}\,\frac{\partial I(i,j)}{\partial i} + \hat{\jmath}\,\frac{\partial I(i,j)}{\partial j}$$

Where: $\frac{\partial I(i,j)}{\partial i}$ is the gradient in the i direction.

$\frac{\partial I(i,j)}{\partial j}$ is the gradient in the j direction.

The gradient magnitude can be computed by the formula:

$$|G| = \sqrt{\left(\frac{\partial I}{\partial i}\right)^2 + \left(\frac{\partial I}{\partial j}\right)^2}$$

OR $|G| = \sqrt{{G_i}^2 + {G_j}^2}$

The gradient magnitude can be computed by the formula:

$$\theta = arctan\left(G_j/G_i\right).$$

The magnitude of gradient computed above gives edge strength and the gradient direction is always perpendicular to the direction of edge.

2.1 Classical operators

Robert, Sobel , Prewitt are classified as classical operators which are easy to operate but highly sensitive to noise.

2.1.1 Robert operator [1]

It is gradient based operator. It firstly computes the sum of the squares of the difference between diagonally adjacent pixels through discrete differentiation and then calculate approximate gradient of the image. The input image is convolved with the default kernels of operator and gradient magnitude and directions are computed. It uses following 2 x2 two kernels:

$D_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ And $D_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$

The plus factor of this operator is its simplicity but having small kernel it is highly sensitive to noise not and not much compatible with today's technology.

2.1.2 Sobel operator [1]

Sobel operator is a discrete differentiation operator used to compute an approximation of the gradient of image intensity function for edge detection. At each pixel of an image, sobel operator gives either the corresponding gradient vector or normal to the vector. It convolves the input image with kernel and computes the gradient magnitude and direction. It uses following 3x3 two kernels:

$$D_i = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \quad \text{And} \quad D_j = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}$$

As compared to Robert operator have slow computation ability but as it has large kernel so it is less sensitive to noise as compared to Robert operator. As having larger mask, errors due to effects of noise are reduced by local averaging within the neighborhood of the mask.

2.1.3 Prewitt operator [1][2]

The function of Prewitt edge detector is almost same as of sobel detector but have different kernels:

$$D_i = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} \quad \text{And} \quad D_j = \begin{bmatrix} +1 & +1 & +1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

Prewitt edge operator gives better performance than that of sobel operator.

2.1.4 Flow chart of general algorithm for classical operators

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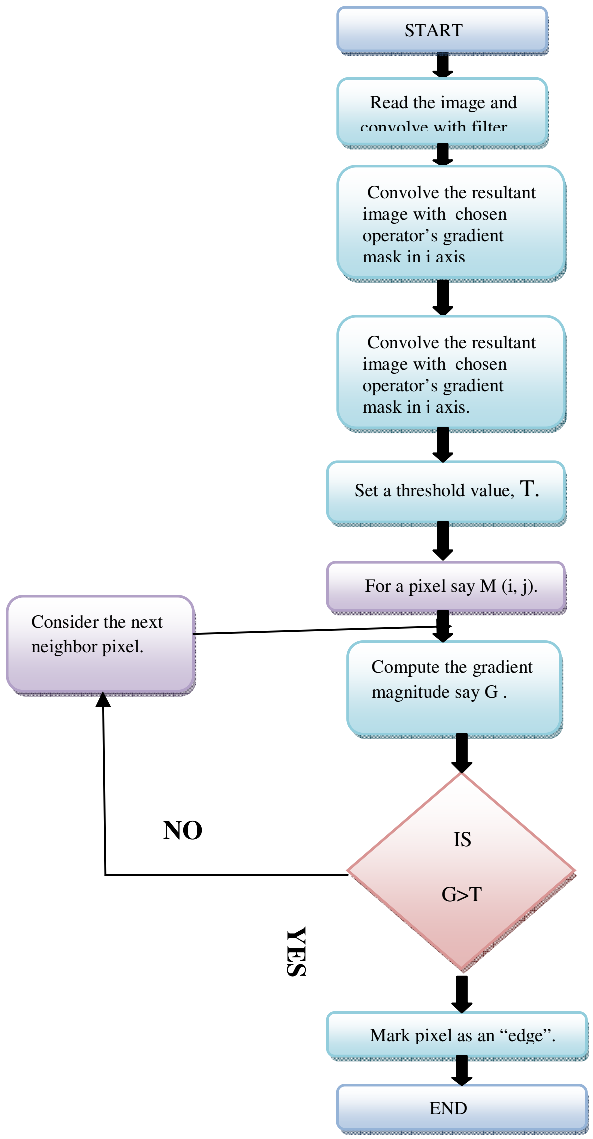

Figure 2

2.2 Canny edge detector [1] [2][3] [4][5]

Canny edge detector have advanced algorithm derived from the previous work of Marr and Hildreth. It is an optimal edge detection technique as provide good detection, clear response and good localization. It is widely used in current image processing techniques with further improvements.

2.2.1 Flow chart of canny edge detection algorithm

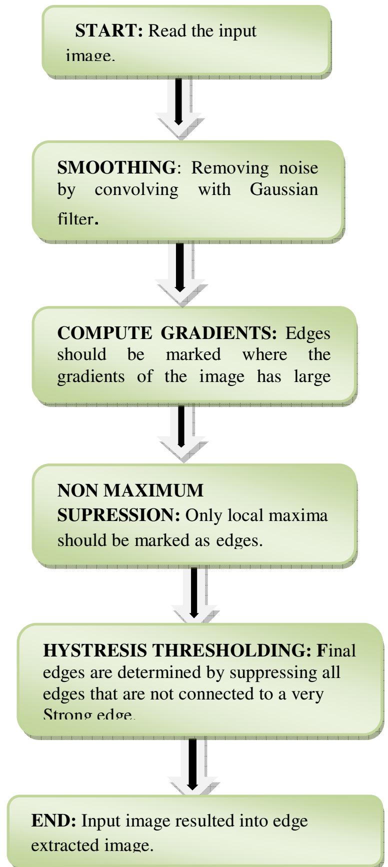

Figure 3

2.2.2 Canny edge detection algorithm

STEP I: Noise reduction by smoothing

Noise contained in image is smoothed by convolving the input image I (i, j) with Gaussian filter G. Mathematically, the smooth resultant image is given by

$$F(i,j) = G * I(i,j)$$

Prewitt operators are simpler to operator as compared to sobel operator but more sensitive to noise in comparison with sobel operator.

STEP II: Finding gradients

In this step we detect the edges where the change in grayscale intensity is maximum. Required areas are determined with the help of gradient of images. Sobel operator is used to determine the gradient at each pixel of smoothened image. Sobel operators in i and j directions are given as

$$D_i = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \quad \text{And} \quad D_j = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

These sobel masks are convolved with smoothed image and giving gradients in i and j directions.

$$G_i = D_i * F(i,j) \quad \text{And} \quad G_j = D_j * F(i,j)$$

Therefore edge strength or magnitude of gradient of a pixel is given by

$$G = \sqrt{{G_i}^2 + {G_j}^2}$$

The direction of gradient is given by $\theta = arctan\left(\frac{G_j}{G_i}\right)$

G_i And G_j are the gradients in the i- and j-directions respectively.

STEP III: Non maximum suppressions:

Non maximum suppression is carried out to preserves all local maxima in the gradient image, and deleting everything else this results in thin edges. For a pixel M (i, j):

- Firstly round the gradient direction θ nearest45°,then compare the gradient magnitude of the pixels in positive and negative gradient directions i.e. If gradient direction is east then compare with gradient of the pixels in east and west directions say E (i, j) and W (i, j) respectively.

- If the edge strength of pixel M (i, j) is largest than that of E (i, j) and W (i, j), then preserve the value of gradient and mark M (i, j) as edge pixel, if not then suppress or remove.

STEP IV: Hysteresis thresholding:

The output of non-maxima suppression still contains the local maxima created by noise. Instead choosing a single threshold, for avoiding the problem of streaking two thresholds t_{high} and t_{low} are used.

For a pixel M (i, j) having gradient magnitude G following conditions exists to detect pixel as edge:

- If G < t_{low} than discard the edge.
- If G > than t_{high} keep the edge.
- If t_{low} < G < andt_{high} and any of its neighbors in a 3 ×3 region around it have gradient magnitudes greater thant_{high}, keep the edge.

- If none of pixel (x, y)'s neighbors have high gradient magnitudes but at least one falls between t_{low} and, t_{high} search the 5 × 5 region to see if any of these pixels have a magnitude greater than thigh. If so, keep the edge.
- Else, discard the edge.

3. SECOND ORDER EDGE DETECTOR [1]

It is based on second order derivative, in particular, the Laplacian $\nabla 2$.In this operator a pixel is marked as an edge at a position where second derivative of an image becomes zero. The laplacian operator $\nabla 2$ for a 2D image I (i, j) is defined by following formula:

$$\nabla^2 = \mathrm{I}(\mathrm{i},\mathrm{j}) = \frac{\partial^2}{\partial \mathrm{x}^2}\mathrm{I}(\mathrm{i},\mathrm{j}) + \frac{\partial^2}{\partial \mathrm{y}^2}\mathrm{I}(\mathrm{i},\mathrm{j})$$

3.1 Laplacian of Gaussian or Marr Hildrith operator [3]

The Marr-Hildreth edge detector was a very popular edge operator before Canny proposed his algorithm. It is a gradient based operator which uses the Laplacian to take the second derivative of an image. It works on zero crossing method. It uses both Gaussian and laplacian operator so that Gaussian operator reduces the noise and laplacian operator detects the sharp edges.

The Gaussian function is defined by the formula:

$$\mathrm{G}\ (\mathrm{i},\mathrm{j}) = \frac{1}{\sqrt{2\Pi\sigma^2}}\ \mathrm{exp}-\left(\frac{i^2+j^2}{2\sigma^2}\right)$$

Where, σ is standard deviation? And the LoG operator is computed from

$$\mathrm{LoG} = \frac{\partial^2}{\partial i^2} G(i,j) + \frac{\partial^2}{\partial j^2} G(i,j) = \frac{i^2+j^2-2\sigma^2}{\sigma^4}\ \mathrm{exp}\ (-\frac{i^2+j^2}{2\sigma^2})$$

The Marr–Hildreth operator, however, suffers from two main limitations. It generates responses that do not correspond to edges, so-called "false edges", and the localization error may be severe at curved edges.

3.1.1 Flow chart of general algorithm for Laplacian of Gaussian operator

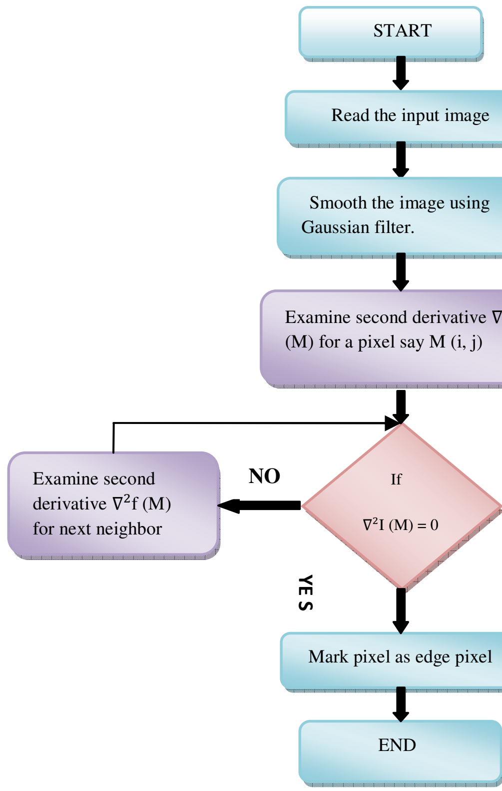

Figure 4

3.1.2 Advantages of canny edge detection algorithm. [1] [2] [3]

On analyzing all these edge detection techniques , it is found that canny gives optimum edge detection .Following are the some points throwing light on the advantages of canny edge detector as compared to other detectors discussed in this paper:

1. **Less Sensitive to noise:** As compared to classical operators like Prewitt, Robert and Sobel canny edge detector is less sensitive to noise. Its uses Gaussian filter which removes noise at a great extent as compared to above filters. LoG operator is also highly sensitive to noise as differentiate twice in comparison to canny operator.

2. **Remove streaking problem:** The classical operators' like Robert uses single thresholding technique but it results into streaking. Streaking means, if the edge gradient just above and just below the set threshold limit it removes the useful part of connected edge, and leave the disconnected final edge. To overcome from this drawback canny detector uses 'hysteresis' technique which uses two threshold values t_{low} and t_{high} as discussed above in canny algorithm.

3. **Adaptive in nature:** Classical operator have fixed kernels so cannot be adapted to a given image. While the performance of canny algorithm depends on variable or adjustable parameters like σ which is thestandard deviation of Gaussian filter and threshold values t_{low}

and t_{high}.Smaller the value of σ results smaller Gaussian filter in turns results in finer edges. So user can changes these parameters and can improve the result of canny algorithm.

4. **Good localization:** LoG operators cannot find edge orientation while canny operator provides edge gradient orientation which results into good localization.

4. CONCLUSION

In this paper we have studied and evaluate different edge detection techniques. We have seen that canny edge detector gives better result as compared to others with some positive points. It is less sensitive to noise, adaptive in nature, resolved the problem of streaking, provides good localization and detects sharper edges as compared to others. It is consider as optimal edge detection technique hence lot of work and improvement on this algorithm has been done and further improvements are possible in future as an improved canny algorithm can detect edges in color image without converting in gray image[6], improved canny algorithm for automatic extraction of moving object in the image guidance[7] . It finds practical application in Runway Detection and Tracking for Unmanned Aerial Vehicle [8], in brain MRI image [9] , cable insulation layer measurement[10], Real-time facial expression recognition[11], edge detection of river regime[12], Automatic Multiple Faces Tracking and Detection[13].Canny edge detection technique is used in license plate reorganization system which is an important part of intelligent traffic system (ITS), finds practical application in traffic management, public safety and military department [14]. It also finds application in medical field as in ultrasound, x –rays etc.

REFERENCES

[1] James Clerk Maxwell,1868 DIGITAL IMAGE PROCESSING Mathematical and Computational Methods.

[2] R .Gonzalez and R. Woods, Digital Image Processing, ,Addison Wesley, 1992, pp 414 - 428.

[3] S. Sridhar, Oxford university publication. , Digital Image Processing.

[4] Shamik Tiwari , Danpat Rai & co.(P) LTD. “Digital Image processing”

[5] J. F. Canny. “A computational approach to edge detection”. IEEE Trans. Pattern Anal. Machine Intell., vol.PAMI-8, no. 6, pp. 679-697, 1986 Journal of Image Processing (IJIP), Volume (3) : Issue (1)

[6] Geng Xing, Chen ken , Hu Xiaoguang “An improved Canny edge detection algorithm for color image” IEEE TRANSATION ,2012 978-1-4673-0311-8/12/$31.00 ©2012 IEEE.

[7] Yuesong Mei, Jianqiao Yu “ An Algorithm for Automatic Extraction of Moving Object in the Image Guidance”, IEEE, International Conference on Intelligent System Design and Engineering Application,2010.978-0-7695-4212-6/10 $26.00 © 2010 IEEE DOI 10.1109/ISDEA.2010.253

[8] Xiaogbin Wang, Baokui Li, Qingbo Geng , “Runway Detection and Tracking for Unmanned Aerial Vehicle Based on an Improved Canny Edge Detection Algorithm”IEEE, 4th International Conference on Intelligent Human-Machine Systems and Cybernetics, 2012. 978-0-7695-4721-3/12 $26.00 © 2012 IEEE DOI 10.1109/IHMSC.2012.132

[9] Sos Agaian, Ali Almuntashri "Noise-Resilient Edge Detection Algorithm for Brain MRI Images", IEEE , 31st Annual International Conference of the IEEE EMBS Minneapolis, Minnesota, USA, September 2-6, 2009.978-1-4244-3296-7/09/$25.00 ©2009 IEEE.

[10] Fan Chun-ling, Wang Dao-he "The Application of Adaptive Canny Algorithm in the Cable Insulation Layer Measurement" IEEE, Second International Workshop on Computer Science and Engineering, 978-0-7695-3881-5/09 $26.00 © 2009 IEEE DOI 10.1109/WCSE.2009.177

[11] PENG Zhao-yi , ZHU Yan-hui , ZHOU Yu "Real-time Facial Expression Recognition Based on Adaptive Canny Operator Edge Detection". IEEE, Second International Conference on Multimedia and Information Technology, 2010. 978-0-7695-4008-5/10 $26.00 © 2010 IEEE DOI 10.1109/MMIT.2010.100 154

[12] Jianjum Zhao, Heng Yu, Xiaoguang Gu and Sheng Wang. "The Edge Detection of River model Based on Self-adaptive Canny Algorithm And Connected Domain Segmentation" IEEE,Proceedings of the 8th World Congress on Intelligent Control and Automation July 6-9 2010, Jinan, China, 978-1-4244-6712-9/10/$26.00 ©2010 IEEE

[13] Mee-Li Chiang, Siong-Hoe Lau "Automatic Multiple Faces Tracking and Detection using Improved Edge Detector Algorithm" IEEE 7th International Conference on IT in Asia (CITA),2011 ,978-1-61284-130-4/11/

[14] Lejiang Guo,Yahui Hu Ze Hu, Xuanlai Tang "The Edge Detection Operators and Their Application in License Plate Recognition, IEEE TRANSATION 2010, 20978-1-4244-5392-4/10/.

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