Optimization in Edge Detection using Ant Colony Optimization

Poonam Kasare, Jyoti Kulkarni, Rajankumar Bichkar

Abstract: Image processing is now emerged in different fields like medical, security and surveillance, remote sensing & satellite applications and much more. Image processing includes different operations such as feature extraction, object detection and recognition, X-ray scanning etc. All such operations required edge detection to get better quality image. Edge detection is performed to distinguish different objects in an image by finding the boundaries or edges between them. Edges are used to isolate particular objects from their background as well as to recognize or classify objects. In this paper, comparison of various edge detection techniques such as Sobel, Prewitt, Roberts, Canny, LoG and Ant Colony Optimization Algorithm is given. Ant colony Optimization(ACO) use parallelism which reduces the computation time as size of an image increases.

Keywords: ACO, Canny, Pheromone.

I. INTRODUCTION

The main aim of edge detection is to find boundaries or edges in an image. Edges are the sudden changes in discontinuities in an image which contains shape information of an object. Discontinuities are calculated by performing first order and second order derivative operators. The first order operators are Sobel, Prewitt and Roberts while second order operators are Canny and Laplacian of Gaussian. To increase the performance of edge detection, optimization algorithms are used such as Ant Colony Optimization Algorithm [4]. According to various literatures, second order operator gives better performance than first order derivative operators [2]. Some morphological operations like erosion, dilation, opening and closing are also used for edge detection and also better technique than differential technique for detecting as well as modifying and manipulating features present in the image [1]. Canny edge detection provides better performance for object detection [3]. But the limitation of derivative operator is that it requires more computational time as each set of operation is applied for each pixel. As size of an image increases, computational time increases..

Ant Colony Optimization reduces the computational time as it uses parallelism [6]. In Edge detection, edge is a part of an image that contains significant local variation and it naturally occurs on the boundary between two different regions in an image

Edges are nothing but the discontinuities or change in intensity. To detect the changes in intensity first order and second order derivatives are used.

The first order derivatives are the gradients calculated by partial differentiation with respect to x and y. Magnitude of this vector is calculated to locate edge pixel and angle at which maximum rate of change occurs is calculated by tan inverse function to find the direction of an edge. The edge detection model which uses first order derivatives are Sobel, Prewitt, Roberts operators While Laplacian of Gaussian uses second order derivative. The rest of paper is organized as follows: Section II gives the

description about the different types of edge detection techniques. Section III explains the ant colony optimization algorithm in detail. Section IV contains the results and discussions and Section V gives conclusion

II. EDGE DETECTION TECHNIQUES

Sobel operator is a first order derivative. It uses concept of smoothening an image to remove noise content from image. This operator consists of 3*3 convolutional kernels. These kernels are used to calculate magnitude and angle of maximum rate of change to localize the sudden changes i.e edges in an image. It plots the edges where gradient value is highest. Sobel detects more edges as compared to other first order derivative. Prewitt operator is same as Sobel operator only difference is of convolutional kernels. It also uses 3*3 convolutional matrix used to calculate magnitude and angle at which maximum rate of change occurs to localize the sudden changes i.e edges in an image. As compare to Sobel operator, Prewitt detector is slightly simpler to implement but produces little bit noisier results. Roberts operator is basic operator consists of 2*2 convolutional kernels. The kernels are designed to respond frequently to edges running at 45 to the pixel grid. This operator used for very basic image. The Canny detector uses double thresholding which makes it better technique among other techniques. Using non-maxima suppression method it enhances the signal to noise ratio [5]. The method can be summarized as follows:

Step1. Remove the noise using Gaussian filter with specified standard deviation, σ.
Step2. Calculate the local gradient and edge direction at each point using any of the previously explained three techniques.
Step3. Apply non- maxima suppression to the gradient magnitude image i.e.

if the value of gradient image is less than at least one of its two neighbors along its direction, then value of non-maxima suppressed image is 0. Otherwise its value is gradient image.
Step4. Use double thresholding and connectivity analysis to detect and link edges i.e. suppose two thresholds T_L and T_H. If a pixel gradient is higher than the upper threshold, then the pixel will be marked as an edge. If a pixel gradient is below the lower threshold, then the pixel will be discarded.
Finally, if the pixel gradient is between the two thresholds, then only the pixel that is connected above the upper threshold is marked as an edge
The Laplacian of Gaussian smoothes an image by convolving image with Gaussian filter to reduce noise effect. The amount of smoothing can be controlled by varying the value of the standard deviation. After smoothning zero crossing is detected. Lastly threshold is applied to zero crossing image. The disadvantage is, bad at corner detection.

III. ANT COLONY OPTIMIZATION

Ant Colony Optimization is a higher level procedure to find, generate a sufficiently good solution to an optimization problem. It is based on real behavior of ants. Here, colony of artificial ants is considered to find out proper optimized solution. Basically ant colony optimization is consists of three steps that are – Initialization, Construct and update, Decision process. The overall algorithm is depend on ants path selection and updated pheromone values while propagating. The Probability of path selection is depending on two parameters, attractive coefficient (η) and pheromone coefficient (τ). The influence of this parameter is controlled using controlling factors β and α respectively. Good solution is obtained by increasing the value of controlling factors α and β.
ACO Algorithm consists of following three stages:

A. Initialization Phase

In initialization stage, artificial ants are assigned in random position. The pheromone and heuristic matrices are initialized which are required to calculate probability of path selection. Pheromone matrix is initialized with some user specific constant while heuristic matrix is initialized by taking product of mean and variance of an image.

B. Construction and update phase

On every iteration, probability of path selection is calculated using following formulae,

$$P_{ij}^n = \frac{[\tau_{i,j}]^\alpha \{\eta_{i,j}\}^\beta}{\sum [\tau_{i,j}]^\alpha \{\eta_{i,j}\}^\beta} \qquad [6]$$

Where,
τ_{ij} is the pheromone value for pixel (i, j)
η_{ij} is the heuristic information at pixel (i, j)
The constants α and β control the influence of the pheromone and heuristic information, respectively.
After moving to a new pixel each ant locally updates pheromone levels on its location by,

$$\tau(i, j) = ((1 - \rho) * \tau(i, j) + (\rho * \tau(init)) \qquad [6]$$

Where,

ρ is the pheromone decay coefficient and τ is the initial pheromone value.
After all pixel make their tours and prior starting a new iteration, global pheromone update is performed by,

$$\tau \leftarrow ((1 - \rho) * \tau + \sum \rho \Delta\tau \qquad [6]$$

C. Decision phase:
In decision phase, edge pixels are decided using final pheromone matrix. Threshold is applied to find the edge pixels. If pixel value is greater than threshold then it is considered as edge. If pixel value is less than threshold then it is discarded.

IV. RESULT AND DISCUSSION

In Ant colony optimization algorithm, various constant are needed to calculate the necessary parameters as discussed in above section.
The values used in this experiment is as below -
Controlling factor for pheromone coefficient, alpha = 0.001;
Controlling factor for attractive coefficient, beta = 0.001;
Pheromone decay constant, rho = 0.01;
Pheromone update factor, phi = 0.00005;
Figure 1 shows the output of edge detection techniques for different tests. Roberts's operator provides less amount of edge detected area as it is basic and simple operator. As complexity of operator increases edge detected area also increases. Canny operator detects more edges as compare to other operators. To increase performance of edge detection operators optimized algorithm i.e. ACO is used and it proved that it gives optimized solution and detects almost all the edge area.Table1, 2 and 3 shows the performance parameters i.e. root mean square error (RMSE). The RMSE represents the cumulative root mean squared error between the edge detected and the original image, lower the RMSE value, higher is the edge detected capability. ACO has higher RMSE value compared with other methods.
The Mutual Information is the parameter used to find out similarity between two images, higher the MI value more is the similarity. From the results, it shows that ACO has higher MI value and provides more similarity with original image. PSNR represents a measure of the peak error between two images. Its value should be low for good edge detector. As the performance of edge detector reduces, its value increases.

Table 1: Performance parameters for test image 1

Technique	RMSE	MI	PSNR
ACO	0.8910	0.0344	53.0568
Canny	0.4541	0.0200	107.6718
LoG	0.3879	0.0549	125.3039
Sobel	0.3104	0.0136	160.0783
Prewitt	0.3121	0.0139	161.3479
Roberts	0.2616	0.0093	178.6234

Table 2: Performance parameters for test image 2

Technique	RMSE	MI	PSNR
ACO	0.8746	0.1404	55.3737
Canny	0.5043	0.0676	106.0585

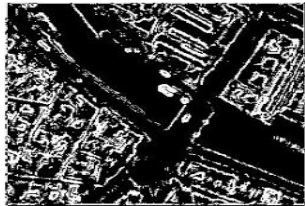| LoG	0.4697	0.0621	124.1553		Roberts	0.4565	0.0218	184.1352
Sobel	0.4604	0.0487	155.1735					
Prewitt	0.4593	0.0474	154.3325					

Input images

Test image1

Test image2

Test image3

ACO
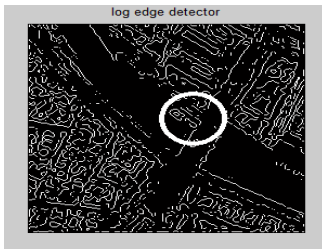

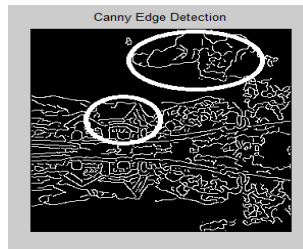ACO output of test image1
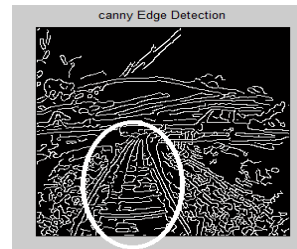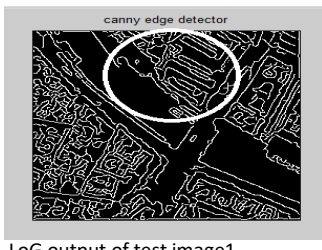
ACO output of test image2

ACO output of test image3

Canny Operator

Canny output of test image1

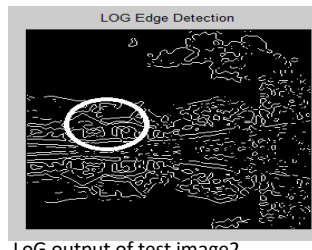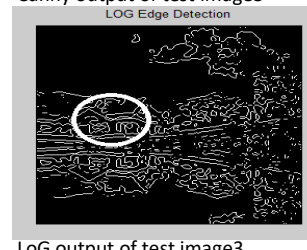Canny output of test image2

Canny output of test image3

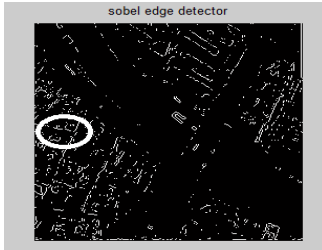LoG Operator

LoG output of test image1
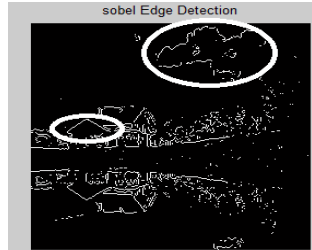
LoG output of test image2
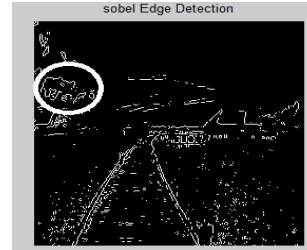
LoG output of test image3
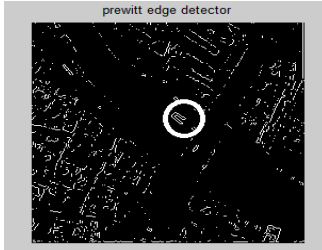
Sobel Operator

Sobel output of test image1

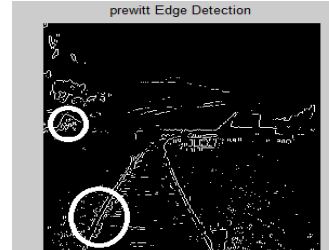Sobel output of test image2

Sobel output of test image3

Prewitt Operator

Prewitt output of test image1

Prewitt output of test image2

Prewitt output of test image3

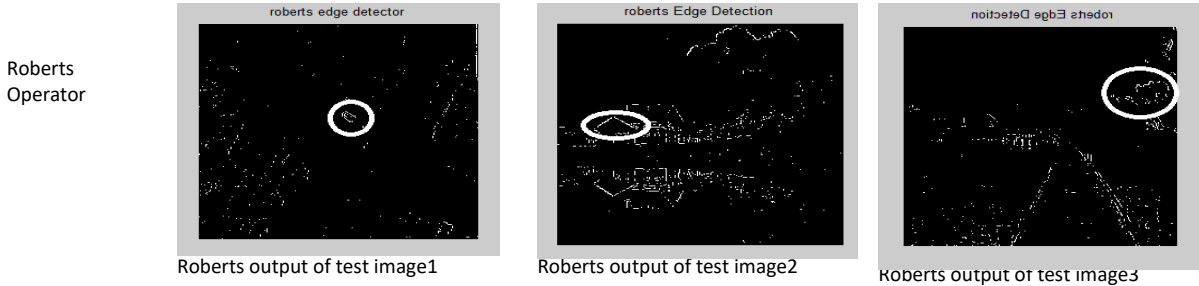# Optimization in Edge Detection using Ant Colony Optimization

Roberts Operator

Roberts output of test image1   Roberts output of test image2   Roberts output of test image3

Fig 1. Output of edge detection techniques for different test images

Table 3: Performance parameters for test image 3

Technique	RMSE	MI	PSNR
ACO	0.9078	0.0759	55.0729
Canny	0.4473	0.0426	95.5083
LoG	0.3844	0.0481	102.5346
Sobel	0.3009	0.0244	104.6172
Prewitt	0.2985	0.0234	104.3590
Roberts	0.2696	0.0156	105.5096

V. CONCLUSION

This paper discussed six different edge detection techniques and performance parameters like root mean square error, mutual information, Peak signal to noise ratio for three different test images. Matlab software is used for this experimentation. Ant colony optimization is giving better performance. As it gives low PSNR and high RMSE value which concludes that it has better edge detection capability.

REFERENCES

1. Dandong Yin, Shaowen Wang, Shihong Du., "A Direction-Guided Ant Colony Optimization Method for Extraction of Urban Road Information From Very-High-Resolution Images", IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, August 2015.
2. Ke Sun, Junping Zhang., "Road Extraction from High Resolution Remote Sensing Images based on Multi-features and Multi-stages", Journal of Information Hiding and Multimedia Signal Processing, Volume 8, Number 1, January 2017.
3. P.N Anil, Dr. S. Natarajan, "Automatic Road Extraction from High Resolution Imagery Based On Statistical Region Merging and Skeletonization", International Journal of Engineering Science and Technology, Vol.2(3), 2010, 165-171.
4. Cristian A. Martinez, Maria E. Buemi, "New ACO Algorithm for Image Edge Detection", Conference Paper, January 2014.
5. Rafael C. Gonzalez, Richard E. Woods., "Digital Image Processing", pearson publication.
6. Rafael C. Gonzalez, Richard E. Woods, Steven Eddins., "Digital Image Processing Using MATLAB", pearson publication.
7. Radhika Chandwadkar, Saurabh Dhole., "Comparison of Edge Detection Techniques", Conference Paper, August 2013.
8. Pooja Sharma, Gurpreet Singh, Amandeep Kaur, "Different Techniques Of Edge Detection In Digital Image Processing", International Journal of Engineering Research and Applications, Vol. 3, Issue 3, May-Jun 2013, pp.458-461.
9. Anna Veronica C. Baterina, "Ant Colony Optimization for Image Edge Detection", WSEAS TRANSACTIONS on SIGNAL PROCESSING, April 2010.
10. Qiaoping Zhang, Isabelle Couloigner, "An integrated approach to extracting urban road Networks from high resolution multi-spectral imagery", 1st EARSeL Workshop of the SIG Urban Remote Sensing, Humboldt-University Berlin, 2-3 March 2006.

AUTHORS PROFILE

Poonam B. Kasare is a PG student of Pimpri Chinchwad College of Engineering. Her specialization of post-graduation is in VLSI and Embedded Systems. Ant colony optimization is her interest area.

Jyoti S. Kulkarni is working as Assistant Professor at the Pimpri Chinchwad College of Engineering. She is currently working towards the Ph.D. degree in Electronics and Telecommunication Engineering from Raisoni College of Engineering and Management research centre. Her research interests include image fusion and optimization techniques. Her teaching interest include data structures and algorithms, object oriented programming, design and analysis of algorithms.

Rajankumar S. Bichkar is working as Principal, Vidya Pratishthan's Kamalnayan Bajaj Institute of Engineering and Technology. His research interest include genetic algorithm. He had published more than 56 research papers in international journals and conferences.

8170