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Particle Swarm Optimization based Edge Detection Algorithms for Computer Tomography Images

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Abstract

Background/Objectives: Detection of image edges plays an important role in medical image processing, segmentation and computer vision applications. **Methods**: It is necessary to have a better edge detection algorithm for the diagnosis of the abnormalities in the images and based on the diagnosis, a treatment procedure can be decided. The existing edge detection algorithms like Canny and Sobel are lack in Edge Preservation Factor (EPF) and they pose a low Signal to Noise Ratio (SNR). These algorithms are not good for noisy images. **Findings**: To overcome these issues, in this paper a Particle Swarm Optimization (PSO) based algorithm is proposed. **Improvements/Applications**: Experimental result proves that the PSO is better when compared with the existing edge detection techniques.

Keywords: CT Images, Edge Detection, Particle Swarm Optimization

1. Introduction

Edge detection is used for identifying points specifically edges in digital images where image brightness changes suddenly. Medical image reconstruction[1] and Remote Monitoring[2] are some of the applications which are in need of finding the continuity of the edges. But it consumes more time in case of noisy images. It is an important method to recognize the objects in the medical images which in turn takes the decision from the image which is processed finally. It also seems that it is required to study a large area of processing to obtain the best output but it may affect time complexity and more broken edges. Edge detectors such as Gaussian based[3], Image transformation based, Statistical based[4], Soft computing based[5] are used to identify the boundaries in the noisy CT images. To date, there have been many algorithms differential which are based on first order derivatives of edge detection. The general drawbacks of these existing algorithms consist of malfunctioning at corners, not able to find the orientation of edges due to which inaccuracy is produced. The canny algorithm is showing fewer edges than other algorithms and sometime produces false zero crossing to detect the edges for the noisy images. In[6] proposed a PSO-based edge detection algorithm.

Nowadays there is an increase in the number of patients with many serious illnesses, which cannot be diagnosed without the imaging modalities like Magnetic Resonance Imaging (MRI) and Computerized Tomography Scan (CT Scan). The main objective of this paper is to propose a better edge detection algorithm for CT images and in turn helping the doctor for an accurate diagnosis and for the betterment of the human kind.

Edge detection[7] algorithms can be mainly divided into two different groups based on the method of detector which are as Gaussian edge detector and gradient edge detector. Canny and Sobel are the two most famous algorithms which lie under these two groups[8,9]. Usually, the traditional algorithms such as Sobel, Prewitt, canny and Laplacian of Gaussian operator[10] are used to detect the edges. But all these belong to high pass filter which is not suitable for noisy medical images. The edge and the noise belong to the range of high frequency. So in real time, it is difficult to find the exact object boundaries of the noise images. At present there are many edge detection techniques existing but they do not provide required

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optimal output and have drawbacks like less accuracy and its time complexity is more. Thus, we can conclude that the general drawback of this edge detection techniques is malfunctioning at borders[11], thus it makes difficult to find the starting point of the edges which leads to inaccuracy.

In most of the previous works, almost all edge detection techniques do not concentrate in detecting the edges continuously in CT images. By said inference, if differential of the intensity value across the input CT image is taken and then finding areas wherever the value is maximum will give us output of edge[12]. Where the gradient- module would count how fast values will change along changes in horizontal as well as vertical directions.

There are several techniques used for edge discovery[13]. These techniques are categorized into various distinct kinds, like, search-based and zero-crossing based. The first category discovers lines by computing a value for the strength of the line. Any time first-order differential equation such as the finding a magnitude for direction for maximum gradient magnitude by a calculated predicted of the direction in local of the line, that is also known direction of gradients. Secondly, another category looks for the crossings generally zero crossing in a second-order derived function calculated picture, in order to discover edges that are the zero-crossings of a non-linear variance values.

Some of the pre-requisite necessary for the edge detection are as follows:

- Application if created must exactly give maximum borders as possible.
- Border point if detected must precisely locate in middle of the border.
- Only once a border should be counted, not more than once.
- Noise of the image must not create false edges.

To accomplish these pre-requisites canny implied a method used to detect the border which gives best solution for the given image. Among various algorithms present till date, canny edge finding algorithm proves to be the best technique which gives dependable output. As a result of its use to fulfill with the four necessities for edge detection and it's easy to implement process, it is one of the most popular algorithms for edge detection.

The Sobel method uses two matrices that is horizontal and vertical gradient matrices which are of dimensions 3 × 3 for edge detection operations. When compared with other edge detection techniques, Sobel method has two of some specific advantages[14,15].

- Since it uses the average factor, it produces some smoothing effect on the noise present in the image.
- As it is the difference to many rows and columns, the elements present on either sides of the image gets enhanced. Thus the edge looks thick and bright.

The main disadvantage of Sobel operator is it is not giving complete view of all edges, but its biggest advantage is that it smoothens the input image to a large extent and thus makes the operation less sensitive to noise.

Particle Swarm Optimization (PSO) has some kind of advantages due to which it becomes the best algorithm to be implemented for image edge detection[16,17]. The advantage of using PSO algorithm is that it is originated from the concept of the intelligence. So, it can be applied in scientific research as well as for engineering use. Also in addition to that it doesn't have any overlapping, mutation calculation. Therefore, the search mainly depends on the speed of the particle. So, the experimental results show that the PSO gives a better improved output when compared with the other existing techniques.

The proposed paper is divided into different sections where Section 1 is introduction about the edge detection, Section 2 gives a brief overview of various existing algorithm used, Section 3 describes about the proposed algorithm, Section 4 explains about the result analysis of the algorithms and Section 5 is about the performance evaluation and conclusion based on the results obtained.

2. Existing Algorithms

Now-a-days we need more specific images so that the treatment over various diseases and problems could be cured as soon as possible. Biomedical application has always gained less importance and also the images obtained from various CT and scan is more complicated to study. Here we are trying to find the solution for the same. Figure 1 reveals that it is too difficult to find the exact location and size as well as small tumor areas in the CT image of the brain due to some noises in the image. Thus, it requires a better image detection technique to get better result.

2.1 Canny Algorithm

It has proven that the necessity for various application of edge discovery is very much same for different systems.

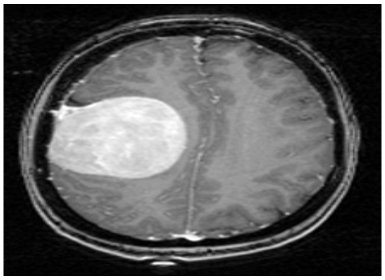


Figure 1. Brain tumor CT image.

Hence, a key to deal with can be provided in different circumstances. The basic necessities for edge discovery can be as:

- Low error rate edge discovery which tells that the methodology should satisfactorily fetch large number of edges possible.
- The point of edge found through the method should correctly confine at the middle of the line.
- The discovered edge of the picture must be checked only one time.
- Also wherever feasible, we make sure that false lines do not appear because of the noise in the picture.

In order to fulfill the above requirements, this algorithm implies the "calculus of variations", a methodology that is used to search the method that proves the methodology. As a result of its use to fulfill with the four necessities for edge detection and it's easy to implement process. It is one of the most popular algorithms for edge detection. Every step used in canny algorithm is described in details as follows:

2.1.1 Gaussian Filter

A 5 × 5 Gaussian mask has been passed across each pixel as a prerequisite step. Images contain noise which may effect in output. Thus to smoothen the picture, a filter called Gaussian is applied to mix with the original picture. The equation for Gaussian filter of size (2*q*+n) × (2*q*+n), where n = 1, is given by:

$$V_{k,l} = \frac{1}{2\pi\sigma^2}\, exp\left(-\frac{(k-(q+1))^2 + (l-(q+1))^2}{2\sigma^2}\right); 1 \le k, l \le (2q+n) \quad (1)$$

It is necessary to understand that the selection of the dimensions of the Gaussian kernel will effect on the performance of the detector. The larger the size, the lower is the affect to noise on the findings.

2.1.2 Finding Gradient Intensity of Image

A line in the picture can point in a number of directions. Hence, this algorithm utilizes four dissimilar filters in order to search straight, slant and other lines in the distorted picture. The other few line discovery functions from scientists like Roberts, Prewitt and Sobel give a value for the first order of derivative in the straight (Q_x) and slant directions (Q_y) respectively. Using these values the gradient and direction may be given as:

$$Q = \sqrt{Q_a^2 + Q_b^2} \quad (2)$$

$$\Theta = a\tan 2(Q_y, Q_x) \quad (3)$$

Where, Q is calculated according to the above method and a tan2 is the methodology that takes two parameters.

2.1.3 Non-Max Crackdown/Non-Max Suppression

Non-max crackdown the other name for non-max suppression generally applied along with border detection algorithm. The picture is been read along with the slant directions of image gradients and if any pixel identified is not a part of this maxima it will be set to 0. This technique will suppress all the information of the mage which is not a part of the local maxima. We can also go for interpolation with any two adjacent pixels. For instance, if any pixel having gradient angle as in the range of 45 to 90 degrees, we will get one value from direction above it and one value from the direction below it, but if it is less than the central pixel value, they will be marked as 0. Thus, it helps to find the better edges.

2.1.4 Thresholding

After applying non-max crackdown, borders will present the real edges accurately. Still, some pixels will not be clear due to differences in the noise and also in color. Thus, to reduce it, it is necessary to remove borders having weak and high values of gradients. We can apply thresholding to differentiate various borders. Thus, two thresholds h-threshold i.e. high and l-threshold i.e. low is used. If border pixels gradient value is more than the high threshold value, it will be marked as strong edge pixel and vice-versa, will be marked as useless borders and will be suppressed while the value ranging between high and low will be marked as weak border. Some weak borders will still be present due to reasons of improper extractions or noise.

2.2 Sobel Algorithm

The Sobel operator[18] given by Sobel–Feldman is applied mostly for processing of images, especially for the edge detection algorithms that are used in picture emphasizing edges. The name Sobel comes from the names of "Sobel Irwin" and "Feldman Gary", studied at the Stanford laboratory for Artificial Intelligence (SAIL). Who put their combined efforts in the invention of Sobel Operator at a speech in 1968 that took place in SAIL; these two scientists proposed and put forth the concept of an Isotropic 3 x 3 Image Gradient Operator. Basically, it is nothing but a simple separate discrimination operator that computes an estimation of the intensity function of an image given by gradient. On every border point present in image, after applying the Sobel method, finally we get follow-on gradient vector of this vector. Sobel–Feldman operator completely depends on the idea of convolving the picture with a tiny, integer-valued and partition able filter in the horizontal and vertical directions. Hence, based on this, we can say that, it is comparatively cheap in regards to the computational values. At the other side, the estimation of the gradient that is obtained is comparatively unrefined, typically for variations in the image that are of the high frequencies.

Algorithm for Sobel Operator:

Step 1: Load the image.

Step 2: A mask Iy Ix, is applied to the image loaded.

Step 3: Then the Sobel algorithm steps is applied along with the gradient.

Step 4: Mask the resultant of Iy, Ix distinctly on the loaded image.

Step 5: Then, we bring together the resultants to discover the obvious absolute gradient i.e. magnitude.

Step 6: The obtained scale of magnitude provides required solution.

3. Proposed Algorithm

3.1 Particle Swarm Optimization based Algorithm

In[19] proposed an evolutionary algorithm namely Particle Swarm Optimisation (PSO) for solving optimisation for implementation and for the high rate of convergence[20]. It is easy when compared with Genetic Algorithms (GA). The Particle Swarm Optimization (PSO) has been used in applications, such as object detection, segmentation, classification of objects and edge detection. Optimized particle swarm called as field of surge intellect that is been influenced by the interactive pattern of birds and natural inhabitants which replicates normalized communal exemplary, for instance, a group of flying insects or a conservatory of fly-fish. We can simply say that, a PSO algorithm for a normal variant takes place with the help of population known as swarm of a particular result known as particles. Thus, particles then wander all over the space that is used for search. This is done based on few basic formulae. The best knowledge position in the space that is used for search and also the best position by the complete swarms are used to conduct the movements of the particles. Later, we discover the better and advanced position, which are then replaced by the older ones to conduct the swarm movements. The Algorithm for the PSO is given as:

- Initialize a particle.
- For every particle, compute f-value. If f-value is more than the maximum f-value (pMax) thus, apply recent updated as the latest pMax.
- Pick up bird-particle having maximum f-value amongst particles as gMax.
- Every Particle, compute p-velocity and revise particle position.
- Keep repeating till required iterations are completed or till the criteria of minimizing error is not obtained.

In PSO, each output is an improved distance in the given area. Each and every particle will have f-values calculated using this f function also called as fitness, which is required improving will also be having velocity for directing direction for "particle". This birds-particle moves in given area by following the present optimum particles. The proposed algorithm instantiated along number of birds-particle i.e. answers after that searching best solution by apprising continuously. Every time each bird-particle is upgraded using adjacent b-values where b is best. The first value is the f-value which is the optimal answer. The f-value is being updated and kept and it is known as p-best. The second calculation by PSO detector is called as g-best value denoted by g-best. Every time bird-particle is participating as other particles adjacent particle, the best value is calculated which is known as l-best given by l-best. Next, the outcome these "best values", bird-particle will update their speed i.e. velocity as well as location.

$$a = a + 2 * r * (p\text{-best} - c) + 2 * r * (g\text{-best} - c) \quad (4)$$

$$c = c + a \quad (5)$$

Where a = velocity of particle.

c = present particle (output-solution).

p-best and g-best = two best values and "r" is a random number lies within the range of (0, 1).

Here, 2 is a learning factor.

4. Results and Discussion

4.1 Conversion based on Canny Edge Detector

Converting the original image into processed image based on canny edge detector. The steps followed for canny edge detection is as explained above where we will take two threshold values and compare them. Also the Gaussian filter and then followed by the intensity gradient is applied which will give us the optimal output. The threshold value that is the high threshold and low threshold is being entered by the user itself. This threshold values generally can range here from 1 to 10. Thus, more the difference in the threshold, higher is the edge detection with less accuracy and preservation, while, less the threshold value, less the edge detection with high accuracy and preservation. Figure 2 shows output for canny edge detection algorithm.

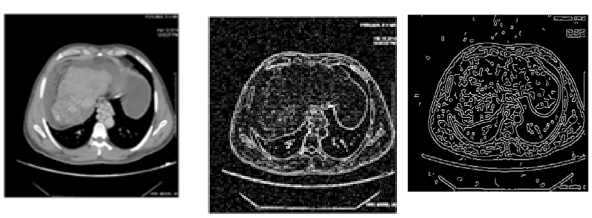


Figure 2. Canny algorithm output.

4.2 Conversion based on Sobel Edge Detector

Converting the original image into processed image based on Sobel edge detector. In which, we will first convert images according to pixels after that we will read difference between left and right pixels and up and down pixels. And after that just by changing the intensity of the image we can get the Sobel. Figure 3 shows output for Sobel edge detection algorithm.

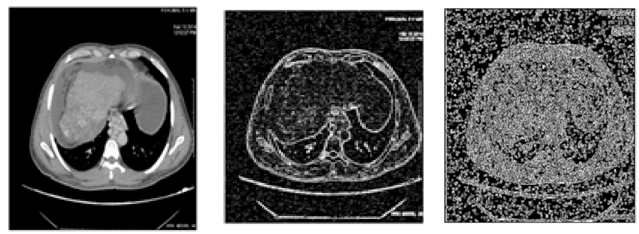


Figure 3. Sobel algorithm output.

4.3 Conversion based on PSO Edge Detector

Adding noise to the original image and after that we will calculate particle velocity and particle position and after that until we attain minimum error criteria we will continue the process which will provide us with better PSO based output, which seems to be much better than traditional methods. The PSO based algorithm output is shown in Figure 4. The first output shows the noisy image where, salt and pepper noise is being added here, while the second output shows the PSO based output.

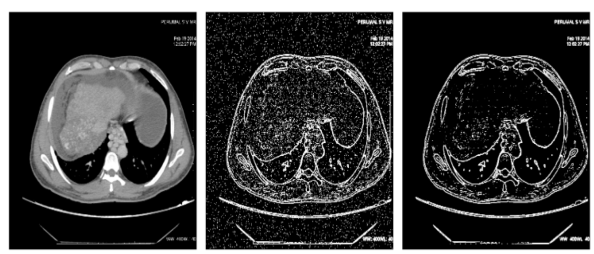
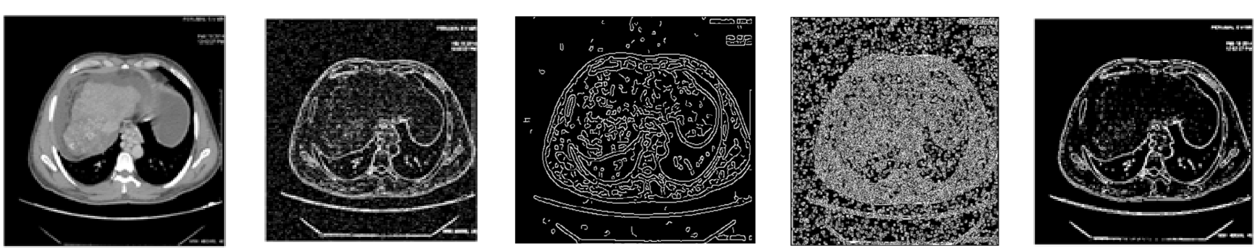


Figure 4. PSO based algorithm output.



Original image Noisy image Canny output Sobel output PSO based output

Figure 5. Comparison output.

Comparing the original image with converted images like, Canny edge detector, Sobel edge detector with Particle Swarm Optimization (PSO) based algorithm and we find that the PSO based algorithm proves much better than the canny and Sobel edge detectors in noisy images. In Figure 5 the comparison is shown in which different methods for border detection is been compared. The canny seems to give best output when normal facial image is considered, but when taking noisy medical images PSO based algorithm output gives much better solution.

5. Performance Evaluation

The parameters such as Signal to Noise Ratio (SNR), Edge Preservative Factor (EPF) and Mean Square Error (MSE) are evaluated to find the performance of the edge detection algorithms. Overall, we can summarize that this image may not be used only for CT images but can be used for many other types of images like skeleton, image fracture images and all other kind of bio-medical images. Thus, by using this implementation we can draw the result based on some parameters which will help us to analyze the better solution for the edge detection for CT images.

5.1 Edge Preservation Factor (EPF)

The capability of edge preservation filter is related with EPF, when it is required to preserve information of edge and simultaneously preserve the edges. Even after smoothing filter is not able to remove the boundaries, it will distort them. Thus, this is not accepted in the context of many areas, such as, medical imaging. The formula for EPF is given as:

$$EPF = \frac{\Sigma(\Delta K - \overline{\Delta K})(\Delta K_n - \overline{\Delta K_n})}{\sqrt{\Sigma(\Delta K - \overline{\Delta K})^2 (\Delta K_n - \overline{\Delta K_n})^2}} \qquad (6)$$

Where, ΔK and ΔK_n are the High Pass Filters (HPF). K and K_n image values are obtained from a 3 × 3 pixel. We can conclude that if the value of EPF is more than the ability to preserve edges is more. The graph representation is shown in Figure 6.

5.2 Signal to Noise Ratio (SNR)

The SNR is a simple quantifier that is required to compare the intensity of the optimized signal to that with the intensity of the disturbance called noise already present.

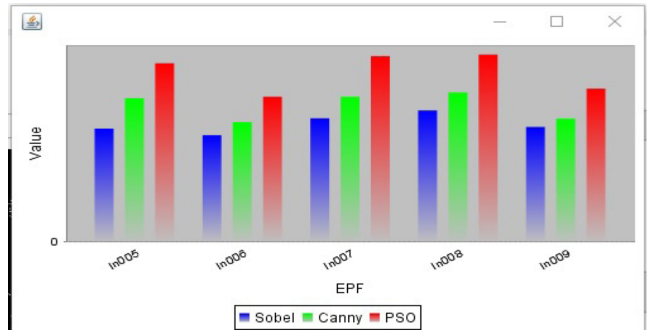


Figure 6. EPF graph.

It can be provided in the form of ratio that shows the intensity of signal to the intensity of error. Figure 7 shows the SNR output.

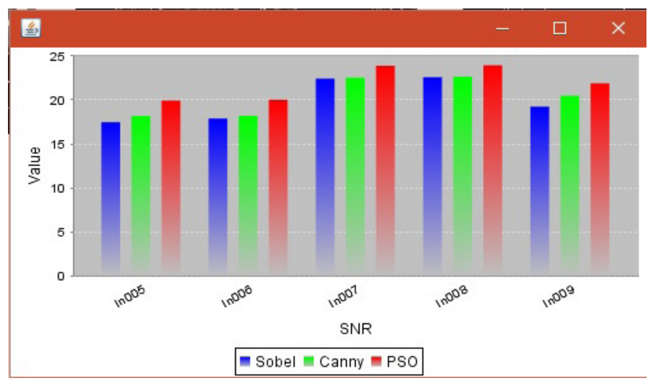


Figure 7. SNR graph.

The formula of SNR is given as follows:

$$SNR = 10\ \log 10\left[\frac{\sum_{f=1}^{w}\sum_{g=1}^{x}(K_n(f,g) - K(f,g))^2}{\sum_{f=1}^{w}\sum_{g=1}^{x}(K_n(f,g))^2}\right] \qquad (7)$$

We can say that the intensity of the signal is more than the disturbance present, if the ratio is more than 0.

Where, the image size is w × x.

f is row, g is column,

K means original image and K_n means filtered image.

5.3 Mean Square Error (MSE):

Mean Square Error measures the aggregate average of the errors in their squares, which we can say that the difference between an estimator and what is estimated. MSE can be said as a risk function, in accordance with the expected answer of the error loss of square or quadrature loss. The difference may be because of randomness which can produce a more accurate estimate of the value.

The MSE is seen to use the dissent parameter of the value in estimation along with the partial side represented in Figure 8. If the value of estimation is not partial, it will play the role of dissent for such value of estimations. MSE and variance both have the same units of measurement that is the square of the quantity that is being estimated. Standard deviation yields the square root of the mean error RMSE which is the square root of the dissent.

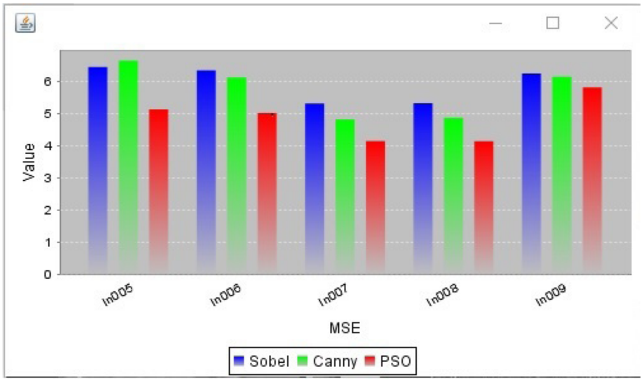


Figure 8. MSE graph.

$$MSE = \left[\frac{1}{P.Q}\sum_{a=0}^{P-1}\sum_{b=0}^{Q-1}\left(K(a,b) - K_n(a,b)\right)^2\right] \quad (8)$$

Where, the image size is P × Q.

a is row, b is column,

K is original image and K_n is filtered image.

Thus, by using these three parameters we compare the output of this proposed paper and can calculate the solution as that EPF and SNR values for PSO based algorithm is more also MSE values is less. From this we can conclude that the PSO based algorithm gives more accurate output compared with other two algorithms. Preservation factor is also seemed to be high for PSO based algorithm. Thus, as a result we can say that in the comparison of canny, Sobel and PSO based methods, the PSO based proves to be a better solution for finding edged output of a CT image.

6. Conclusion

This paper gives an improved edge detection algorithm comparison using different algorithms. The PSO based output seems to be much better than the existing algorithms for noisy CT images. The general basic step obtained is to convert the image into grey scale i.e. black and white image and then applying steps of the algorithm. The experimental outcomes show that the proposed Particle Swarm Optimization algorithm is more effective for medical image denoising and detecting the edges when compared with the existing algorithms. Also, a noteworthy performance in noisy parameter was recorded. However, the proposed algorithm can perform in noisy environment of noise level ≤ 50%. The result reveals that almost 10% improvement in detection of edges can be seen in noisy environment as compared with the normal images having negligible or no noise.

7. References

1. Gudmundsson M, El-Kwae EA, Kabuka MR. Edge detection in medical images using a Genetic Algorithm. IEEE Transactions on Medical Imaging.1998 Jun; 17(3):469–74.
2. Jiang W, Lam KM, Shen TZ. Efficient edge detection using simplified Gabor wavelets. IEEE Transactions on Systems, Man and Cybernetics. Part B (Cybernetics). 2009 Aug; 39(4):1036–47.
3. Sen D, Pal SK. Gradient histogram: Thresholding in a region of interest for edge detection. Image and Vision Computing. 2010 Apr; 28(4):677–95.
4. Lim DH. Robust edge detection in noisy images. Computational Statistics and Data Analysis. 2006 Feb; 50(3):803–12.
5. Setayesh M, Zhang M, Johnston M. Detection of continuous, smooth and thin edges in noisy images using constrained Particle Swarm Optimisation. Proceedings of the 13th Annual Conference on Genetic and Evolutionary Computation; 2011 Jul; p. 45–52.
6. Setayesh M, Johnston M, Zhang M. Edge and corner extraction using Particle Swarm Optimisation. Springer Berlin Heidelberg: Australasian Joint Conference on Artificial Intelligence; 2010 Dec. p. 323–33.
7. Acharjya PP, Das R, Ghoshal D. Study and comparison of different edge detectors for image segmentation. Global Journal of Computer Science and Technology. 2012; 12(13):1–5.
8. Maini R, Aggarwal H. Study and comparison of various image edge detection techniques. IJIP. 2009 Mar; 3(1):1–11.
9. Setayesh M, Zhang M, Johnston M. Improving edge detection using Particle Swarm Optimisation. 2010 25th International Conference on Image and Vision Computing New Zealand (IVCNZ); 2010 Nov. p. 1–8.
10. Huertas A, Medioni G. Detection of intensity changes with sub-pixel accuracy using Laplacian-Gaussian masks. IEEE Transactions on Pattern Analysis and Machine Intelligence. 1986 Sep; 8(5):651–64.
11. Saini S, Kasliwal B, Bhatia S. Comparative study of image edge detection algorithms. 2013 Nov. p. 1–5. arXiv preprint arXiv:1311.4963.

12. Bin L, Yamane MS. Comparison for image edge detection algorithms. International Organization of Scientific Research. Journal of Computer Engineering. 2012 Jul-Aug; 2(6):1–4.
13. Shrivakshan GT, Chandrasekar C. A comparison of various edge detection techniques used in image processing. International Journal of Computer Science Issues. 2012 Sep; 9(5):269–76.
14. Vincent OR, Folorunso O. A descriptive algorithm for Sobel image edge detection. Proceedings of Informing Science and IT Education Conference (InSITE). 2009 Jun; 40:97–107.
15. Gupta S, Mazumdar SG. Sobel edge detection algorithm. International Journal of Computer Science and Management Research. 2013 Feb; 2:1578–83.
16. Rini DP, Shamsuddin SM, Yuhaniz SS. Particle Swarm Optimization: Technique, system and challenges. International Journal of Computer Applications. 2011 Jan; 14(1):19–26.
17. Yan X, Wu Q, Liu H, Huang W. An improved Particle Swarm Optimization algorithm and its application. International Journal of Computer Science. 2013; 10(1):316–24.
18. Abbasi TA, Abbasi MU. A novel FPGA-based architecture for Sobel edge detection operator. International Journal of Electronics. 2007 Oct; 94(9):889–96.
19. Kennedy J, Eberhart RC, Shi Y. Swarm intelligence. Morgan Kaufmann.1st ed; 2001 Apr.
20. AlRashidi MR, El-Hawary ME. A survey of Particle Swarm Optimization applications in electric power systems. IEEE Transactions on Evolutionary Computation. 2009 Aug; 13(4):913–8.