A Novel Method for Edge Detection in Images Based on Particle Swarm Optimization

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Abstract. Edges give important structural information about the images. Edge detection is a process of identifying and locating the edges in an image. Edges are the points where discontinuity of intensity occurs. It also represents the boundaries of objects in images. In this paper a new edge detection method based on Particle Swarm Optimization is discussed. The proposed method uses morphological operations and a thresholding technique to improve the result of edge detector. This algorithm performs better in images comparing to other traditional methods of edge detection. The performance of proposed method is compared with traditional edge detection methods such as Sobel, Prewitt, Laplacian of Gaussian and Canny with parameters Baddeley’s Delta Metric. Statistical analysis is performed to evaluate accuracy of edge detection techniques.

1. Introduction
The boundaries between different textures in images are defined as edges. They are always important characteristics of images since edges indicates higher frequency information. Edge detection is the name for a set of mathematical methods which aims at identifying points in a digital image at which the image brightness changes sharply or more formally, has discontinuities in intensity. Edge detection for an image is helpful for many applications in the field of image processing and computer vision, which includes image segmentation, image registration, data compression, pattern recognitions, image classification and so on.

There are large numbers of edge detection algorithms that are widely used for edge detection. Edge detection algorithms are classified into two categories, they are first order derivative based methods and second order derivative based methods. In [1] explains edge detection algorithms which are based on the first derivatives of pixels are used to detect the edges in an image. These methods are simple and fast. In [2] Wang and Xin propose the category of edge detection algorithms uses the second derivatives to detect edges. Its major advantage over the first derivative based edge detectors is it’s good localization ability. D. Ziou and S. Tabbone explain comparative analysis of various edge detection techniques in [3]. The evidence for the best detector type is examined by studying the edge maps relative to each other through different parameters. The Canny’s edge detection algorithm performs better than all other operators under almost all scenarios.

These methods are simple and typically applied to a particular pixel or its neighbors or a particular area. Images with complex objects or shapes these algorithms cannot effectively detect the edges. These limitations are overcomes by using artificial intelligence (AI). Swarm intelligence (SI) is an artificial intelligence technique based on the study of collective behavior in decentralized, self-organized systems. Examples of these systems found in nature, which includes ant colonies, bird flocking and fish schooling. Particle Swarm Optimization (PSO) is a recent computational intelligence method, introduced by Kennedy and Eberhart in 1995 [4]. PSO is a population-based algorithm for problem solving based on social psychological principles.
From the literature it is well clear that the existing edge detection methods have accuracy up to 60% (it depends upon the complexity of image). To improve accuracy, here we propose a new method of edge detection based on PSO. Obtained simulation results show that proposed method performs better than the traditional edge detection methods. The proposed method of edge detection using PSO uses a morphological operator and a thresholding technique for better result. The edge detection using proposed method has high accuracy and good localization capability comparing to traditional edge detection methods. Our contributions in this work are summarized as follows:

- We propose edge detector that use PSO algorithm for detection of edges in image. The PSO can be used to detect more complex edges in image and hence to increase the localization accuracy.
- From the existing PSO based edge detector, we propose a novel method which uses Morphological and Thresholding algorithm along with PSO edge detector, which improves accuracy of edge detector.
- Performance analysis of each edge detector is evaluated using the parameters Baddeley's Delta Metric (BDM) and accuracy. Both analysis shows that proposed method have better performance than traditional methods of edge detection.

2. Background

In this section, the background theories related to this work is discussed.

2.1. Edge detection approaches

Changes in intensity or discontinuities in an image are marked as edges. Otherwise they are the points of significant transitions in an image. Most of the shape information about an image is enclosed in edges. So edge detection is important step in many of image processing applications. Some of the traditional edge detectors are defined here which are used in this work for the comparison of proposed method with some parameters.

Sobel edge detector uses sobel approximation filter, which is used as a gradient with smoothing. A convolution mask of size 3 x 3 is usually used to detect gradients in X and Y directions [5]. In prewitt edge detector it is similar to sobel only difference is prewitt filter [6] is used. Laplacian of Gaussian (LoG) is another method which detects edges by checking for whether zero crossings occurs or not after filtering with a Gaussian filter. This method is accurate method because it combines the effect of both filtering [7]. Canny edge detector is a multistage algorithm which can find edges in wide range [8].

2.2. Particle swarm optimization (PSO)

Particle swarm optimization (PSO) is a universal global optimization, inspired by the social behavior of animals and other biological populations. Recently, PSO has been used in many research areas because of ease of its implementation, fewer operations and high speed of convergence. PSO algorithm is defined in this section, as proposed by Kennedy and Eberhart [4].

In the PSO there is a population of m particles that fly through an n-dimensional search space. The position of the ith particle is represented as the vector \( X_i(t) = (X_{i1}(t), X_{i2}(t), \ldots, X_{im}(t)) \) and is changed according to its own experience and that of its neighbors. Let \( X_{pbesti} \) denote the best position of ith so far and \( X_{gbesti} \) denotes the best position of population so far [9].

3. Proposed method of edge detection

A block diagram of edge detection using PSO is shown in Figure 1. Proposed method consists of morphological operator and thresholding algorithm along with PSO edge detector. Morphological operator is used for image enhancement technique and it also act as noise removal filter. PSO edge detector is to locate the points of discontinuities in image and to obtain edge map of image. Thresholding algorithm is
used to classify detected points is edge or not. Single threshold value is used which is obtained by maximum entropy algorithm. The edge detectors performance is analyzed by BDM and accuracy.

![Figure 1. Proposed method of edge detection](image)

### 3.1. Morphological operator

The morphological operators work with two data's. The original data to be processed and the other is structuring element. Each structuring element has a shape which can be thought as a parameter to the operation. The morphological operator used in our method is used to smoothen the image, to get the final image aggregation of all the extracted edge information. The algorithm is as follows:

\[
E_1 = \sum_{i=1}^{5} \{(M \cdot B_i) \ominus B_i - (M \cdot B_i)\} \\
E_2 = \sum_{i=1}^{5} \{(M \cdot B_i) - (M \cdot B_i) \ominus B_i\} \\
E_3 = \sum_{i=1}^{5} \{(M \cdot B_i) \ominus B_i - (M \cdot B_i) \oplus B_i\}
\]

Where \(B_i\) is the square structuring element of 3×3. \(F\) is the input image then \(M\) is defined as:

\[
M = (F \cdot B_i) \circ B_i
\]

Final output of morphological operator is:

\[
E_4 = (\sum_{i=1}^{3} E_i)/3
\]

### 3.2. PSO edge detector

How PSO can detect edges in image is explained in algorithm 1. After the optimization, obtained fitness curves which indicate the edges and mark these edges in image. Fitness function is dependent upon homogeneity and uniformity factors. The fitness function for PSO is given by maximizing \(f_c\) to find the best fitting curve which passes through a pixel.

\[
f_c = H_c - U_c
\]

\(H_c\) and \(U_c\) are homogeneity and uniformity factors respectively.

### Algorithm 1 : PSO Edge Detection Algorithm

- Initialize PSO population randomly(position and velocity of each particle)
- Repeat
  - For all particle do
  - Evaluate the fitness value of the particle
  - Find in the particle neighborhood, the leader particle
  - Calculate particle velocity according to equation (2)
  - Update particle position according to equation (1)
- End
- Update leader
- Select best particle in the population

### 3.3. Thresholding

Once we have computed a measure of edge strength using PSO edge detector, the next stage is to apply a threshold, to decide whether edges are present or not at an image point. So setting threshold value is important procedure. Here maximum entropy algorithm is used to set threshold. It is a histogram based method to find optimum threshold. After thresholding the image is transformed into edge map of the input image. Transformation to edge map according to threshold \(T\) is explained in equation (9).

\[
f(x, y) = \begin{cases} 
255, & g(x, y) \geq T \\
0, & g(x, y) < T
\end{cases}
\]

Where \(g(x, y)\) is input image and \(f(x, y)\) is the edge map obtained.
4. Experimental results & analysis

The edge detection in images is done using traditional edge detection methods and proposed method. In proposed method morphological operator initially smooth’s the image, then PSO edge detector find the edge strength magnitude by locating the points of discontinuities in image. Thresholding is applied to locate all the edge points in image. The performance comparison is made between proposed method and traditional methods using parameters BDM and Accuracy.

We use one image for the experiment in which they are natural image which are commonly used for the evaluation of edge detection algorithm. The artificial ground truth image is provided by University of Cordoba (UCO) [10]. Localization accuracy of edge detectors are evaluated by the comparison with the ground truth. Ground truth images contain thin and single pixel width edges and they are generated by a specified algorithm. Figure 2 shows the original images and their outputs using various edge detectors, from these figure it is clear that edges are more clear and continuous in proposed method of edge detection. The number of broken edges is less in proposed method comparing with other methods of edge detection.

![Figure 2. Outputs of various edge detectors for ‘Coffee Maker’ image.](image)

Performance of proposed method of edge detection is analyzed by comparing with traditional edge detectors with parameters BDM and Accuracy. BDM is a parameter used to calculate the dissimilarity measure between two binary images. i.e., more the value, more the detected image varies from ideal image [11]. Accuracy is a statistical measure which can be calculated by the difference between edge pixels obtained by edge detection methods and a reference map (Ground truth) can be inferred.

Table 1 shows the performance analysis of different edge detector for Coffee Maker image with parameters BDM and accuracy. From the tables, it is clear that accuracy of proposed method is high when comparing to other methods. It is higher than that of PSO edge detector. Accuracy of proposed method is greater than 70%. Among the traditional edge detection techniques Canny is better, even though it does not have accuracy above 60%.

BDM is dissimilarity measure between two images. Ideally for an edge detector it is zero, in practical for a good edge detector it is smaller as possible. Here, the proposed method shows small value of BDM for image. It shows that output of proposed method have more similarity to ground truth image. The above figure and table shows that proposed method of edge detection based on PSO have better performance in quantitative analysis; it also shows better result in visual analysis also.

| Technique   | BDM    | Accuracy |
|-------------|--------|----------|
| Sobel       | 18.121 | 45.4     |
| Prewitt     | 17.543 | 46.82    |
| LoG         | 16.89  | 51.21    |
| Canny       | 13.079 | 58.5     |
| PSO         | 9.612  | 63.2     |
| Proposed Method | 7.11  | 72.254   |

5. Conclusion
In this paper, we proposed a novel method of edge detection based on PSO. Here the work done is to extract all edge patterns of an image with minimum computation time. Experimental results are observed for traditional edge detection methods, PSO edge detector and proposed method. Among traditional edge detectors canny edge detector performs better than other techniques. On visual analysis we have concluded that the proposed method gives a good quality of edge map relative to other methods discussed here. The output of PSO edge detector has good quality than the canny edge detector; it shows that optimization algorithms are also suitable for edge detection. Morphological operator helps to remove unwanted information's and makes the edge pixels more clearly. Thresholding technique has increased the localization accuracy of the proposed method of classifying the each edge pixel. Proposed method gives better performance in quantitative analysis also, proposed method have smaller value of BDM relative to other methods discussed here. Accuracy of the proposed method is above 70%, it is the best result for an edge detector.

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