Optimization of Laplace of Gaussian (LoG) filter for enhanced edge detection: a new approach

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***Abstract*— In this paper a very remarkable approach on edge detection has been explored. The most important aspect of image segmentation is edge detection. Edge detection is a meaningful interpretation of discontinuities of similar intensity values in image analysis [1]. Laplace of Gaussian (LoG) filter is a conventional edge detecting tool. Threshold neighboring pixel value (T) and standard deviation parameters are optimized with the help of Cuckoo Search optimization in order to augment the edge detection potential of LoG. PFOM (Pratt's Figure of Merit) is used as quality factor for edge detection analysis.**

***Keywords*— Laplace of Gaussian filter, PFOM, optimization, cuckoo search, Levy Flight**

I. INTRODUCTION

Edge detection is a very important aspect of image segmentation and analysis. Conventional methods include a first order derivative and second order derivative which detects change or discontinuity in neighboring pixel intensity [1]. General edge detecting filters include Sobel filter [1, 2], Prewitt filter [3], Robert's edge detector [1], Canny edge detector [4], Zero Crossing Filter [1, 2] and Laplace of Gaussian filter. Here LoG filter parameters are optimized with the help of CSO algorithm. PFOM is selected as the objective function and maximum value of PFOM for a particular value of T and standard deviation (σ) indicates best case of edge detection.

II. LAPLACE OF GAUSSIAN

Gaussian function is given by the following expression

$$G(\mathrm{x,y}) = -e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (1)$$

Then the Laplace of Gaussian is given by (2)

$$\nabla^2 G(x,y) = -[\frac{(x^2+y^2)-\sigma^2}{\sigma^4}]e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (2)$$

As told explained earlier it is a second order derivative function. At first image is convoluted with Gaussian filter which introduces Gaussian blurring, which in effect cause reduction of noise. Then laplacian of the result is taken. It is same as convolving the function with the given entire function [1]. A double edge image is produced, due to the laplacian operation. Zero crossing between the double edges represents the edges [1, 2].

III. CUCKOO SEARCH ALGORITHM

Optimization operation is performed through Cuckoo search algorithm. Cuckoo search is a nature inspired metaheuristic algorithm [5].

A. Cuckoo Breeding behaviour

CS algorithm is inspired from the breeding behaviour of cuckoos. Some species of cuckoo lay eggs in a host bird's nest; in some cases, even removing the eggs of that host bird in order to increase the survival probability of its own eggs. If a host bird somehow detects this anomaly, it either abandons its own nest or throws away the cuckoo's eggs. Studies have shown that in some cases, cuckoo eggs seems similar to that of the host's eggs and even some species of cuckoo chicks can mimic the voice of the host bird's chicks. This increases the probability of survival of cuckoo chicks [6].

B. Levy Flight

Mathematically speaking, a Levy flight is a special case Random Walk which has a heavy tailed probability distribution. Studies have shown that some species of insects, even animals such as spider monkeys show movement in Levy Flight in order to find randomly distributed food sources [7, 8]. Next step of a foraging animal primarily depends on its present state and the next step length. Hence the Random walk whose step length is drawn from Levy distribution is termed as Levy flight.

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C. Mechanism

Each egg in a nest represents a solution while a cuckoo egg represents a new solution. The target is to replace the host eggs that are replacing old solution with potentially better and new solution [9]. In our algorithm we have used a multiple number of eggs in a nest. Hence for generating potentially better solution, we perform a Levy Flight. Let the new solution be $x_i(t+1)$ which replaces $x_i(t)$ then

$$x_i(t+1) = x_i(t) + \alpha \oplus Levy(\lambda) \tag{3}$$

Where 'α' is the step length and is generally drawn from Levy distribution.

IV. PFOM

Pratt's Figure of Merit is a very useful measure for determining the performance of edge detectors [1]. It measures the difference between contours [11]. For two different contours the expression for figure of merit of Pratt is given by:

$$IMP = \frac{1}{\max(N_I, N_B)} \sum_{i=1}^{N_B} \frac{1}{1+\alpha \times d_i^2} \tag{4}$$

N_I and N_B denotes the points at the edges of the given image and ground truth image, whereas d_i is the distance between an edge pixel and nearest edge pixel of the ground truth image [11]. IMP varies between 0 and 1 and gives a qualitative analysis of edge detection. In ideal condition IMP value reaches 1.

V. IMPLEMENTATION OF OPTIMIZED PARAMETERS IN LoG

PFOM value is set as the objective function, where as the lower and upper limits of T and σ are both fixed within 0 and 1. For a given input image in "Fig 1", the optimum values of the parameters of the LoG filter is determined using CSO algorithm. As mentioned earlier the output image having maximum PFOM value will indicate best edge detection case.

Fig. 1. Input Image

VI. RESULTS

As explained earlier the default LoG filter kernel is a [5X5] matrix. Threshold value factor (T) is taken within the range 0.1 to 0.8 and the standard deviation value within 0.1 to 0.8. Maximum PFOM value indicates best case of edge detection. Fig. 2-7 shows the outputs at different parametric assessments.

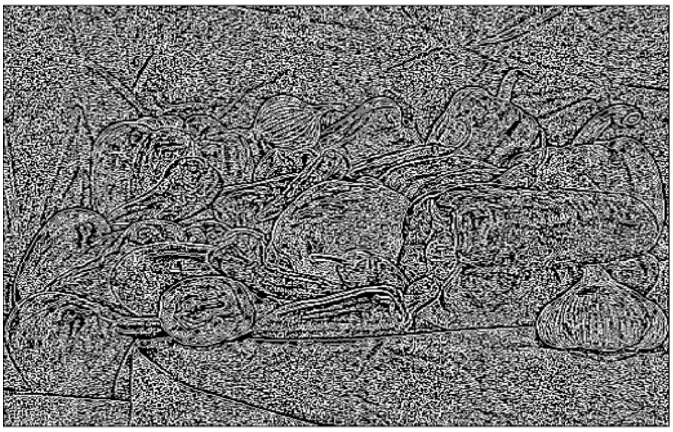

Fig. 2. T=0.1, σ=0.1, PFOM=.3745

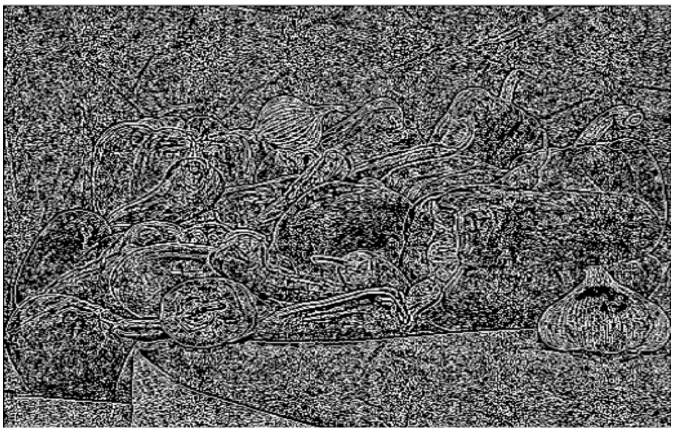

Fig. 3. T=0.2, σ=0.2, PFOM=.3769

Fig. 4. T=0.4, σ=0.4, PFOM=.7543

Fig. 5. T=0.6, σ=0.6, PFOM=.0236

Fig. 6. T=0.8, σ=0.8, PFOM=0.0

Fig. 7. T=0.1463, σ=0.5083, PFOM=.8065

Maximum PFOM value is obtained for threshold values (T)=0.1463 and standard deviation (σ)=0.5083. Corresponding PFOM value obtained is 0.8065 which is evidently the greatest value within the given range of sigma and T value, indicating the case of best edge detection (Fig. 7.).

TABLE I. PFOM SCORES OF EDGE DETECTORS

Method	**Sobel**	**Prewitt**	**LOG(optimized)**	**Robert's**
PFOM	.6152	.6122	.8065	.5528

VII. CONCLUSION

CS based optimization of Laplace of Gaussian (LoG) filter parameters has been investigated in this paper. Very few (here, only two) parameters were required for running the CS algorithm. Significant improvement in edge detection quality can be observed in case of optimized LoG filter. In future this algorithm can be implemented for optimization of more complicated edge detectors for paramount image segmentation purpose.

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