OPTIMIZATION OF GAUSSIAN & OUTLIER FILTERS FOR ENHANCED IMAGE DENOISING – A NOVEL APPROACH

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ABSTRACT

In this paper we aim at optimizing the performance of two widely used image filters – Gaussian and Outlier for denoising pre-corrupted image. The images have been intentionally corrupted using salt & pepper noise. Cuckoo Search algorithm has been used to optimize the performance of the two filters. The performance gradation has been done on the basis of PSNR values of the images after filtering. Higher is the PSNR value, better is the performance of the filter. The results assimilated in this paper clearly indicate the capability of Gaussian and Outlier filters in processing image corrupted by salt & pepper noise after being tuned to their respective peak performances.

KEYWORDS: *Gaussian Filter, Outlier Filter, Cuckoo Search Algorithm, Levy Flight, PSNR, Salt & Pepper noise, Optimization, Image Processing.*

I. INTRODUCTION

Our eyes are one of the most advanced sensing organs in the body and information through vision serves as a very important source of information [6, 10, 11, 12]. An image delivers an idea about size, shape, location, features, colors etc. of any object. The importance of images as a source of information demands for proper maintenance of images while various operations like compression, transfer etc. Image filtering deals with denoising an image and preserving the data of an image [6, 10, 11, 12]. The basic principle on which denoising is based is very simple – every image is continuous in nature and are made up of small units known as pixels, each of which carry a unique data[6, 11, 12]. Image filtering falls as a subclass of signal filtering [6, 10, 11, 12]. The need to filter images arises from the fact that images constitute a very broad and important range of information carriers [6, 10, 11, 12]. Images are generally treated as a 2 – dimensional signal, especially in the domain of image processing [6]. The operations on an image are similar to that on a signal, except that in a signal we have time as our reference variable whereas in an image it the spatial coordinates [6]. Thus an image can be represented in the form f(x, y) [6, 10, 12]. The type of value the function will return depends on the type of image. In our work we have considered the monochromatic image [6, 10, 11, 12]. Thus the function in this case returns the grey scale value [6, 10, 11, 12]. In this work we have examined and compared the performances of two of the most widely used image filter/algorithm Gaussian and Outlier. Gaussian is based on the concept of Gaussian distribution whereas Outlier is a modification in algorithm of median filtering. Both the filters have been subjected to corrupted images. The noise is Salt & Pepper noise and has been introduced intentionally for analysis. The parameter chosen for the comparison is the PSNR [3, 6, 7].This comparison has been done after we have fine-tuned the filter by optimizing it using a new metaheuristic algorithm known has the Cuckoo Search algorithm [1, 2]. The algorithm is inspired and has been developed by observing the unique breeding pattern of cuckoo and the Levy flight pattern exhibited in birds while flying [1,5]. The parameters that have been used in case of Gaussian filters for tuning are the filter mask and the standard deviation [4, 8, 9]. In case of Outlier the performance defining parameter is the tolerance level [10].

This work has been presented through the following topics – Image filtering, introduction to PSNR, a short summary of Gaussian and Outlier filters, an overview of the concept and algorithm of the cuckoo search algorithm used in the work & a brief of our procedure. The work also includes some of the generated results for the survey for readers. In the end, our work concludes with the inference we have drawn from our research & the future applications of our work. We, the authors, have expressed our gratitude and acknowledged the creators of the optimization algorithm. The reference section includes all of our literature survey which have helped the authors in implementing the given work.

II. IMAGE FILTERING

For nearly all processing purposes an image is taken in the form of a two dimensional signal, where the parameters of the image are a function of its spatial coordinates – f(x, y) [6, 10, 11, 12]. The value returned by this function maybe intensity, grey scale etc. In this work we have dealt with monochromatic images, so the function in this returns the grey scale value [6].

Any value of the spatial coordinates, within the image size limits, points to a specific area known as pixel. Pixel is the most basic division of an image [6, 11, 12]. A pixel holds just one unique data, for example in monochromatic image just one grey scale value [6]. Thus any operation on an image is basically alteration of data at pixel level. An effect of a continuous like image is formed when different pixels of slowly changing grey scale values are arranged in a pattern [6, 10, 11, 12].

When we say that an image is corrupt, what is implied is that the original grey scale value of one or more pixels gets replaced [6, 10, 11, 12]. The new pixel values together tend to make the image meaningless in general.

By filtering an image, we attempt to replace the values of corrupted pixels with a value very close to the original value [6]. The generation and replacement is done by functions known as image filters [6, 10, 11, 12]. These functions try to replace corrupted pixels by generating a data through a mathematical operation, and then replacing the pixel with that data [6].

For any pixel we have similar adjoining pixels in an image. These pixels may or may not contain the original information of the corrupted pixel, what we are sure of is that the original value lies around the values of the surrounding pixels [6]. Filters use this information to generate the data for corrupted pixel [6, 10, 11, 12]. An image may not look visually enhanced but its signal to noise ratio changes drastically after filtering.

III. PEAK SIGNAL – TO – NOISE RATIO (PSNR)

Any evaluation done has to be with respect to a performance parameter [3, 7, 10, 12]. For a signal, this parameter is usually the signal to noise ratio. In real systems a signal is never entirely deficient of noise. Whether or not the filtered signal can be used depends upon the amount of noise a user or system can permit with the signal [3, 7, 10, 12]. In order to have a generalized system of denoting noise tolerance, the amount of allowable noise is usually mentioned as a ratio of the amplitude of signal to the noise amplitude, known as the signal to noise ratio [3, 7, 10, 12]. Greater is the ratio, more filtered a signal is. [3, 10, 12]

The peak signal-to-noise ratio or the PSNR is defined as the ratio between the powers of original signal to the power of corrupting noise [3, 7, 10, 12]. To bring down PSNR to a common depiction domain, it is represented in the logarithmic decibel scale. [3]For a general mathematical representation, let us consider an image matrix of size $\alpha \times \beta$. As mentioned earlier, the value of a pixel is a function of spatial coordinates (x, y). [7]Now, considering a function O(x, y) denoting the original value of pixel and C(x, y) the corrupted value of pixel,

The mean error,

$$m_e = \frac{1}{\alpha \times \beta} \sum_{i=0}^{\alpha-1} \sum_{j=0}^{\beta-1} [O(i,j) - C(i,j)]$$

Thus, $$PSNR = 10 \times log_{10} \left[\frac{m_i^2}{m_e}\right]$$ …….. [3, 7, 10]

In the given equations, m_i represents the peak energy value of that particular pixel. In our analysis we have compared the PSNR values of images filtered by Gaussian and Outlier filters at various parametric standards [3, 7, 10, 12].

IV. GAUSSIAN AND OUTLIER FILTERS – A SUMMARY

Gaussian filter is a low pass filter. It is widely deployed in signal filtering. The filter has a characteristic blurring effect on an image along with filtering [4, 8, 9]. The working principle of a Gaussian filter is based on the Gaussian distribution function. [4, 8, 9]
The Gaussian function in one dimension is given by the expression-[4, 8, 9]

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-x^2}{2\sigma^2}}$$

To use it for an image, we need to convert it into a 2 – dimensional function of spatial coordinates (x, y). [4, 8, 9]

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

The Gaussian filter has been regulated by using the standard deviation and the filter mask as its performance variables in the optimization algorithm. [4, 8, 9]

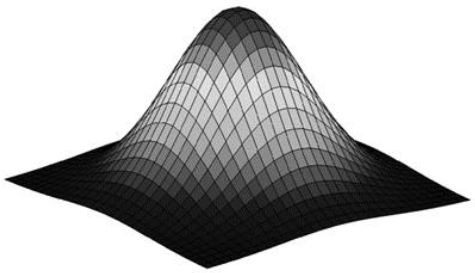

Fig (1) - A Gaussian Filter mask in 3 - dimensions

Generating Gaussian blur is equivalent to convolving an image with a kernel of Gaussian values. The implementation of Outlier was proposed by Pratt [10] to replace the tedious and lengthy algorithm of the median filter.
Pratt proposed that the level of tolerance, D, should be predefined. This value is nothing but the difference in grey values of the pixel [10]. The algorithm for Outlier filter is -

1) Fix the value D as per requirement.
2) Calculate the mean 'm' of the surrounding pixels of the noisy pixel.
3) Calculate the difference between the grey values of noisy pixel with the value m, if this difference crosses the tolerance D, replace the noisy pixel with value m. The only performance parameter of the Outlier filter is the tolerance D.[10]

V. CUCKOO SEARCH OPTIMIZATION – AN OVERVIEW OF CONCEPT AND ALGORITHM

The Cuckoo search mechanism is a novel system of optimization, a new metaheuristic algorithm. It was introduced and developed by Xin-She Yang and Suash Deb. They were inspired by the unique breeding behavior of a cuckoo, and used the concept in their optimization algorithm along with the concept of Levy flight. [1, 2, 5, 13, 14]
Some of the old metaheuristic algorithms like for example, the Particle Swarm technique (PSO) have too been inspired and developed keeping a natural system as its base [1, 2, 14]. The reason why designers of new algorithm resort to observing the natural behaviors and/or patterns is because through

the course of evolution, these systems have developed into highly efficient models [1, 2, 14]. Of all the properties exhibited by these systems two of which are most significant, and are used in development of a new algorithm are – the survival of only the best elements/parts and modeling itself to fit appropriately in the environment [1,2, 14]. From the viewpoint of an optimization algorithm these two features transform into – the ability of the algorithm to generate only the best possible results after every major step and the power of algorithm to spread itself over the entire domain of the objective function respectively[1,2, 14].

In Cuckoo Search algorithm, the best results, which survive after every iteration, are generated by imitating the breeding pattern of the cuckoos [1, 2, 14]. Whereas the extent of spread of the optimization in filtering results for the next iteration is generated through the Levy flight distribution [1, 2, 5]. The following describe the features of the cuckoo reproduction behavior and Levy flight mechanism in brief and its analogy with algorithm of optimization –

- The reproduction pattern is "aggressive" [1, 2]. The cuckoos never lay their eggs in their own nests. If in case the egg has been laid in a shared nest, they may destroy other's eggs. For the other bird, the options on finding a cuckoo's eggs are to either destroy the egg or may abandon the nest. Thus the egg is destroyed or it may survive [1, 2, 14].
  In the algorithm, an egg that has been laid by the cuckoo represents a new solution to the search. Before advancing to the next stage, a distribution function determines the number of surviving solutions. It is similar to an egg either being spared or being destroyed by any other bird [1, 2, 14]. These new solutions serve as the population for the next iteration [1, 2, 14].
- The cuckoos have also developed various camouflages to increase the chances of the survival of its eggs [1, 2, 14]. It may match the color of its egg with the eggs of host birds and the baby cuckoo can even learn the call of the host bird [1, 2, 14]. These measures increase the probability of survival of a cuckoo's eggs even more. The eggs which camouflage well survive longer [1, 2].
  The algorithm analogy to this is that with more iteration we approach better answers, better solutions. The iterations of the algorithm keep on continuing until the required threshold or optimized value is reached.
- The Levy flight distribution is based on the random flight pattern exhibited by birds [5]. The flight patterns are very irregular in nature and are occasioned with sudden right-angled turns [5]. Levy flight behavior has been observed in many birds, for example fireflies [5]. Mathematically the Levy flight is a special case of random movement having a heavy tailed probability distribution [5]. The next step of the bird or animal implementing Levy flight depends usually on its present state and the length of its next step [5]. The length of the next stage is drawn from the Levy distribution and hence the name [5].
  The Levy flight distribution gives the algorithm the extent of search for solutions. The distribution generates a different value with every iteration [5]. Mathematically, if x (t) represents the number of solutions in the t^{th} stage, then $x(t+1) = x(t) + \alpha \oplus \text{Levy}(\lambda)$ [5].

The features and analogies have been summarized not specific to a specific optimization, but in general. As per requirement, minor changes are made to the algorithm, but in principle it remains the same.

VI. PROCEDURE

The primary objective of our work is to filter intentionally corrupted monochromatic images by Gaussian and Outlier filters. The filter parameters have been optimized by Cuckoo Search algorithm to obtain peak filter performance.

The idea is to take a reference, in the form of uncorrupted original image, to determine the PSNR values of the filtered images. We have taken an image and converted it to grey scale (as shown in Fig. (2) for further operations. The thus converted image has been corrupted using salt and pepper noise (0.02), as shown in Fig (3).

In order to draw a fair comparison between the two filters Gaussian & Outlier [4, 7, 8, 9, 10], we have first enhanced them using the Cuckoo Search optimization [1, 2, 13]. The variables used in optimization for Gaussian filter are the filter mask and the standard deviation of the filter whereas in the case of Outlier it is the tolerance value [4, 7, 8, 9, 10].

The results given by the optimization have then been deployed in the particular filters.
A number of results have been produced for different parametric standards and then the PSNR value has been calculated with respect to the original image for each case [3, 7, 11, 12]. As stated previously PSNR value has been considered the parameter for performance evaluation in our work [3, 7, 11, 12]. The methodology of our work is presented in brief in Fig (4).

Fig (2) – Original Gray scale image

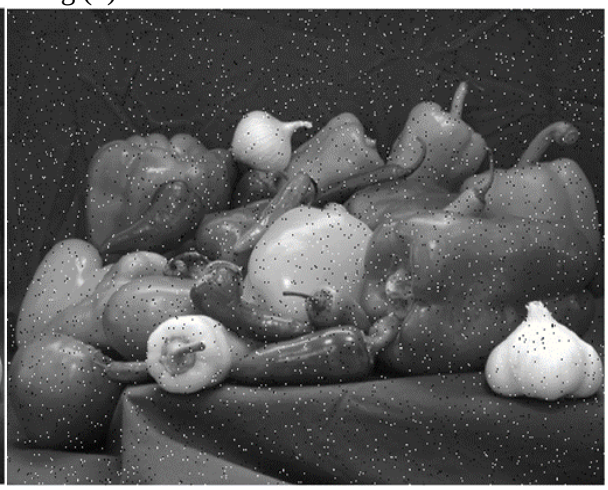

Fig (3) – Corrupted Image

VII. RESULTS

We have generated various results at different parametric standards. Some of the results have been presented in this paper.

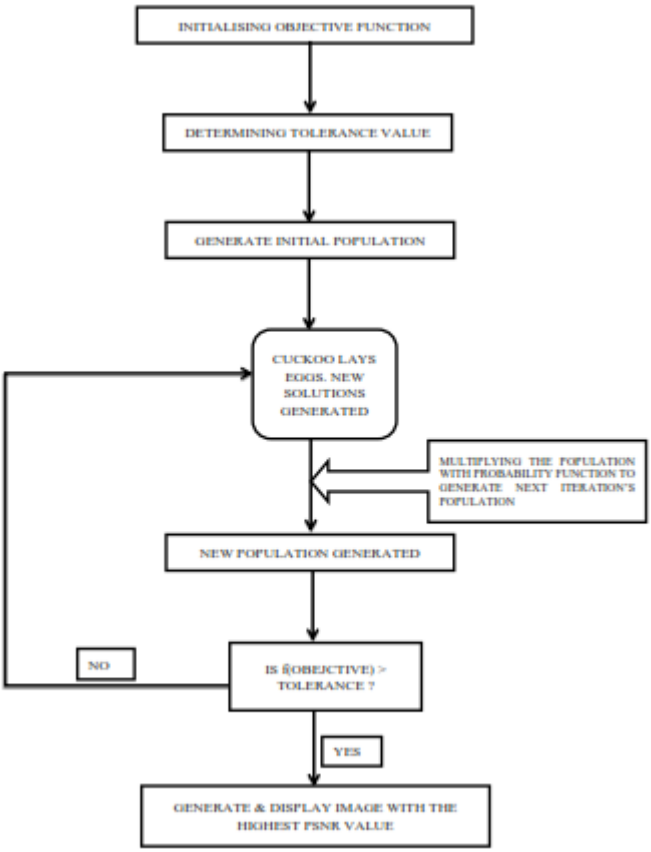

Fig 4. GAUSSIAN FILTER RESULTS

For σ = 0.3

Fig (5) – Filter Mask = 4X4, PSNR = 26.9479

Fig (6) – Filter Mask = 7X7, PSNR = 22.1161

For σ = 0.6

Fig (7) – Filter Mask = 4X4, PSNR = 27.6814

Fig (8) – Filter Mask = 7X7, PSNR = 27.8442

For σ = 1.2217

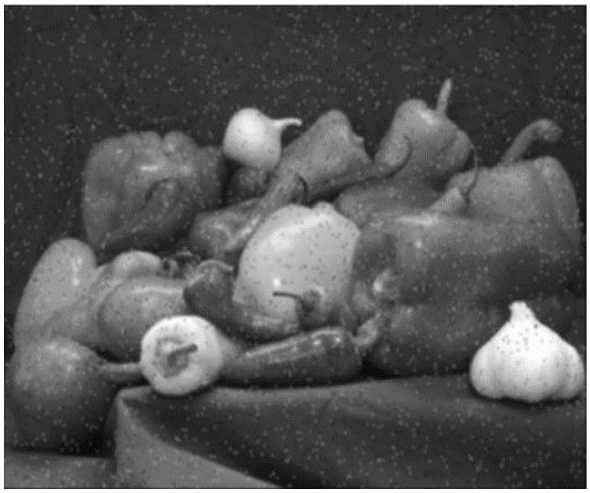

Fig (9) – Filter Mask = 4X4, PSNR = 29.8576

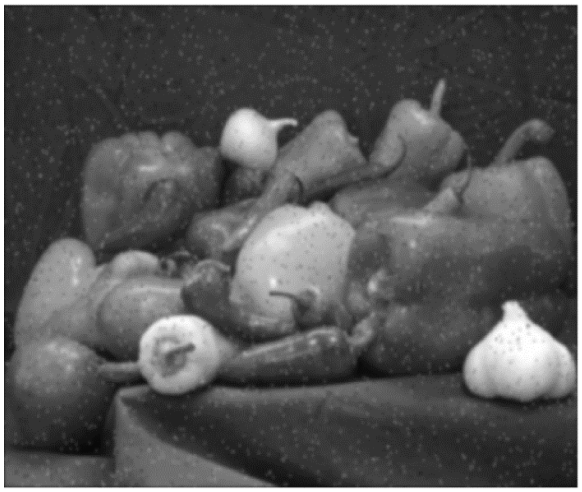

Fig (10) – Filter Mask = 7X7, PSNR = 31.2788

For σ = 2.4

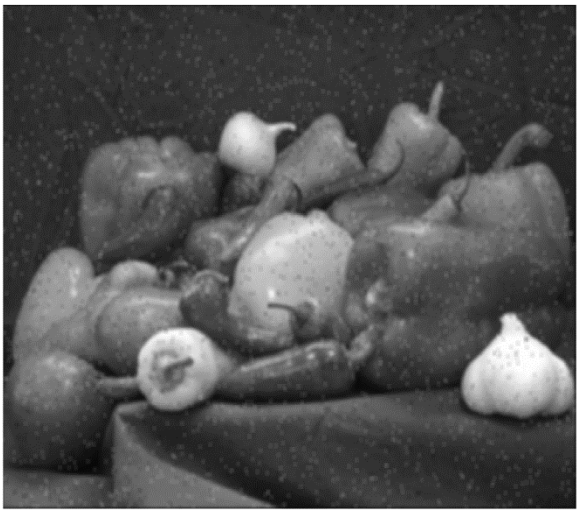

Fig (11) – Filter Mask = 4X4, PSNR = 29.9194

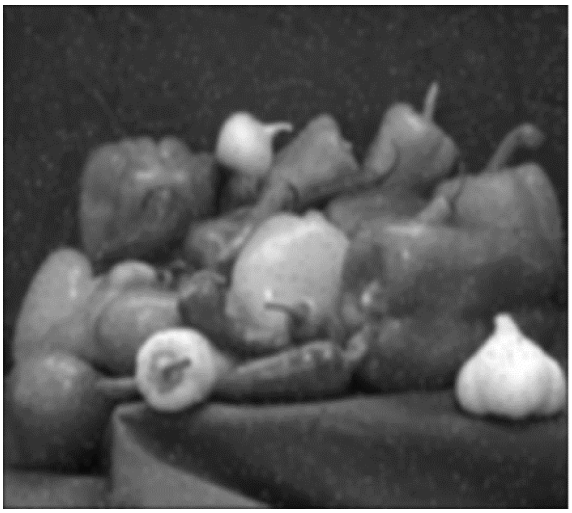

Fig (12) – Filter Mask = 7X7, PSNR = 30.2243

OUTLIER FILTER RESULTS

Fig (13) - D = 1, PSNR = 21.9845

Fig (14) – D = 0.6, PSNR = 28.3449

Fig (15) – D = 0.8, PSNR = 23.9990

Fig (16) – D = 0.1, PSNR = 32.8476

Fig (17) – D = 0.4, PSNR = 33.0920

Fig (18) – D = 0.1909, PSNR = 37.6587

VIII. CONCLUSION

The paper can be summarized as follows –

- The filters Gaussian and Outlier have been optimized using the Cuckoo Search algorithm.
- The optimized filters have been used to filter pre corrupted monochromatic images (the corruption is done using Salt & Pepper noise) at different parametric standards.
- The PSNR values of various filtered images have been calculated.

The PSNR values serve as the yardstick against which all the filter performance have been analyzed and concluded.

The size of image used in this work is 512 X 384. Number of nests initially initialized = 25. The ratio of probability factor to the discovery rate of alien eggs = 0.25. Number of eggs per nest = 1. Tolerance value for generating the final result = 37.2787.
The peak performance has been observed in obtained optimum parameters in case of both the filters. The best result can be observed in –

Gaussian Filter – for Standard Deviation value (σ) = 1.2217, Filter Mask – 7X7. The PSNR value = 31.2788. Refer Fig(10)

- Outlier Filter – for tolerance value D = 0.1909. The PSNR value = 37.6587. Refer Fig(18)

Readers may also note that the Outlier filter performs better on optimization when compared to Gaussian filter in case of salt & pepper noise.

IX. FUTURE WORK

There are various other image filters which can be optimized for best performance and may be compared with other filters for a relative performance evaluation [15, 16, 17, 18]. The algorithm for optimization chosen in this work was Cuckoo Search. Other algorithms can also be applied to tune the filters for peak performance [15, 17, 18]. As new algorithms and/or filter concepts are being developed, various evaluations such as one presented in this work may be performed and the results may be applied for high performance filtering.

ACKNOWLEDGMENT

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BIOGRAPHY

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