Image fusion approach with noise reduction using Genetic Algorithm

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***Abstract*— Image fusion is becoming a challenging field as for its importance to different applications, Multi focus image fusion is a type of image fusion that is used in medical fields, surveillances, and military issues to get the image all in focus from multi images everyone is in focus in a different part, and for making the input images more accurate before making the fusing process we use Genetic Algorithm (GA) for image de-noising as a preprocessing process. In our research paper we introduce a new approach that begin with image de-noising using GA and then apply the curvelet transform for image decomposition to get a multi focus image fusion image that is focused in all of its parts. The results show that Curvelet transform had been proven to be effective at detecting image activity along curves, and increasing the quality of the obtained fused images. And applying the mean fusion rule for fusing multi-focus images gives accurate results than PCA, contrast and mode fusion rule, Also, GA shows more accurate results in image de-noising after comparing it to contourlet transform.**

Keywords—Multi-focus image fusion; Curvelet transform; genetic algorithm Introduction

I. INTRODUCTION

The driving forces in today‘s manufacturing environments especially with recent rapid developments in the field of sensing technologies are quality improvement and cost reduction. The quality of many raw materials, parts, and products can be measured by visual inspection. However, the Inspection by eye is costly, subjective, qualitative, inaccurate, eye-straining, and time consuming. For high speed and real time applications, manual inspection is not possible. The result of the use of these applications is a great increase in the amount of data. As the volume of data grows, the need to combine data gathered from different sources to extract the most useful information also increases. The technique which performs this is Image fusion that is widely recognized as an important tool for improving performance in image based applications such as remote sensing, machine vision, medical imaging, and optical microscopy and so on.

Image fusion is a process of combining set of images to integrate complementary and redundant information to provide a composite image which could be used to better understanding of the entire scene and will be more informative and complete than any of the input images. When a lens focuses on a subject at a certain distance, all subjects at that distance are sharply focused. Subjects not at the same distance are out of focus and theoretically are not sharp. It is often not possible to get an image that contains all relevant objects in focus. One way to overcome this problem is multi-focus image fusion, in which one can acquire a series of pictures with different focus settings and fuse them to produce an image with extended depth of field.

In the past years Genetic algorithm was used with image fusion for solving optimization problems such as used for estimating the weights of the weighted average Pixel level weighted average [4], then GA used for solving optimization problems for image fusion in another manner in which it is used for determining the best size of the block in [5], Michifumi Yoshioka presented an approach based on genetic algorithm for minimizing noise from original image. Most of algorithms proposed in literature are either noise dependent or threshold governed. In real time environment the type of noise in the image signal is unknown. So applying an algorithm specific to noise, will never be successful under these conditions. These disadvantages can be reduced by using a hybrid filter that consists of de-noising filters [1], In recent years image fusion had been used for many applications and many techniques had been used for achieving this one of the most popular techniques was Pyramid [7] and wavelet [6] are the most widely studied and used multi-resolution image fusion schemes. There are many types of pyramid and wavelet decomposition algorithms in recent years; however, not much research has been conducted on fusion rules. wavelets transform can only reflect "through" edge characteristics, but cannot express, To overcome the limitation of the wavelet transform, Donoho et al. has proposed the concept of Curvelet transform, which uses edges as basic elements, possesses maturity, and can adapt well to the image characteristics. “Along edge characteristics” [8]. Moreover, curvelet Transform has anisotropy and has better direction than wavelet can provide more information to image processing [9] [10].

We introduce in this paper a multi focus image fusion using curvelet transform and image de-noising using Genetic algorithm (GA). The basic idea is to apply the GA to filter sequence to get the best filter sequence for de-noising the input images. And then using the curvelet transform as a tool for fusing the two images to get a more focus fused image.

The paper is organized as follows. Section 2 explains the proposed fusion approach and an introduction of using GA for image de-noising. Section 3 the experimental results of the proposed approach, performance analysis showing the results of applying the quality measures and its graph and comparison with other schemes then it is followed by conclusion in section 4.

II. Proposed Image Fusion Approach

In our proposed approach we first used Genetic Algorithm (GA) as a de-noising tool, Then this de-noised image which comes from applying GA to the Hybrid filter entered to the next stage which is applying the image fusion process using curvelet transform to the two input images to obtain one fused image which is better in it's focusing from the other two input images.

Block diagram for our proposed approach is illustrated in (Fig. 1)

A. Image de-noising using GA

A variety of algorithms have been evolved from nature. GA is one of the simplest and most popular evolutionary algorithms. Genetic Algorithms called as (GA) are based on natural selection discovered by Charles Darwin. GA makes use of the simplest representation, reproduction and diversity mechanism. Optimization with GA is performed through natural exchange of genetic material between parents. Offspring's are formed from parent genes. Fitness of offspring's is evaluated. The fittest individuals are allowed to breed only. GA are being used in different applications such as function Optimization, System Identification and Control, Image Processing, Parameter Optimization of Controllers, Multi-Objective Optimization, etc.

Hybrid filter is a sequential filter where different filters are arranged in a sequence to obtain a noise free image. Peak Signal to Noise Ratio (PSNR) is one of the performance indices which determine the quality of the image.

Here we used PSNR as our fitness function for the GA which is directly proportional to the value of PSNR. Better the value of PSNR better is the quality of image.

Initial population:

De-noising using GA begins with initial population P0 with size μ and number of genes (filters) in a chromosome with size gnum, so we have the initial population is a matrix μ * gnum.

Selection: After applying the fitness function to the initial population we apply the selection function to select the highly fitness function chromosomes to be used for the next new generation and here we use the roulette wheel selection type for reproducing the new generation.

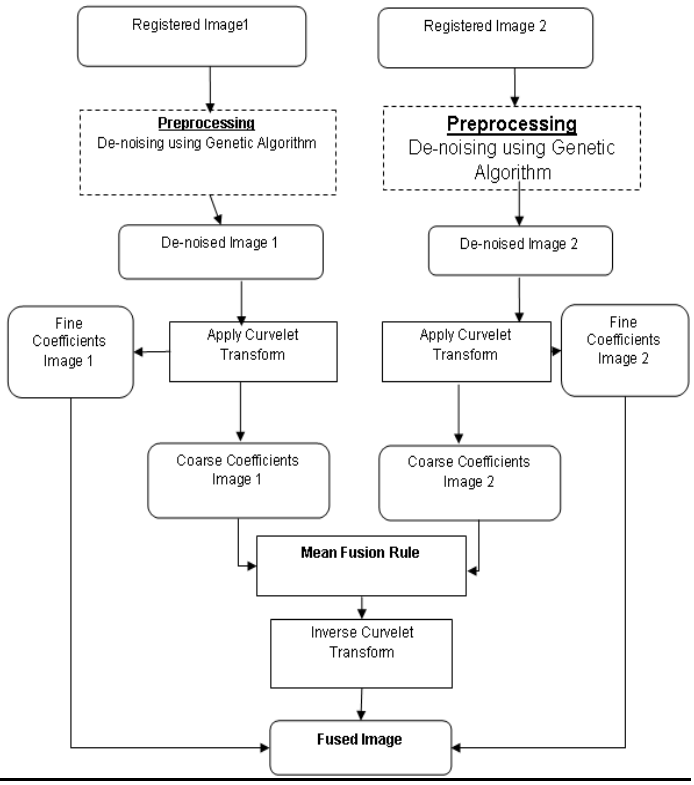

Fig. 1. Block diagram for image fusion using Curvelet transform and de-noising using GA

Fitness Function:

The problem objective function can be defined as follows:

$$\text{Objective} = \text{Max}(f) \quad (1)$$

Here PSNR can be defined as:

$$\text{PSNR} = 10 \times \log_{10}\left(\frac{(2552 \times M \times N)}{\sum\sum (x(i,j) - y(i,j))^2}\right) \quad (2)$$

Where *y (i, j)* in PSNR can be defined as:

$$y(i,j) = \underbrace{I_5(W_5 * [\ldots[I_2(W_2 * [I_1(W_1 * y_1)])]]}_{(5)} \quad (3)$$

(2) (1)

The sequence of the equation starts from 1 and ends by 5

y_1 is the initial corrupted image and * represents convolution.

3- W_k is the filters applied and I_k is the Boolean operators. Where *k* varies as $1 \le k \le 5$.

$$I_k(W_k * y_k) = \begin{cases} y_{k+1}, & \text{if } I_k = 1; \\ y_k, & \text{if } I_k = 0. \end{cases} \quad (4)$$

In above equation, $I_k=0$ will imply that no convolution will take place and $I_k=1$ will imply that image y_k will be convoluted with the filter W_k to give a new image y_{k+1}.

Constraints:

$I_k \ge 0$ and $W_k \ge 1$ where $1 \le k \le 5$

$I_k \in \{0, 1\}$, $W_k \in [1, 5]$

W_k can be Mean, Contourlet, Average, Pyramid and Gaussian filters depending on the value W_k from 1 to 5.

Crossover: After individuals are selected, reproduction involves crossing the individual's chromosomes to produce their offspring's chromosome. Crossover is a random process, we use a single point crossover by choosing Pc where

$0 \leq Pc \leq 1$.

Mutation: By mutation individuals (chromosomes) are randomly changed. These variations (mutation steps) are mostly small. They will be applied to the variables of the individuals with a low probability Pm where $0 \leq Pm \leq 1$.

(Fig.2.) Shows the flow diagram of how GA used to de-noise a corrupted image Firstly, corrupted image and the smoothing filters are passed as an input to the GA function. GA analyses the system quality by comparing the values of the fitness function obtained by various sequences. GA uses SNR or PSNR as the fitness function for evaluating the best sequence of smoothing filters. After the completion of the first iteration, new set of sequences are created by the process of crossover and mutation. Mutation operator is used to avoid the local minima trapping of the algorithm. The probability of selection of a sequence from the set is directly proportional to the value of its fitness function. The new set of sequences then replaces the previous set. The process continues until the stopping criterion is achieved. The sequence, that gives the maximum value of SNR or PSNR, is said to be the best sequence. This sequence is passed as input to the Sequence Application Function. Sequence Application Function applies the filters on the corrupted image in that sequence. The resultant image is the noise removed image.

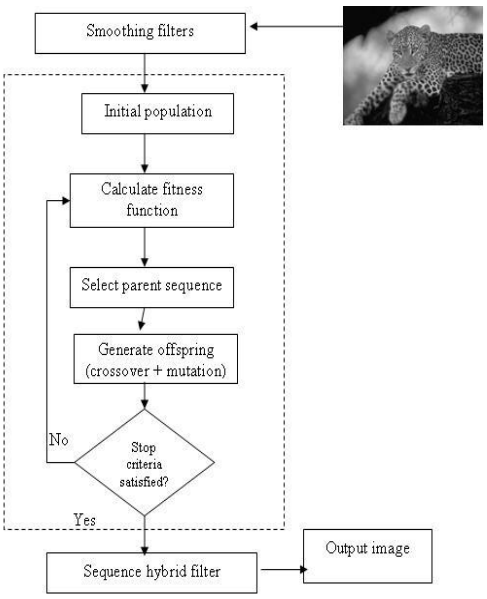

Fig. 2. Image De-noising using Genetic Algorithm (GA) applied to Sequence Hybrid Filter

B. Image Fusion by Curvelet Transform:

1) Curvelet Transform

Curvelet transform is a tool for representation of curved shapes in images. The concept of curvelet transform is based on the segmentation of the whole image into small overlapping tiles and then applying ridgelet transform on each tile.

Here we are using wrapping algorithm based curvelet decomposition.

The wrapping discrete curvelet transform is implemented using the following steps:

Step 1: FFT of the image is taken and the resulting Fourier samples is divided into collection of digital corona tiles as shown in "Fig. 3".
Step 2: For each corona tile, the tile is translated to the origin.
Step 3: The parallelogram shaped support of the tile is wrapped around a rectangle centred at the origin.
Step 4: The Inverse FFT of the wrapped support is determined and finally the resulting curvelet array is added to the collection of curvelet coefficients.

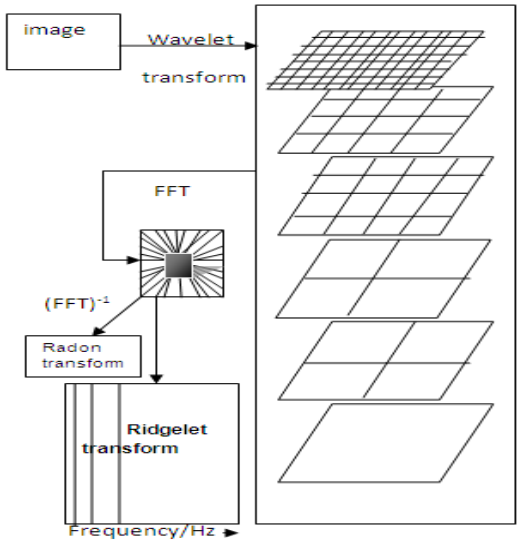

Fig. 3. Curvelet Transform

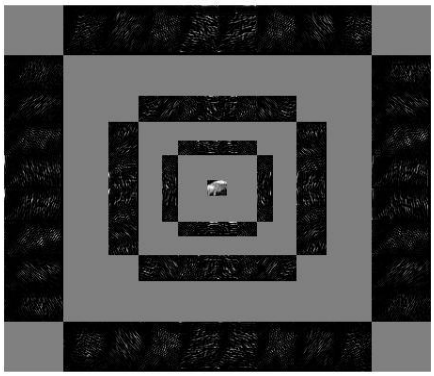

Fig. 4. Curvelet Coefficients of Tiger image

2) Fusion Rules

There are a variety of techniques that have been reported as valid image fusion processes. Some of these are Statistics based and Wavelet based.

Some of the popular fusion techniques based on statistical analysis of the images are max or min and mean, Principle Component Analysis (PCA) and contrast.

Assuming that images are collected simultaneously with accurate registration, images can be fused element wise, taking the maximum, the minimum, and the mean values.

The figures illustrated below show the registered and fused images using different fusion techniques like max or min, mean, Principle Component Analysis (PCA), contrast and wavelet based.

In our approach we use the popular mean fusion rule, as by applying the quality measure PSNR (Peak Signal to Noise Ratio) it gives the highest PSNR (Peak signal to noise Ratio).

III. EXPERMINTAL RESULTS

Techniques for performing image de-noising and image fusion vary widely depending on the specific application, imaging modality, and other factors there is currently no single de-noising filter that can de-noise all types of noises and there is no single fusion method that yields acceptable results for all types of applications. The present research work proposes an approach that is more general and can be applied to a variety of image data. The performance of the proposed research work was analyzed using various experiments.

This section presents the experimental results obtained during performance analysis.

A. Data Set

The proposed approach was tested with six pairs of images (Fig. 5.). Each image is used as a representation of different scenes. All set of images represent the situation where, due to the limited depth-of-focus of optical lenses in cameras, it is not possible to get an image which is in focus everywhere.

Objective image quality measures play an important role in various image processing applications. There are different types of object quality or distortion assessment approaches. The fused images are evaluated, taking the following parameters into consideration.

Seven quality measures were used during experimentation to evaluate the efficiency of the proposed approach of image fusion using curvelet. They are Root Mean Square Error (RMSE), Peak Signal to Noise Ratio (PSNR), Normalized Absolute Error, Normalized Cross Correlation, Maximum Difference, Average Difference and Structural Content.

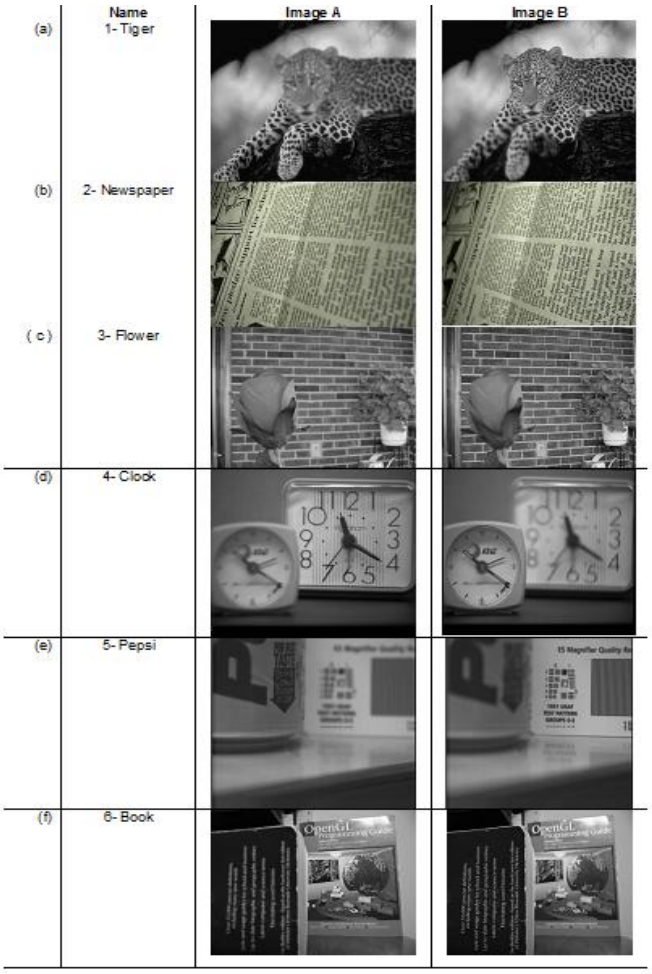

Fig. 5. Test Images

The following table is for the parameters used when using the GA:

TABLE I. PARAMETER SETTING FOR DE-NOISING USING GA

Parameters	Definition	Values
μ	Population size	25
Pc	Crossover probability	0.4
Pm	Mutation probability	0.01
Itrnum	Number of iterations	20
Gnum	Number of genes (filters)	5

A. Performance Analysis

The visual results of applying our approach are illustrated in the following figure:

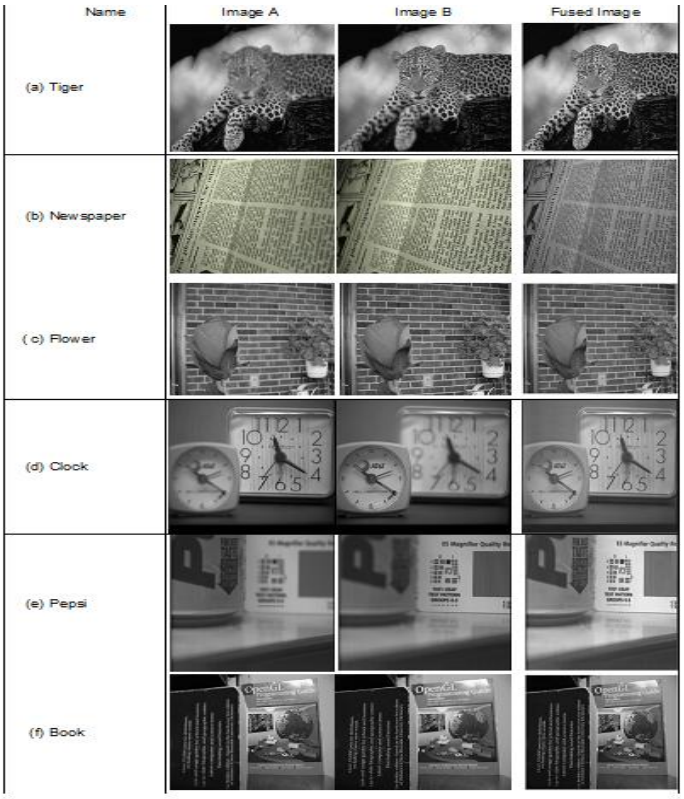

Fig. 6. Visual results of the approach

By applying the quality measure PSNR to set of images these are the result of the image de-noising using the GA which show that GA gives the best PSNR value as it is an optimization function. The next table [Table 2.] gives the value of the PSNR after each iteration by applying 20 iterations to the clock image, we found the best PSNR was 38.7426 and it was stable after iteration number 9 till the 20 iteration.

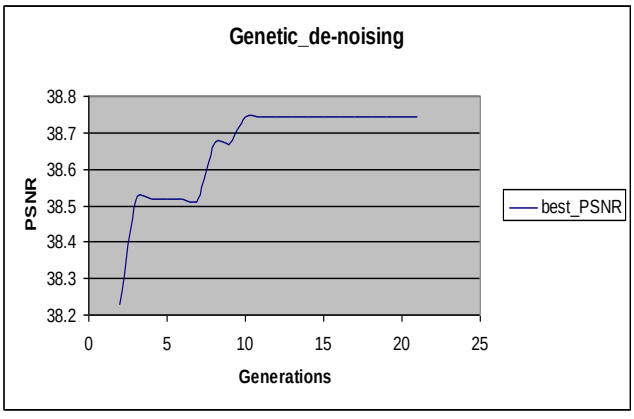

Fig. 7. Genetic performance using PSNR

TABLE II. THE BEST PSNR ALONG 20 ITERATIONS USING GA

Num_Iterations	Best_PSNR
1	38.2302
2	38.5201
3	38.5201
4	38.5201
5	38.5201
6	38.5201
7	38.6701
8	38.6701
9	38.7426
10	38.7426
11	38.7426
12	38.7426
13	38.7426
14	38.7426
15	38.7426
16	38.7426
17	38.7426
18	38.7426
19	38.7426
20	38.7426

By applying quality measures to the set of dataset images these are the results of the image fusion approach using curvelet and mean fusion rule with RMSE, PSNR and Maximum Differenece.

TABLE III. THE RESULT OF APPLYING RMSE, PSNR, MAXIMUM DIFFERENCE TO DATASET

Image	RMSE	PSNR	Maximum Difference
1-Tiger	119.5014	27.3571	80.8271
2-Newspaper	1.4926e+003	16.3913	199.3773
3-Flower	86.6267	30.8525	53.4359
4-Clock	94.4028	28.3810	72.6575
5-Pepsi	20.1524	35.0875	34.6182
6-Book	38.6760	32.2564	83.0727

By applying Quality measures to different fusion rules for the six set of images these are the result tables and its graph:

1) The first table is for the Pepsi Image by applying the Fuse mode, PCA, contrast and fuse mean using curvelet transform, and its graph of these results.

Pepsi Image

TABLE IV. THE RESULT OF APPLYING DIFFERENT FUSION RULES TO PEPSI IMAGE USING DIFFERENT EVALUATION FUNCTIONS

	MSE	PSNR	MD
Fuse mod	323.7387	23.0289	83
PCA	242.8457	24.2775	98
Contrast	65.0607	29.9976	91.8697
Fuse mean	53.4359	30.8525	86.6267

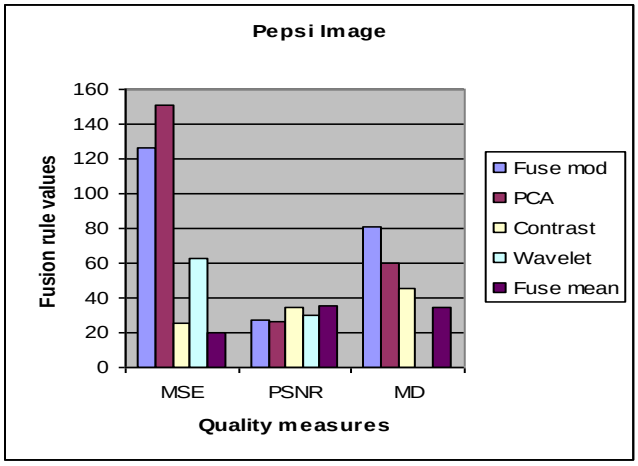

Fig. 8. Graph of table 4

2) The first table is for the Tiger Image by applying the Fuse mode, PCA, contrast and fuse mean using curvelet transform, and its graph of these results.

Tiger Image

TABLE V. THE RESULT OF APPLYING DIFFERENT FUSION RULES TO TIGER IMAGE USING DIFFERENT EVALUATION FUNCTIONS

	MSE	**PSNR**	**MD**
Fuse mod	174.9141	25.7026	87
PCA	179.1189	25.5994	90
Contrast	122.7919	27.2351	80.633
Fuse mean	119.5014	27.3571	80.8271

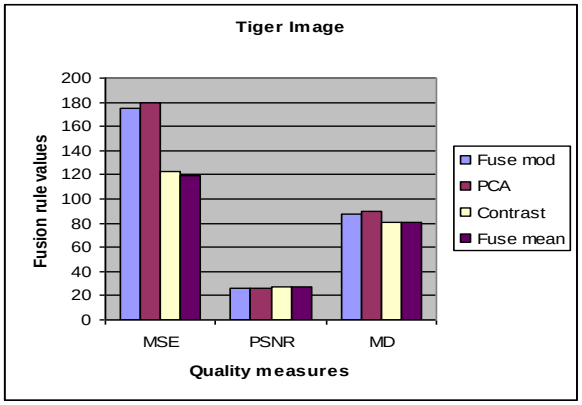

Fig. 9. Graph of table 5

3) The first table is for the Pepsi Image by applying the Fuse mode, PCA, contrast and fuse mean using curvelet transform, and its graph of these results.

Flower Image

TABLE VI. THE RESULT OF APPLYING DIFFERENT FUSION RULES TO FLOWER IMAGE USING DIFFERENT EVALUATION FUNCTIONS

	MSE	PSNR	MD
Fuse mod	126.7544	27.1012	81
PCA	150.8274	26.346	60
Contrast	25.1908	34.1184	45
Fuse mean	20.1524	35.0875	34.6182

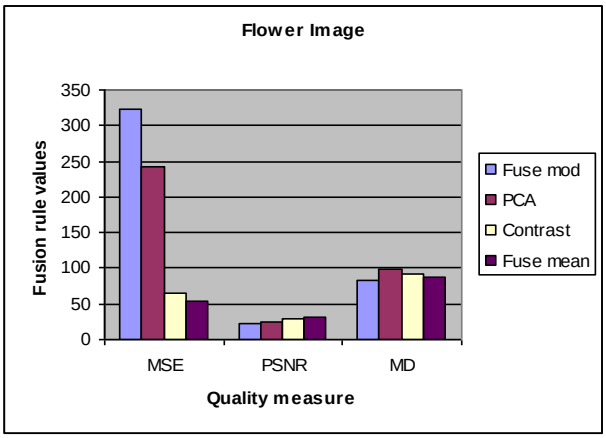

Fig. 10. Graph of table 6

B. Comparison with Other Schemes

From the tables of the previous section, The fusing of the images using curvelet and mean average fusion rule, we see that by applying the MSE for all the fusion rules the best MSE that give the low value which is the fusion mean, and for the PSNR the best value is the one that give the greater PSNR which is also fusion mean, but for the last one which is MD the best one is the one with the smaller value and it is the second one on this.

The below figures show the difference of the result of applying mean average and the wavelet for fusing the two images of the clock image.

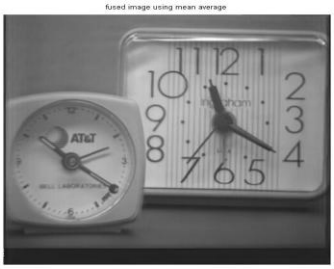

Fig. 11. Fusing using curvelet with mean average

Fig. 12. Result of fusing using wavelet

Contourlet Transform that is seen as a discrete form of a particular curvelet transform had been used as a tool for image de-noising and it had been shown that it a good tool for this.

Now comparing the GA and the contourlet for image de-noising and using the PSNR as a quality measure to get the one that is better we had been given that the best PSNR is for GA which gave 38.7426 and contourlet gave 33.5483 by these results as an example for applying it to the Clock picture Image A and gave 35.0965 by applying contourlet for clock picture Image B.

IV. Conclusion

In this paper we present a new approach by applying GA as a de-noising process, and showed that it is a much more benefit as a de-noising techniques than the other techniques that we used for comparison, and then used image fusion using curvelet transform using mean fusion rule as a much more good method for fusing than other fusion methods and rules and applied to two grey scale images.

V. Future Work

The future scope for this approach is using it with one grey scale image and one colored image and get the same result that is quite better than any others. And further future work we can use other datasets and analysis.

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