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Enhancement of Quality of Visible And Infrared Images Using Genetic Algorithm

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Abstract: In this paper, genetic algorithm has been investigated for the enhancement of the visible and infrared images. The algorithm was effective as the contents of the images became clear with the successive iterations. The algorithm was applied on the image for 200 random DNAs with successive iterations. The analysis of the results showed that the quality of images get enhanced with the successive iterations.

Keywords: Genetic Algorithm, Image Enhancement, DNA.

I. INTRODUCTION

Digital image processing possess their application in intelligent transportation systems such as automatic number plate recognition, traffic sign recognition, weather forecasting, and in medical field for diagnosis of diseases, satellite systems, remote areas , space research etc [1]. The high quality of an image is the prime requirement and is possible to obtain using image enhancement techniques. There is no such theory of image enhancement. It's a visual perception [2] [3]. Image enhancement is the method to enhance the quality of images in term of contrast, brightness and sharpness [4-7]. The main objective of image is to enhance the image so that the processed image is more suitable for a particular set of application. Most of the enhancement techniques [8][9] require manual adjustments of the parameters to obtain satisfactory results. In some applications, automatic adjustment of the parameters is desired and Genetic Algorithms [10] are best suited for these types of applications.

In this paper, the effect of genetic algorithm on the enhancement of quality of visible and infrared images has been investigated. Infrared Imaging has been discussed in Section II .The details of genetic algorithm have been presented in the Section III. The mathematical formulations used in the algorithm are presented in Section IV .The proposed work and the methodology adopted for the investigations are discussed in Section V. The experimentation and results are presented in Section VI. The paper is concluded in section VII..

II. IR IMAGING

IR refers to the region beyond the red end of the visible colour spectrum, a region located between the visible and the microwave regions of the electromagnetic spectrum.IR images are the source of information which is mainly used in night time applications, such as night vision driver assistance systems, military applications, surveillance systems etc.

Infrared image processing is a new field emerging for the evolution of night vision cameras. It also has applications in thermal medical imaging [11][12]. This evolution of night vision cameras has encouraged the research in infrared image enhancement for information extraction from these images. These images have a special nature of large black areas and small details due to the absence of the appropriate amount of light required for imaging. So, the main objective is to reinforce the details to get as much details as possible. The enhancement of infrared images is slightly different from traditional image enhancement in dealing with the large black areas and the small details.

III. GENETIC ALGORITHM

Genetic algorithm is a type of search algorithm that takes input and computes an output where multiple solutions might be taken. It is a mechanism based on natural selection and natural genetic. It works well in global search space.

A Genetic Algorithm provides the systematic random search. Genetic Algorithms provide a simple and almost generic method to solve complex optimization problems. It is a derivative-free and stochastic optimization method. A Genetic Algorithm needs less prior information about the problems to be solved than the conventional optimization schemes [27]. Basically in this algorithm the new child or chromosome obtained is made up of combination of features of their parents. So it can be applied on any image to get the new enhanced image which is much better than the original one that contains features of parents.

Genetic algorithms manipulate a population of potential solutions for the problem to be solved. Usually, each solution is coded as a binary string that is equivalent to the genetic material of individuals in nature. Each solution is associated with a fitness value which is used to rank a particular solution against all other solutions [24]. The

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various Genetic algorithm uses operators such as selection, crossover and mutation to get the next generation which may contain chromosomes providing better fitness [23].Selection determines which solutions are to be preserved and allowed to reproduce and which are deserve to die out. There are different techniques to implement selection in genetic algorithms. They are Tournament selection, Roulette wheel selection, Rank selection, Steady-State Selection, etc [20]. The crossover operator is used to create new solutions from the existing solutions available in the mating pool after applying selection operator [25]. The most popular crossover selects any two solutions strings randomly from the mating pool and some portion of the strings is exchanged between the strings. A probability of crossover is also introduced in order to give freedom to an individual solution string to determine whether the solution would go for crossover or not .Another operation, called mutation, leads to the introduction of new features in to the solution strings of the population pool to maintain diversity in the population [26].In this paper a genetic algorithm has been proposed for enhancing the infrared images.

IV. MATHEMATICAL FORMULATION

The mathematical framework for enhancing the images and the selection parameters are defined in [13][30].

A. Transformation Parameters Selection

The intensity I of the color image I_C can be determined by:

$$I(m,n) = 0.2989r(m,n) + 0.587(m,n) + 0.114b(m,n) \quad (1)$$

Where r, g, b are the red, green, and blue components of I_c, respectively and m and n are the row and column pixel locations respectively [26].Assuming I to be 8-bits per pixel, I_n is the normalized version of I, such that:

$$I_n(m.n) = \frac{I(m,n)}{255} \quad (2)$$

It has been studied that linear input-output intensity relationships doesn't produce a good visual in comparison to direct viewing of scene. The non-linear transformation for DRC is used which is based on the extraction of some information from the range histogram. I_n is mapped to I_n^{drc} using the following:

$$I_n^{drc} = \begin{cases} (I_n)^x + \alpha & 0 < x < 1 \\ \left(0.5 + (0.5I_n)^x\right) + \alpha & x \geq 1 \end{cases} \quad (3)$$

For $0 < x < 1$, the details in the dark regions are enhanced and for $x \geq 1$, the overshoots in the image are suppressed so as to make the content viewable for the observer.

The value of x is given by:

$$x = \begin{cases} 0.2, \; if\; (f(r_1 + r_2) \geq f(r_3 + r_4)) \Lambda (f(r_1) \geq f(r_2)) \\ 0.5, \; if\; (f(r_1 + r_2) \geq f(r_3 + r_4)) \Lambda (f(r_1) \geq f(r_2)) \\ 3.0, \; if\; (f(r_1 + r_2) \geq f(r_3 + r_4)) \Lambda (f(r_3) \geq f(r_4)) \\ 5.0, \; if\; (f(r_1 + r_2) \geq f(r_3 + r_4)) \Lambda (f(r_3) \geq f(r_4)) \end{cases} \quad (4)$$

Where $f(r)$ refers to number of pixels between the range $(r), f(a_1 + a_2) = f(a_1 + a_2)$ and Λ is the logical AND operator. α Is the offset parameter, helping to adjust the brightness of image.

B. Surround and Color Restoration Parameter Selection

Many local enhancement methods rely on center/surround ratios .Gaussian has been investigated as the optimal surround function. It has been investigated that Gaussian form produced good dynamic range compression over a range of space constants .The Luminance information of surrounding pixels is obtained by using 2D discrete spatial convolution with a Gaussian Kernel, $G(m,n)$ defined as:

$$G(m,n) = K \exp\left[\frac{-(m^2 + n^2)}{\sigma^2{}_s}\right] \quad (5)$$

Where σ_s is the surround space constant equal to the standard deviation of $G(m,n)$ and K is determined under the constant that $\sum_{m,n} G(m,n) = 1$ (1)

The center-surround contrast enhancement is defined as:

$$I_{enh}(m,n) = 255(I_n{}^{drc}(m,n))^{E(m,n)} \quad (6)$$

Where, $E(m,n)$ is given by: (2)

$$E(m,n) = \left[\frac{I_{filt}(m,n)}{I(m,n)}\right]^S \quad (7)$$

$$I_{filt}(m,n) = I(m,n) * G(m,n) \quad (8)$$

δ Is an adaptive enhancement parameter related to the global standard deviation of the input intensity image, $I(m,n)$ and $*$ is the convolution operator, $I(m,n)$ is defined by: (3)

$$S = \begin{cases} 3 & for\ \sigma \leq 7 \\ 1.5 & for\ 7 < \sigma \leq 20 \\ 1 & for\ \sigma \geq 20 \end{cases} \quad (9)$$

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σ is the contrast-standard deviation of the original intensity image, if $\sigma < 7$, the image has poor contrast and the contrast of the image will be increased. If $\sigma \geq 20$, the image has sufficient contrast and the contrast will not be changed. Finally, the enhanced image can be obtained by linear color restoration based on chromatic information contained in the original image as:

$$S_j(x,y) = I_{enh}(x,y)\frac{I_j(x,y)}{I(x,y)}\lambda_j \qquad (10)$$

C. Normalized Intensity Parameter

If μ_n be the normalized intensity parameter, then, for grey scale images, normalized intensity parameter can be evaluated as:

$$\mu_n = \begin{cases} \dfrac{\mu}{225} & for\ \mu < 154 \\ 1 - \dfrac{\mu}{225} & otherwise \end{cases} \qquad (11)$$

where μ is the mean brightness of the image. A region is considered to have adequate brightness for $0.4 \leq \mu \leq 0.6$ [13].

D. Normalized Contrast Parameter

The normalized contrast parameter (σ_n) can be given as:

$$\sigma_n = \begin{cases} \dfrac{\sigma}{225} & for\ \sigma < 154 \\ 1 - \dfrac{\sigma}{225} & otherwise \end{cases} \qquad (12)$$

(12)

where σ is the standard deviation. A region is considered to have enough contrast when $0.25 \leq \sigma_n \leq 0.5$, for $\sigma_n < 0.25$ the region has poor contrast and for $\sigma_n > 0.5$, the region has too much contrast [10].

E. Normalized Sharpness Parameter

Let S_n be normalized sharpness parameter given as:

$$S_n = \min(2.0, \frac{S}{100}) \qquad (13)$$

When $S_n > 0.8$, the region has sufficient sharpness.

Sharpness (S) is directly proportional to the high frequency content of an image and is given as,

$$S = \sqrt{\|h \otimes I\|^2} = \sqrt{\sum_{v_1=0}^{M_1-1}\sum_{v_2=0}^{M_2-1}\left|\hat{h}[v_1,v_2]\hat{I}[v_1,v_2]\right|}$$

Where h is a high pass filter obtained from the inverse discrete Fourier transform (IDFT) and $\hat{h}$ is its direct Discrete Fourier Transform (DFT). $\hat{I}$ is the DFT of Image *I*. The role of $\hat{h}$ (or *h*) is to weight the energy at the high frequencies relative to the low frequencies, thereby, emphasizing the contribution of the high frequencies to *S*. The larger the value of *S*, greater is the sharpness of *I*.

$$\text{Conversel h} = \text{IDFT}\left(1 - \exp\left(-\frac{v_1^2 + v_2^2}{\alpha^2}\right)\right) \qquad (15)$$

(11)

where v_1 and v_2 are the spatial parameters. Here, α is the attenuation parameter representing decaying of the impulse response of the Gaussian filter. A smaller value of α implies that fewer frequencies are attenuated and vice versa. The parameter I represents the given image.

F. Image Quality Factor

The parameters σ_n, μ_n and S_n are used for evaluating the image quality or quality factor (Q) defined as:

$$Q = 0.5\mu_n + \sigma_n + 0.1S_n \qquad (16)$$

where the value of Q lies between 0 and 1. The quality of an image expresses the hidden details in the image.

V. PROPOSED WORK AND METHODOLOGY

In this paper, an attempt has been made to enhance the quality of the visible and infrared images using the improved genetic algorithm so that they are better in visualization by the observer than the original images. The modified Continuous Genetic Algorithm is shown in Fig.2 in the form of a flow chart. Following steps have been performed to achieve this objective.

A. Capture the Images
B. Initializing the population
In this paper, an initial population of 10 random DNAs was generated. We have used continuous genetic algorithm in which real coding is used to represent a solution. The advantage of GA with real values is that they are more consistent, precise and faster in execution as compared to binary representations.

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In our research, each random DNA consists of 10 genes defined by $r_{1a}, r_{1b}, r_{2a}, r_{2b}, r_{3a}, r_{3b}, r_{4a}, r_{4b}, \alpha, y$. .Here, l_1 , l_2 , l_3 and l_4 are the differences between the sub ranges $r_{1a} - r_{1b}, r_{2a} - r_{2b}, r_{3a} - r_{3b}, r_{4a} - r_{4b}, \alpha, y$ respectively.l_1, l_2 , l_3 and l_4 are random lengths generated between ranges 20 to 150.The sum of l_1 , l_2 , l_3 and l_4 should not exceed 255.

Therefore, reduction factor is introduced with which the respective differences l_1 , l_2 , l_3 and l_4 are their multiplied. It is described as:

$$reduction\ \ factor = \frac{255}{\sum_{i=1}^{4} l_i} \tag{17}$$

The DNA is defined by parameters:

$r_{1a} = 0, r_{1b} = r_{1a} + l_1, r_{2a} = r_{1b} + 1, r_{2b} = r_{2a} + l_2,$

$r_{3a} = r_{2b} + 1, r_{3b} = r_{3a} + l_3, r_{4a} = r_{3b} + 1, r_{4b} = 255$

one value of α is taken from -1 to 1 with an auto increment of 0.1 and y is taken from -10 to 10 with an auto increment of 0.1.

C. Enhancement process using the respective DNA

Enhancement of the image for the individual DNA is carried out using the mathematical formulation given in equations (1-16).

The equation (4) is applied as the DNA parameters .The output of the enhancement process is an enhanced content of the image.

D. Calculate fitness function

The images are resized to 510 * 510 pixels and sub-images of 50 * 50 pixels were constructed.

The quality for each sub-image in calculation.

In our research, it has been investigated that the following fitness function (image quality) is a good choice for an objective criterion.

$$Q_n = \frac{\sum p_i}{(M-1)} \tag{18}$$

where, M is the total sub-images in the image, $\sum p_i$ is the total number of sub-images in the image with $Q > 0.55$ and Q is defined by equation (16).

E. Sort the fitness function in descending order

The fitness function obtained for the population of DNAs is sorted in descending order.

F. Obtain DNAs corresponding to sorted fitness function

The DNAs corresponding to the sorted fitness functions are obtained and are now these represent the DNA population to be used in further steps.

Here, the first DNA represents the best DNA corresponding to best parameter set as obtained by using the fitness function.

G. Enhancement process to display the best image corresponding to DNA1

All the mathematical formulations used in step 3 are repeated and the output is displayed.

H. Mating

Mate the first DNA with one random DNA "m" selected from positions 2 to 10.

The $string_1$ obtained from DNA_1 is represented as:

$$string_1 = [l_{1_1}, l_{2_1}, l_{3_1}, l_{4_1}, \alpha_1, y_1] \tag{19}$$

where $l_{1_1}, l_{2_1}, l_{3_1}$ and l_{4_1} are the differences between the sub- ranges and $string_2$ obtained from DNA_2 is represented as:

$$string_1 = [l_{1_m}, l_{2_m}, l_{3_m}, l_{4_m}, \alpha_m, y_m] \tag{20}$$

A random position for crossover between 1 and 5 is chosen. The DNAs are spliced and are represented as:

$$string_3 = [string_1(1:i), string_2(i+1:6)] \tag{21}$$

$$string_4 = [string_2(1:i), string_1(i+1:6)] \tag{22}$$

From $string_3$;

$$l_1 = string_{3(1)}, l_2 = string_{3(2)}, l_3 = string_{3(3)}, l_4 = string_{3(4)}, \alpha = string_{3(5)}, y = string_{3(6)} \tag{23}$$

Equation (15) is used and after that the respective differences l_1, l_2, l_3 and l_4 are multiplied with it.

The DNA is defined by parameters:

$r_{1a} = 0,$

$r_{1b} = r_{1a} + l_1, r_{2a} = r_{1b} + 1, r_{2b} = r_{2a} + l_2,$

$r_{3a} = r_{2b} + 1, r_{3b} = r_{3a} + l_3, r_{4a} = r_{3b} + 1, r_{4b} = 255$,

one value of α is taken from -1 to 1 with an auto increment of 0.1 and y is taken from -10 to 10 with an auto increment of 0.1.

Thus offspring 1st is reconstructed from $string_3$ .Similarly, offspring 2nd is reconstructed from $string_4$

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Place the DNAs of the new off springs in place of DNA_N and DNA_{N-1}

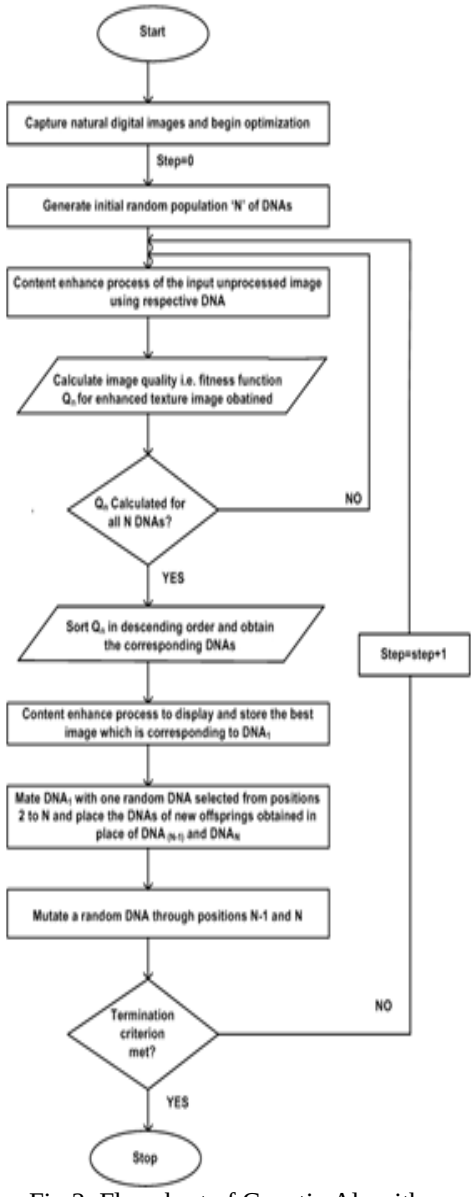

Fig 2: Flowchart of Genetic Algorithm

I. Mutation

Mutate a random DNA through position $N-1$ and N which contains the new offspring's DNA. The difference between the sub-ranges of the random DNA chosen is calculated to give the respective differences as:

$$l_1 = r_{1b} - r_{1a} \quad (24)$$

$$l_2 = r_{2b} - r_{2a} \quad (25)$$

$$l_3 = r_{3b} - r_{3a} \quad (26)$$

$$l_4 = r_{4b} - r_{4a} \quad (27)$$

The string is represented as:

$$string_5 = [l_1, l_2, l_3, l_4, \alpha, y] \quad (28)$$

Then a random gene from $string_5$ is selected and the change is introduced accordingly. The DNA is reconstructed using equation (17) by multiplying the respective differences l_1, l_2, l_3 and l_4 with it. The DNA is defined by $r_{1a} = 0, r_{1b} = r_{1a} + l_1, r_{2a} = r_{1b} + 1, r_{2b} = r_{2a} + l_2, r_{3a} = r_{2b} + 1, r_{4a} = r_{3b} + 1, r_{4b} = 255$ one value of α is taken from -1 to 1 with an auto increment of 0.1 and y is taken from -10 to 10 with an auto increment of 0.1

J. Go step 3 and repeat

The algorithm stops after a predetermined number if iterations. The algorithm repeats itself by going to step 3 unless and until the predetermined number of iterations to enhance the content of image are not over.

VI. EXPERIMENTATION AND RESULTS

VISIBLE IMAGE

Fig 3: Original Visible Image and Images at successive Iterations

Table1: Table depicting different DNA parameters And Quality at successive iterations

Iteration No.	Quality	DNA Parameters									
1	0	0	32	33	86	87	149	150	255	-0.8	-7.9
2	0.17	0	60	61	112	113	173	174	255	-0.8	-8
134	0.19	0	62	63	116	117	179	180	255	-0.6	-8
141	0.23	0	75	76	140	141	216	217	255	-0.6	-8.2
142	0.28	0	73	74	127	128	190	191	255	-0.6	-8.5
153	0.31	0	75	76	131	132	196	197	255	-0.6	-8.7
158	0.32	0	72	73	131	132	200	201	255	-0.6	-8.9
200	0.32	0	72	73	131	132	200	201	255	-0.6	-8.9

2.INFRA RED IMAGE

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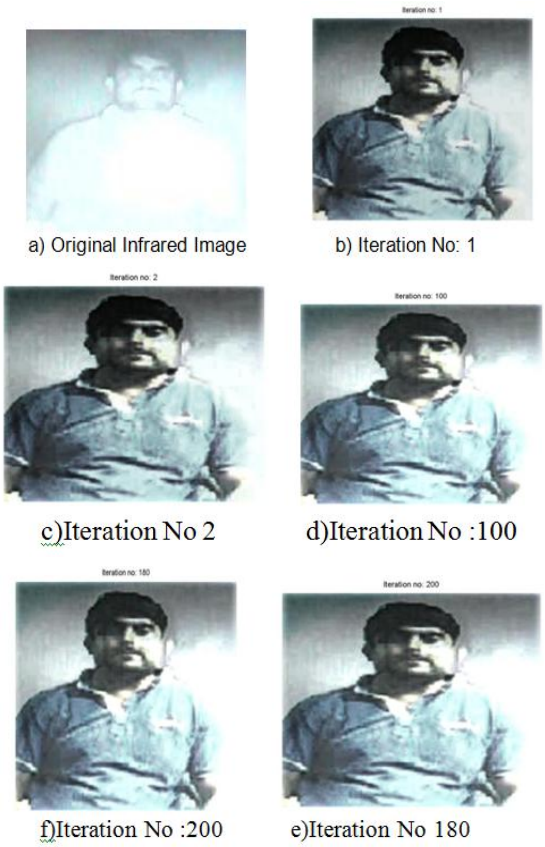

Fig 4: Original Infrared Image and Images at successive Iterations

Table2: Table depicting different DNA parameters And Quality at successive iteration

Iteration No.	Quality	DNA Parameters									
1	0.50	0	58	59	98	99	142	143	255	0.04	1
2	0.52	0	59	60	99	100	144	145	255	0.04	1
100	0.57	0	59	60	119	120	160	161	255	0.14	1
120	0.57	0	59	60	119	120	160	161	255	0.14	1
180	0.57	0	59	60	119	120	160	161	255	0.14	1
200	0.57	0	59	60	119	120	160	161	255	0.14	1

VII. CONCLUSION

In the present work, Image Enhancement is carried out by using an improved Genetic Algorithm. The classical image enhancement techniques like linear contrast stretching and histogram equalization suffer from the drawback that they treat the image globally for enhancement. Therefore, Genetic Algorithm which evolves the parameters of a local enhancement method that better adapts to the local contents in the image is used. The study presented here is a small part of the enhancement of visible and infrared images. In addition, other images like ultrasound, MRI, X-ray images etc. can also be taken and effects of iterations on various parameters of image can be studied. The proposed work can be further extended to remote sensing using the proposed Continuous Genetic Algorithm

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