Grayscale Digital Halftoning using Optimization Techniques

Submitted

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May 2015

Dedicated to my Family

DEPT. OF ELECTRONICS AND COMMUNICATION ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA – 769008, ODISHA, INDIA

Certificate

This is to certify that the work in the proposition entitled "Image Halftoning Using Optimization Techniques" by **Karnati Venkata Naga Lalitha** Bearing Roll Number **710ec4146** is a record of the original research work completed by her amid 2014 - 2015 under my supervision and direction in the partial fulfillment for Dual Degree in Electronics and Communication Engineering (Communication and Signal Processing), National Institute of Technology, Rourkela.

Place: NIT Rourkela

Date: 01-06-2015

Prof.A. K. Sahoo

NIT Rourkela

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I certify that

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Abstract

In this paper a complete outline of advanced Digital halftoning techniques is given. This paper explains halftoning from its definition, application of halftoning to different useful techniques which are improved to give a high signal to noise ratio image. Apart from signal to noise ratio another parameter which measures the similarity between two images is also shown in this paper. Additionally the drawback of each method and comparison of the SNR, and SSIM of all methods is also shown in this paper. Error diffusion technique using FS, Stucki and JJN filters is an efficient approach to halftoning. Its main drawback is that it undergoes linear distortion. This paper is completely describing the error diffusion method and the improvements made to error diffusion so as to get a well-defined and a visually pleasing halftone image. However an evolutionary algorithms called as particle swarm optimization and Genetic Algorithm are used to create filters for the image block wise and comparing with that of the image and then finally reconstructing the whole image. In these methods of PSO and GA the cost function is formulated based on the SSIM, average minority pixel distance and the string with the best cost function value is sorted using the Evolutionary algorithms. As the human eye acts as a spatial low pass filter the image which is to be halftoned is filtered through any visual model such as a HVS model and then undergoes through the process of evolutionary algorithms.

CHAPTER-1

INTRODUCTION

1.1 Introduction

In our advanced world, we are always presented to diverse pictures delivered by books, TV, magazines, notice daily papers, and so on. As a part of day by day life, pictures have developed into numerous profitable business attempts. Printing industry is one of the case. As of late huge financial forces is produced by printing industry organizations because of the expanding interest for amazing printing high constancy dark scale pictures, for example, photos , outline rendering craftsmanship, magazine format and so forth.

Digital halftoning [1] often refered to as "spatial dithering ", is a significant innovation utilized as a part of printing pictures. It is a methodology of making a binary estimate to an examined grayscale picture that makes the figment of a constant tone picture. At present, there are different strategies to halftone a picture. To accomplish great halftone picture, the customary methodology is to utilize a high determination printer . However these sorts of printers are regularly moderate and costly. In this manner the exploration of new halftoning systems which creates a vastly improved quality halftoning by utilizing low determination printers, has been a prevalent point in the previous three decades or somewhere in the vicinity.

1.2 Definition

Digital Halftoning [1] refers to a process where a continuous tone image of different graylevels is reduced to lesser number of graylevels most probably 0 and 1 so that when viewed from a distance the dots created by 1 on the paper blur and create an illusion of the continuous tone image.

1.3 How it Works

The grayscale advanced picture comprises of 256 gray level, however any highly contrasting printers can just have one hued ink. In this manner it is obliged to supplant the extensive variety of grayscale pixels for printers. The 256 gray levels ought to some way or another to be spoken to by simply putting the dark ink on the white paper. Halftoning is a representation method for an image for changing the continuous gray level image into a picture just comprising of ones and zeros. Such that a programming is given to the printer that if there is 1 shoot a dot on the paper else leave the corresponding place as zero.

As we know that the human visual system [2] has the spatial low pass filter property, human eyes along these lines can see patches of high contrast spot as a the normal dark when seen from huge separation. Our eyes can't be recognize the spots designs on the off chance that they are little. Rather, our eyes will incorporate the dark dots and non -printed regions as a changing shades of grey.

Since the human eyes have the low pass spatial-filter characteristics, human eyes see patches of high contrast checks as a normal gray when seen from adequately far away. Our eyes can't recognize the specks designs on the off chance that they are sufficiently little. Rather, our eyes coordinate the dark dots and the non-printed regions as fluctuating shades of dim. Zooming in a piece of the halftoning picture, we can see that the picture is really organized by a certain methodology of appropriated dark spots.

Figure 1: Original Lena image

Figure 2: Halftoned Image

Figure 3 : Zoomed view of Halftoned image

1.4 Motivation

A halftone picture is a picture contained discrete spots instead of persistent tones such that when seen from a far distance the dots smudge together making the deception of continuous tone pictures. By halftoning a picture it can be printed utilizing less ink. Consequently printers utilization halftoning to print pages all the more productively. Pictures experience a screen with holes. Amid the printing methodology, ink went through the holes in the screen, making spots on the paper. If there is a 1 then the printer will shoot a dot on the paper else nothing will be shot on the paper. However the more efficient method used is error diffusion. But error diffusion methods disadvantages such as linear distortion. To avoid those problems conventional methods such as modified error diffusion, adaptive threshold modulation are implemented. But these conventional methods does not show the difference between visual and printer models. So a model based halftoning which shows the difference is used called as Least square model based halftoning, Weighted least square halftoning etc., But these methods are also deterministic in nature not having the best quality nature. So a method called Particle swarm Optimization is implemented expecting to give a best quality image because its going through an evolutionary process. The implementation of PSO gives rise to another image quality measurement metric called as Structural similarity measurement index measure which is used to measure the similarity between two images.

1.5 Problem Statement

The Problem Statement of this paper is that to get a better halftone image with higher Visual to Signal Ratio and Structural Similarity Index Measure. To achieve this and to preserve the ink we need a high determination printer which is very rare and costly. So if we halftone an image before printing we can get a better image with a low determination printer itself. There are also some methods which were discovered such as Thresholding, Dithering and Error Diffusion.

But these previous methods used such Thresholding sometimes leads to a constant gray level in some images. Where as dithering leads to the periodicity that for a period of a sub image the pixel values may be same. Error Diffusion however is the Solution to periodicity caused by dithering. But even Error Diffusion has some disadvantages such as directional artifacts, sharpening and added additive noise. To get rid of this problem we replaced the standard quantizer with a adaptive quantizer. This reduces the drawbacks which are caused by the error diffusion but also have a drawback that they does not take into consideration the printer model and the human visual system model(HVS Model). To Avoid these Problems We got a Model based Halftoning method which uses both the printer model and the eye model. This Least squares Model based Halftoning Method is deterministic in nature which does not yield best halftones where as the halftoning method using evolutionary algorithms lead to a better image because they undergo a process of iterations.

1.6 Organization of Thesis

The Thesis Consists of six chapters as organized below

- Chapter 1.This chapter tells us why to use halftoning and how the techniques are used in our daily life. It also gives about the motivation about to start a project. It also gives the problem statement about which we are working on.
- Chapter 2. The 2nd Chapter named as halftoning shows us the different methods of halftoning which are already existing and the results of those methods such as Thresholding, Dithering, Error Diffusion and Dot error Diffusion. At last there is also table showing the PSNR values of all these methods.
- Chapter 3. The 3rd chapter named as Adaptive Threshold Modulation discusses the disadvantages of the error diffusion halftoning such as directional artifacts, nonlinear distortion and additive noise. To overcome these methods called as Conventional Error Diffusion, Edge Enhanced Error Diffusion, Green Noise Digital Halftoning are discussed and also the output images got through these methods are also shown. At last the table with all the PSNR values is also shown.
- Chapter 4. 4th chapter named as Model Based Halftoning exploits both the printer model and the eye model which has not been done in the adaptive threshold

modulation. Taking into account these models we got least squares model based halftoning, Modified Error Diffusion and Weighted Least Squares Model based Halftoning.

- Chapter 5. 5th chapter named as Halftoning using Evolutionary Algorithms uses evolutionary algorithms such as Particle Swarm Optimization(PSO) and Genetic Algorithm which are iterative techniques.
- Chapter 6. 6th chapter named as Results and Discussion discusses about the result obtained through all the methods and which one is the best one.

1.7 Conclusion

This chapter gave us about the introduction, motivation chapter wise description of what we have done in each chapter, Disadvantages of all the methods and why to choose an other method and their related Objective Evaluation Parameters.

CHAPTER -2

HALFTONING METHODS

2.1 Halftoning Methods

There are numerous methods in halftoning strategies. The calculation can be arranged into three classifications, in view of their computational quality . The main and one of the least difficult strategy is to work on every pixel separately, without considering neighbour. The second technique is district based strategy which measures every pixel utilizing an are of operation rather than the straight forward point for operation. The last strategy is an iterative technique. Not at all like the past two strategy , this iterative system typically work over the whole unique picture and iteratively attempt to minimize the delays or errors. On the other hand, the last kind of strategies are time requesting not withstanding for the pictures of little sizes. In this segment a brief presentation of some basic halftoning technique as an illustrative are shown.

The different kinds of halftoning techniques are

I. Constant thresholding
II. Dithering
III. Error diffusion

2.1.1 Constant Thresholding

Constant thresholding refers to the method where the image pixel is compared to a constant value and pixel which is greater than the threshold is given as 1 otherwise as 0.
The pseudo code for this method of halftoning is given as below

Start

For number of rows

For number of columns

If Original image >= Threshold

Then

New image=1

Else

New image =0

The image below shows the output got through following the thresholding method. The image used here is the lena image and the image first converted into double image so that the pixel values are between 0 and 1 and the thresholding value applied is 0.5

Figure 4: Halftoned image using Constant Thresholding

2.1.2 Dithering

In the constant thresholding technique a constant threshold id applied to the whole image. Opposing this method a method called as dithering is used where a thresholding matrix is created and the matrix is repeated over the whole image giving the thresholded image.

Dithering is also of two types

a) Clustered dot dithering
b) Dispersed dot dithering

Clustered Dot Dithering

In clustered dot dithering the matrix formed for dithering may be of different order such as 8x8 or 4x4 but the numbers in the matrix form a cluster. Such matrices for clustered dot dithering can be shown below.The given matrix can be repeated using the repmat and can be compared with the whole image.

14	10	11	15
9	3	0	4
8	2	1	5
13	7	6	12

Figure 5 : clustered dithering matrix of order 4

62	57	48	36	37	49	58	63
56	47	35	21	22	38	50	59
46	34	20	10	11	23	39	51
33	19	9	3	0	4	12	24
32	18	8	2	1	5	13	25
45	31	17	7	6	14	26	40
55	44	30	16	15	27	41	52
61	54	43	29	28	42	53	60

Figure 6 : clustered dithering matrix of order 8

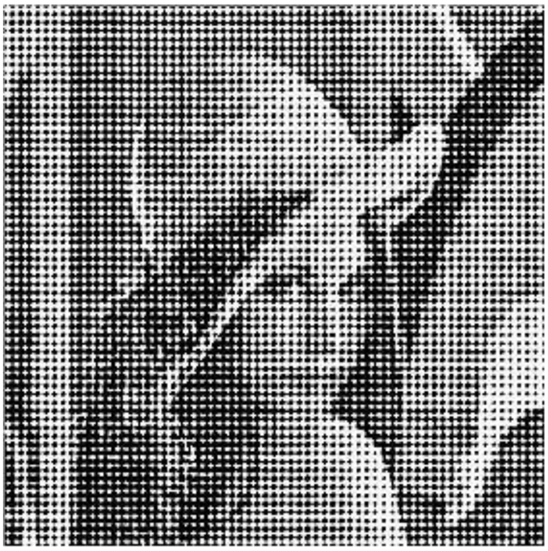
Threshold values are arranged to build a matrix kind of shape

a) Threshold matrix which is representing 65 graylevels.

b) Threshold matrix which is representing 16 graylevels.

Using repmat matlab function we repeat the dithering matrix through out the image and then apply thresholding

The final images after applying clustered dot dithering to lena images are shown below



(a)

(b)

Figure 7 : clustered dot dithered image using 2x2 and 8x8 matrix respectively

Dispersed Dot Dithering

In dispersed dot dithering the dithering matrix may be formed using the bayers optimum index matrix which can be recursively defined as

4*D+1	4*D+2
4*D+3	4*D

Where D is

1	2
3	0

Such matrices are shown below

5	9	6	10
13	1	14	2
7	11	4	8
15	3	12	0

Figure 8 : Dispersed dithered matrix of order 4

1	2
3	0

Figure 9 : Dispersed dithered matrix of order 2

The final images after applying dispersed dot dithering to lena images are shown below

(a) (b)

Figure 10 : Dispersed dithered image using 4x4 and 6x6 respectively

2.1.3 Error Diffusion

Error Diffusion is a sort of halftoning technique in which the thresholded error is distributed to the top, bottom, right and left pixels which are not been processed. Its principle utilization is to change over a gray level picture into a binary image, however it has different applications. Not at all like numerous other halftoning systems, error diffusion is named a range operation, on the grounds that what the calculation does at one area impacts what happens at different areas. This implies buffering is obliged, and complicates parallel processing. thresholding operations for example ordered dithering, don't have these complications. Error diffusion tends to enahncement of edges in an image. This can make the images more plesasing than that of the other halftoning techniques.

An error diffusion algorithm is characterized by the following steps:

1. Pick a specification of the pixels.

2. At every pixel area, add to the info I(i) a weighted normal of the previous errors in some area to acquire the modified input M(i).

3. Pick O(i) a component of V nearest to M(i).

4. calculate the error as e(i) as M(i)-O(i).

The easiest type of error diffusion can be

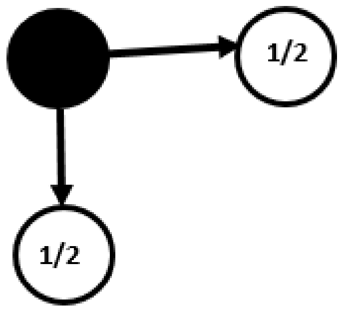


Figure 11 : Error distribution to the surrounding pixels

With the help of error diffusion 50% of the error from the current pixel is diffused to the pixel on the right and half to the pixel below. In a colour error diffusion method the diffusion should be appliied to the R G B planes separately. Another vital point to note here is that the aggregate sum of error diffused ought to never exceed an estimation of 1. Much of the time the aggregate sum of error diffused will be equal to 1 despite the fact that sum of error diffused is less than 1. It is likewise critical to guarantee that when a part of the error is diffused to neighboring pixels it doesn't bring about invalid qualities (e.g. go beneath 0 or over 255). If a value go outside of the substantial range then it is ought to be truncated (e.g. 10 future truncated to 0 and 260 eventual truncated to 255). The nature of this kind of error diffusion however is really poor and not very many individuals would really utilize it. A superior one, and the most popular one is Floyd-Steinberg error diffusion. This can be demonstrated as follows:

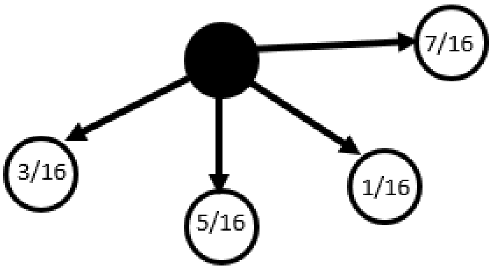


Figure 12 : Floyd and Steinberg Filter pixel distribution

The black dot filled with black colour represents the current pixel.With Floyd-Steinberg error diffusion the error is distributed amongst all the neighboring pixels giving a much more pleasant general dithering impact. The above figure also shows the FS distribution where the error is minimum because the error is diffused between all the pixels.

Other such types of filter such as stucki and JJN filter matrices are shown below

		X	8/42	4/42
2/42	4/42	8/42	4/42	2/42
1/42	2/42	4/42	2/42	1/42

(a)

		X	7/48	5/48
3/48	5/48	7/48	5/48	3/48
1/48	3/48	5/48	3/48	1/48

(b)

Figure 13 : Stucki Filter and JJN Filter Matrcies

Finally the block diagram of the error diffusion algorithm is shown below.

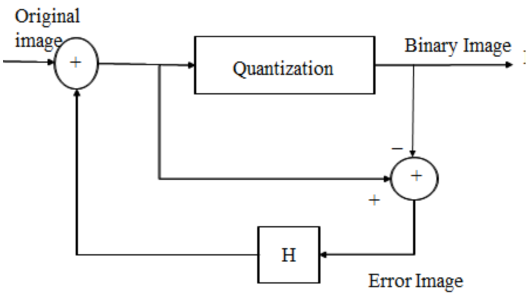


Figure 14 : Error diffusion Block Diagram

Where H is the hysteresis filter such as FS,Stucki,JJN Filter

The output images obtained after applying error diffusion to the lena image using FS filter,Stucki and JJN filter are shown below.

Figure 15 : Halftoned image using error diffusion

using

(a) FS filter , (b) Stucki , (c) JJN filter

We have introduced a straightforward and productive variable-coefficient errordiffusion calculation. It takes care of critical visual issues natural to the first Floyd-Steinberg calculation. In the meantime, it is speedier than most other error diffusion calculations, and it creates sharp, outwardly satisfying yield.

2.2 Dot Error Diffusion

The dot error diffusion[3] system for halftoning, spoke to by Knuth is an engaging method which tries to hold the immense highlights of error diffusion while offering liberal parallelism. Then again, shockingly, almost no work has been done on streamlining of the claimed class cross section. In this work we will exhibit that the class cross section that can further be streamlined by considering the properties of human visual framework model (HVS). The consequent halftones will by then be of the same quality concerning oversight spread . Since dot dispersion moreover offers extended parallelism, it now is by all accounts an engaging unmistakable choice for error diffusion. [3]

The equations used in the dot error diffusion are same as that of the error diffusion but the error which we get is distributed to the below and diagonal pixels with the help of the following equations shown.

$$xh(n1,n2) = \begin{cases} 1, & if\ x(n1,n2) \geq 0.5 \\ 0, & if\ x(n1,n2) < 0.5 \end{cases} \quad (1)$$

The error e is figured as e(n1,n2) = x(n1,n2) — xh(n1,n2). We then take a look at the eight neighboring pixels of (n1,n2) and substitute the contone pixel with a changed variant for those neighbors which is having a higher class number. In particular, the neighbours having the higher class numbers are replaced by the below formula

x(i,j) + 2*e(n1,n2)/w (for orthogonal neighbours)

x(i,j) + e(n1,n2)/w (for diagonal neighbours) (2)

where w is such that the whole of the weights added to all the neighbors is definitely e(n1 , n2). The extra variable of two for orthogonal neighbors (i.e., vertically and on a level plane abutting neighbors) is because vertically or equitably masterminded bumble illustrations are more unmistakable than the inclining examples.

The dot error diffused image shown below

Figure 16 : Dot Error diffused Image

The table showing the PSNR values for all the above methods is shown below.

Table 1 : Table showing the PSNR values for the above discussed methods

Method	PSNR (in dB)
Fixed Thresholding	5.735632
Random Thresholding	5.735732
Clustered(8)	5.749535
Clustered(2)	5.749423
Dispersed(4)	5.750976
Dispersed(6)	5.750521
Error Diffusion (FS)	6.777928
Error Diffusion (Stucki)	7.778144
Error Diffusion (JJN)	7.786565

Drawbacks

- Thresholding may be for some images may be continuous because some of the pixels may be always greater than a fixed value.
- Dithering is periodic in nature. The image got through the Dithering techniques are appearing to be periodic patterns.
- Error Diffusion on the other hand is not periodic but leads to disadvantages such as linear and nonlinear distortion, additive noise.

Summary

The various halftoning techniques which are previously available have been discussed in this chapter. The methods include Thresholding, Dithering, Error Diffusion. The improvement of Error Diffusion is Dot error Diffusion which is discussed above. The Drawbacks are also discussed and the next chapter shows the adaptive threshold modulation which reduces the drawbacks of error diffusion.

CHAPTER – 3

ADAPTIVE THRESHOLD MODULATION

3.1 Adaptive Threshold Modulation

Grayscale advanced image halftoning technique quantizes each and every pixel to one bit either 0 or 1. In error diffusion halftoning, the term quantization error [3] means that the difference between the original pixel value of the image and the quantized value at every pixel is shifted and fed back to the next pixel to spread the quantization error among all the neighbouring grayscale pixels. Threshold Modulation, which changes the quantizer data, has been already used to lessen either directional antiquities or straight mutilation. Error Diffusion leads to several disadvantages such as sharpening, added additive noise and nonlinear distortion . This paper displays a versatile limit regulation system to enhance halftone quality by upgrading error diffusion parameters at all least squares sense. The structure models the quantizer certainly, so a wide assortment of quantizers may be utilized. Taking into account the system, made us to give rise to the new methods of halftoning techniques called as 1) edge enhancement halftoning [3] and 2) green noise digital halftoning [3]. In edge enhancement halftoning, by taking control on the sharpening control parameter we minimize linear distortion. We might likewise separate directional antiques by supplanting a deterministic bit flipping (DBF) quantizer instead of a thresholding quantizer. For green noise halftoning, we try to upgrade the hysteresis coefficients by some parameter.

3.2 Conventional Error Diffusion

The conventional error diffusion [4] where the quantization is not constant as in error diffusion but it is adaptive in nature. It reduces the nonlinear distortion, linear distortion and additive noise. The block diagram of the Conventional error diffusion is shown below where the original image is passed through the quantization technique and the resulted output is added to the original image pixel values. The added values are then passed through the Hysteresis filter and then fed to the original image.

The block diagram of the conventional error diffusion block diagram is shown below

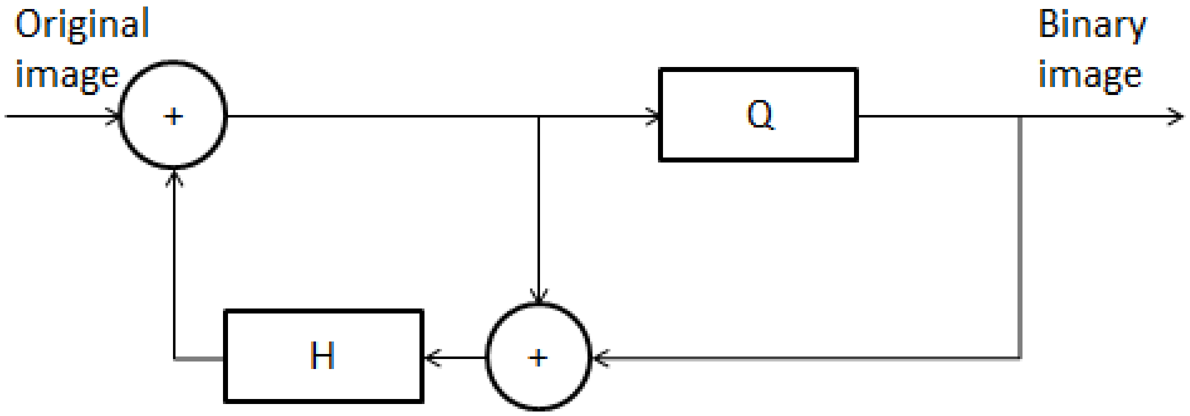


Figure 17 : Block Diagram of Conventional Error Diffusion

Where H is the hysteresis filter such as FS Filter ,Stucki Filter and JJN Filter.

3.3 Deterministic Bit Flipping

The deterministic bit flipping is almost same as that of the Thresholding in the upper value. Only the lower value becomes -1 instead of 0 as in Thresholding.

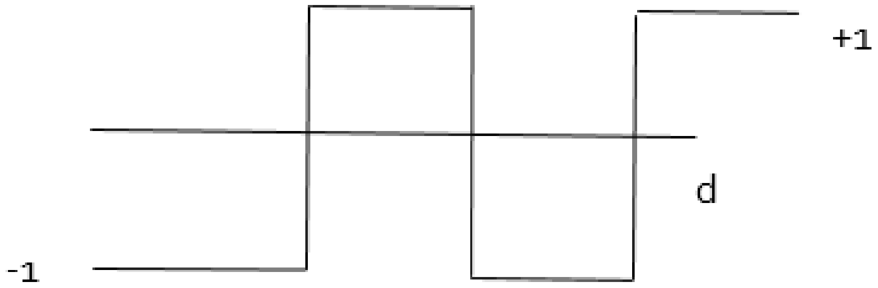


Figure 18 : The deterministic bit flipping method

The output image of the conventional error diffusion [4] method is below. The thresholding method used here is the Deterministic bit flipping.

Figure 19 : Output image using Conventional error Diffusion

The filter used here is the Floyd and Steinberg Filter

3.4 Edge Enhancement Halftoning

Edge enhancement [3] is an image processing filtering technique that enhances the edge contrast of an image or video which is used to improve its sharpness. The main disadvantage of the error diffusion is linear distortion. This method is used to reduce the linear distortion which is the drawback of the error diffusion. This method is implemented to reduce that drawback.

The block diagram of the edge enhancement halftoning is shown below

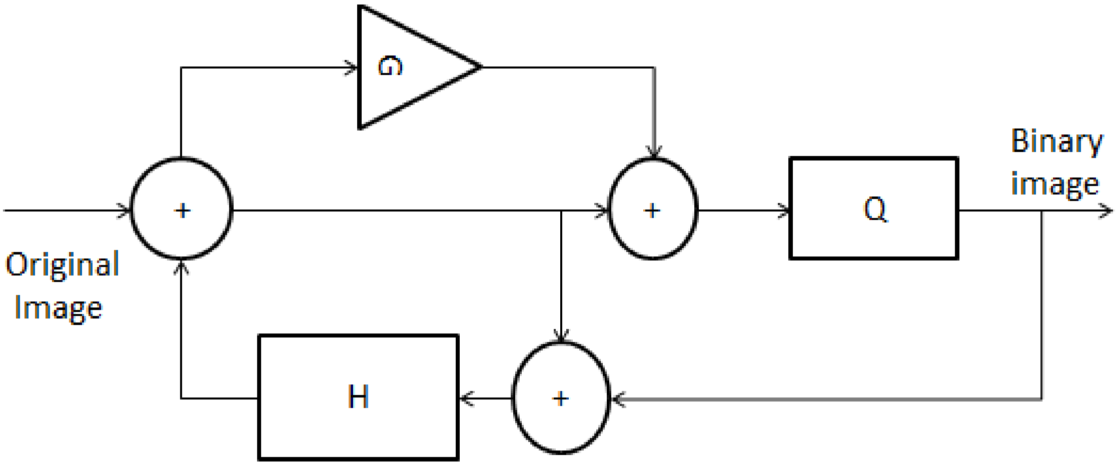


Figure 20 : Edge Enhancement Error Diffusion

Where G is some gain where G=0.5 for the experiment done and H is the hysteresis filter

In edge enhancement halftoning we modify the conventional error diffusion for adjusting the sharpness of the halftoning image. The threshold modulation here scales the image by a scaling factor 'G' and add the obtained result to the quantizer input. As G increases the sharpness of the resulting halftone increases. Small values of G can cause blurring of the image and the larger values can cause sharpening. Hence G can be used to reduce the linear distortion.

We develop the edge enhancement halftoning for the following cases such as

i. A fixed error filter which is finite in nature and a standard quantizer function and [3],
ii. An adaptive error filter which is finite and a standard quantizer function and [3] and
iii. A fixed error filter which is finite and a non standard quantizer function [3].

The output image which has been obtained using the edge enhanced error diffusion using deterministic bit flipping is shown below

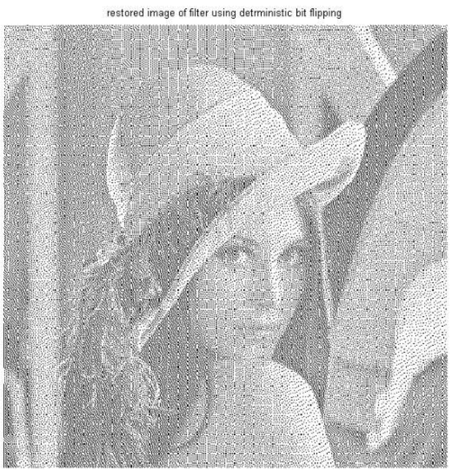


Figure 21 : Edge Enhanced Halftoned image using deterministic bit flipping

3.5 Green Noise Digital Halftoning

The Green Noise digital halftoning is the improvement of the Edge Enhancement error diffusion method where the Gain and the FIR filter is added to the quantizer input.

The block diagram of the Green noise digital halftoning is shown below

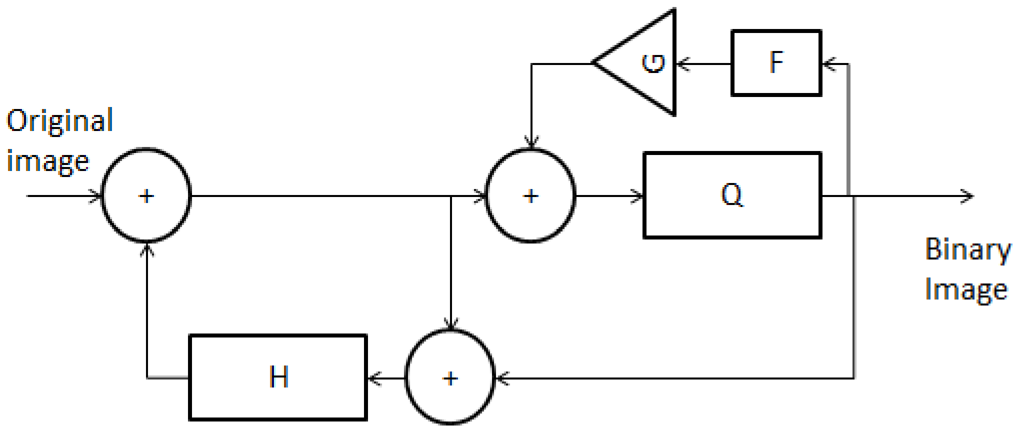


Figure 22 : Block diagram of green noise digital halftoning

Most generally the optimal value of G for the compensation of the sharpness depends on the factors

i. Error filter coefficients
ii. Quantizer function
iii. The input grayscale image

The image obtained through the green noise digital halftoning shown in the below figure

Figure 23 : Block diagram of green noise digital halftoning

The larger value of G gives the image more sharpening and the lesser value of G causes blurring of the image. So we have to select the proper value of G.

The impact of including a separated rendition of the yield of the quantizer info brings about bunching of yield pixels. Green clamour makes printing gadgets, for example, laser printers, much less demanding to anticipate. The advantages of green-noise digital halftoning are in printing procedures with nonideal printing conditions. The quantization clamor contains transitional recurrence between blue commotion examples and requested dither examples. They call it "green noise." The hysteresis consistent G controls the measure of the dab bunches in green clamour advanced halftones. We utilize the hypothesis grew in past ED to adjust the hysteresis channel coefficients. All calculations including the technique indicated in Fig 16 need to utilize serpentine examining to stay away from solid slanting relics.

Drawbacks

- Conventional Error Diffusion reduces the nonlinear distortion but does not show any improvement in the sharpening of the image.
- Edge Enhance Error Diffusion halftoning even though reduces the sharpening of the image it adds more additive noise to the image.
- Green noise digital halftoning only reduces the additive noise and leads to sharpening.

Summary

The Drawbacks of the various Adaptive threshold modulation techniques are shown above. These techniques does not take printer model and the eye model into consideration. The next chapter takes all the models into consideration and thus it is named as Model Based Halftoning.

CHAPTER-4

MODEL BASED HALFTONING

4.1 Model Based Halftoning

The Model Based Halftoning takes into account both the printer model and eye model into account. The block diagram of the model based halftoning is shown below where it is passed through a halftoner first and then printer model and then finally to the eye model.

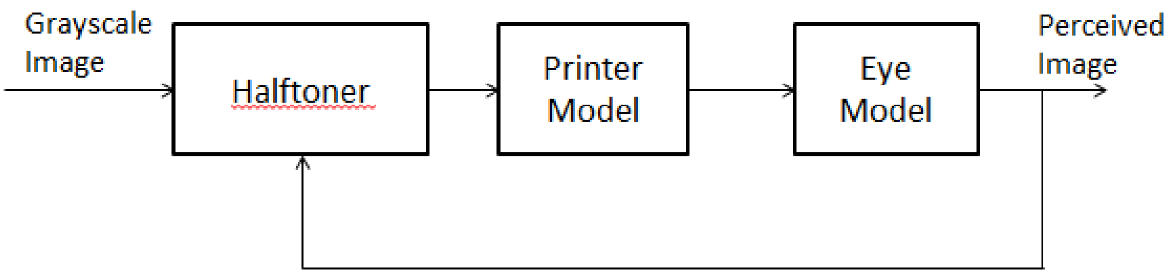


Figure 24 : Block diagram of model based Halftoning

The characteristics of the Human visual system model (HVS Model) and the printer model are discussed in the below sub chapters.

4.2 Human Visual System (HVS) Model

A human visual system model (HVS model) [5] is utilized in the fields of computer vision, image processing and video processing specialists to manage organic and psychological methodologies that are not yet completely caught on. Such a model is utilized to improve the practices of what is an extremely complex framework. As our insight into the genuine visual framework enhances, the model is upgraded.

Halftoning works on the background that the human eye that is the Human Visual System, shows the low-pass filter characteristics that blurs the dots to form a continous tone image . Such vision-model-based halftoning systems will be depicted later. In this segment, we depict a portion of the HVS models that they utilize.In spite of the fact that each halftoning strategy is in view of this comprehension of human vision, certain halftoning techniques make explicit utilization of a HVS model [6].

There are many number of researchers who have given their own particular numerical mathematical statement to model the human vision framework numerically. These model serves to plan such a gadget utilizing which we can enhances the nature of halftoning.

Some of these models which are used are shown in the table

Table 2 : Table showing the Contrast sensitivity function **[7]** of different HVS models

Author	Contrast Sensitivity function,H(p)	Constants
Campbell	$k(e^{-2\pi\alpha p} - e^{-2\pi\beta p})$	$\alpha = 0.012, \beta = 0.046$
Nasanen	$\exp(\frac{-p}{c\log L+D})$	c=0.525,d=0.391,L=11

These are the mathematical formulas which really gives the mask or screen . We pass the orignal image through these masks furthermore the halftoned picture and afterward contrast the after effect of both. According with the distinction we change the parameter in the halftoned picture to minimize the overall error in the image.

4.2 Printer Model

Laser printers are equipped for creating black spots on a bit of paper, more often than not on a rectangular framework [8]. On the other hand, most printers deliver generally circular dark spots. Accordingly, there is overlap between nearby spots, and dark dots spread adjoining space that ought to be white. This outcomes in signifcant distortion in the printed pictures. Most halftoning systems accept that the printed dark specks are square.

Conventional techniques for instance traditional screening, are genuinely hearty to printer twists to the expense of spatial and gray scale resolution. Then again, model-based systems misuse the qualities of every printer to build both gray scale and spatial resolution [9].

The printer model overlapping is shown below

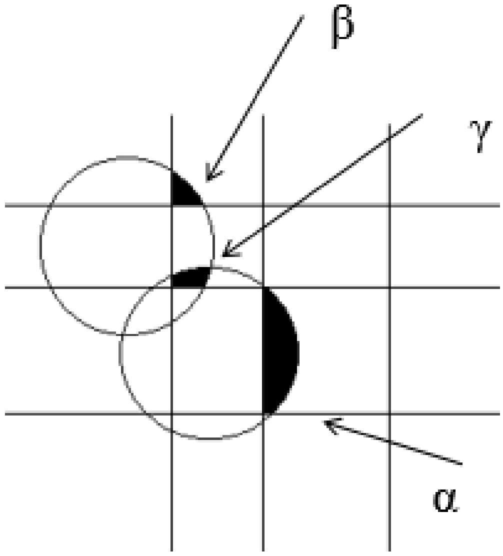


Figure 25 : Figure showing the dot overlap in printer model

The equations corresponding to the printer model are given as

$$P_{i,j} = P(W_{i,j}) = \begin{cases} 1 \text{ if } b_{i,j}=1 \text{ else} \\ (f_1 * \alpha) + (f_2 * \beta) - (f_3 * \gamma) \end{cases}$$

For HP Printer $\alpha = 0.33$, $\beta = 0.029$, $\gamma = 0.098$

4.3 Modified Error Diffusion

Stucki was the first to recommend utilizing a speck cover model to record for printer twists. Pappas and Neuho demonstrated that, by inserting a printer model into error diffusion [9] algorithm it is conceivable not just to right for the effects of printer distortion additionally to adventure them to deliver more dark levels. The error diffusion procedure produces more sharper pictures than conventional screening methods, yet it acts in a very sensitive manner when acted to printer consequences. We allude to the subsequent calculation as Modified error diffusion(MED) [9]. In it was demonstrated that while Stucki's calculation is more efficient computationally, the MED has better execution [9].

A block diagram of the Modified error diffusion is shown below

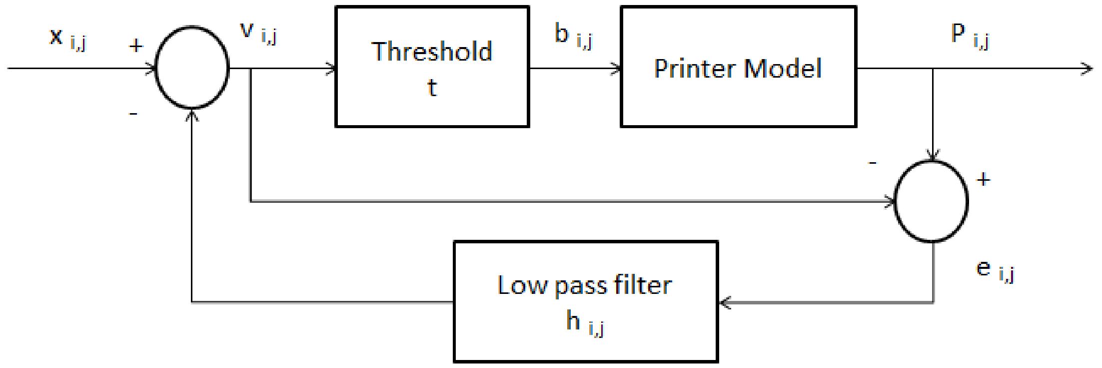


Figure 26 : Block Diagram Showing the MED

Where F is the Finite impulse response filter such as Low pass Gaussian or Low pass Butterworth Filter.The modified error diffusion is same as that of the error diffusion where instead of a hysteresis filter a finite impulse response filter is placed.

4.4 Least Squares Model

A least-squares problem can be termed as a problem with no constraints and an objective which is a sum of squares of the terms of the form $A_i^{\ T} x - b_i$.

A belongs to $R^{k \times n}$

The solution of a least-squares problem can be reduced to solving a set of linear equations

$$(A^TA)x = A^Tb$$

For minimum squares issues we have great calculations (and programming usage) for tackling the issue to high exactness, with high unwavering quality. The minimum squares issue can be settled in a period more or less relatively . A current desktop Computer can settle a minimum squares issue with many variables, and a great many terms, in no time flat; all the more intense PCs, obviously, can settle bigger issues, or the same size issues, quicker. Algorithms also, programming for comprehending minimum squares issues are sufficiently solid for inserted improvement

By and large we can explain significantly bigger minimum squares issues, by abusing some exceptional structure in the coefficient lattice A. Assume, for instance, that the network An is inadequate, which implies that it has far less than kxn nonzero passages. By misusing sparsity, we can more often than not unravel the slightest squares issue much speedier than request n^2k. A present desktop PC can fathom an inadequate minimum squares issue with a huge number of variables, and countless terms, in around a moment.

For to a great degree vast issues (say, with a large number of variables), or for issues with demanding constant processing necessities, fathoming a minimum squares issue can be a test. Anyway, in the greater part of cases, we can say that current techniques are extremely successful, and greatly dependable. For sure, we can say that illuminating minimum squares issues (that are not on the limit of what is at present achievable) is an (experienced) innovation, that can be dependably utilized by numerous individuals who do not know, and don't have to know, the subtle elements.

The next chapter shows the application of the least Squares based Optimization to the grayscale digital halftoning technique using the implementation of different models such as Human visual system model, Printer model etc., That’s why the name of the next chapter is also named as the model based halftoning because the error between the different models is minimized.

4.5 Least Square Model Based Halftoning

Least squares model based (LSMB) [11] halftoning where this strategy portrays both the contrast between the human visual system model and the printer model. It attempts to make a perfect halftoned which is a substitute for the error diffused image ideal in nature,by reducing the square of the error that is the Mean Square Error(MSE) between the output [9] of the course of the printer and visual models to the binary image and the output of the of the visual model to the first grayscale image. In this paper it is shown that the one-dimensional (1-D) least squares issue, in which each segment or area of the image is being halftoned automatically, can be realized using the Viterbi algorithm which only can take place in 1-D but not in 2-D. To get the comprehensive perfect course of action. yet, the because of the Viterbi algorithm can't be used in 2-D. In this paper, the two-dimensional (2-D) least squares arrangement is achieved through subsequent iterations where the error is fed back, which are simply guaranteed to make an area perfect. Trials exhibit that LSMB halftoning makes better halftone images with higher spatial and grayscale resolution comparing to all that of the conventional techniques. We moreover show that the implementation of the least squares system wipes out most of the drawbacks associated with the error diffusion technique. We investigate the execution of the LSMB counts more than an extent of audit partitions, or proportionately, printer resolutions. We also exhibit that the LSMB technique issues us correct control of picture sharpness.

The least squares model-based (LSMB) halftoning methodology endeavors to minimize the squared error between the ouput of the at a time implementation of the printer and visual models in light of the binary image and the yield of the visual model because of the gray scale picture [10]. The minimum squares methodology is noncasual in nature. That is, the choices anytime in the picture depend upon the "past" and additionally "future" choices but not as the casual systems. In standard error diffusion, the choices anytime in the picture rely on upon the "past" just. It is this nature that is the noncausality nature of the minimum squares approach that issues it the flexibility to make sharp moves and track edges better than already depicted methodologies.

The 2-D least-squares halftoning can be formulated by the equations as shown below

$$e = \sum \sum (zi,j - wi,j)^2 \qquad (3)$$

$$z_{i,j} = n(x_{i,j}) * h'_{i,j} \tag{4}$$

$$w_{i,j}=n(x_{i,j}) * h_{i,j} \tag{5}$$

we find the value of $b_{i,j}$ that minimizes the mean squared error

$$E= \sum (z_{k,l} - w_{k,l})^2 \tag{6}$$

Where x(i,j) is the original grayscale image

h(i,j) is the impulse response of the filter

b(i,j) is the binary approximation of the original image.

And '*' represents convolution

The boundary conditions for the image are given as

b(i,j) = 0 for i<1 and i>Nw ,j<1 and j>Nh

x(i,j) = 0 for i<1 and i>Nw ,j<1 and j>Nh

Nw is the number of pixels in horizontal row

Nh is the number of pixels in vertical row

these boundary conditions should be followed because the printer should take the values other than the rows and columns as zero.

Finally the block diagram of the LSMB halftoning which implements all the above equations is shown below

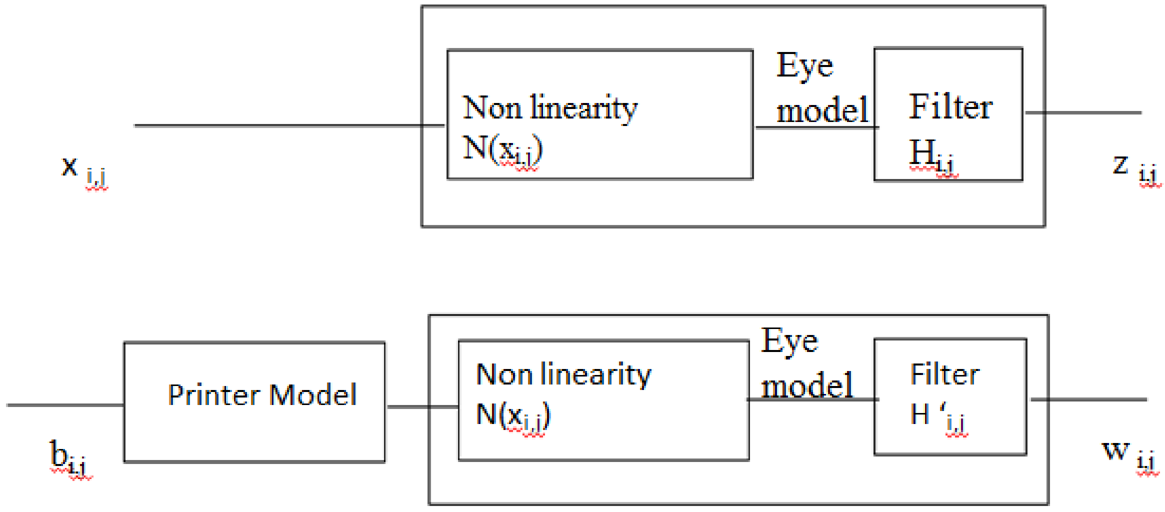


Figure 27 : Block diagram of the LSMB Halftoning

The parameters are same as described above.

The output images showing the LSMB halftoning are shown below. The filters used here are Gaussian and butterworth filters.

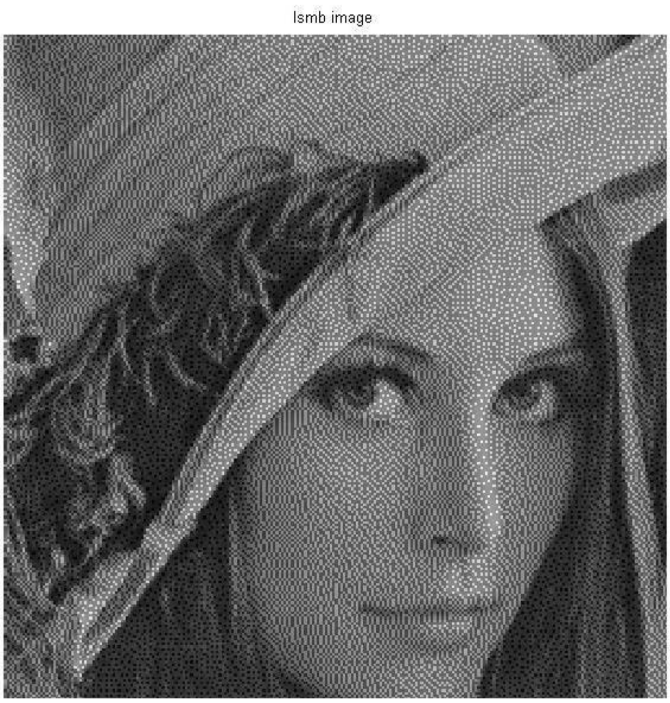


Figure 28 : LSMB Halfroned image using Gaussian filter of frequency 100 and FS Filter

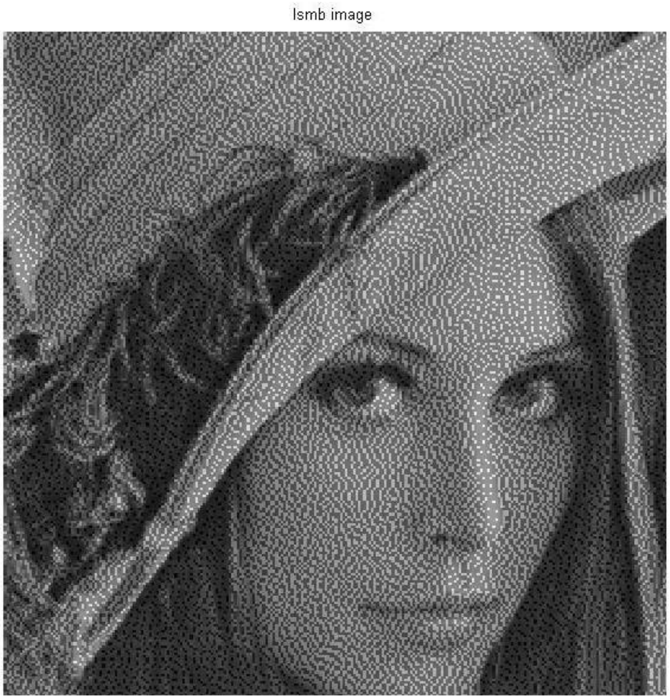


Figure 29 : LSMB Halfroned image using Gaussian filter of frequency 100 and JJN Filter

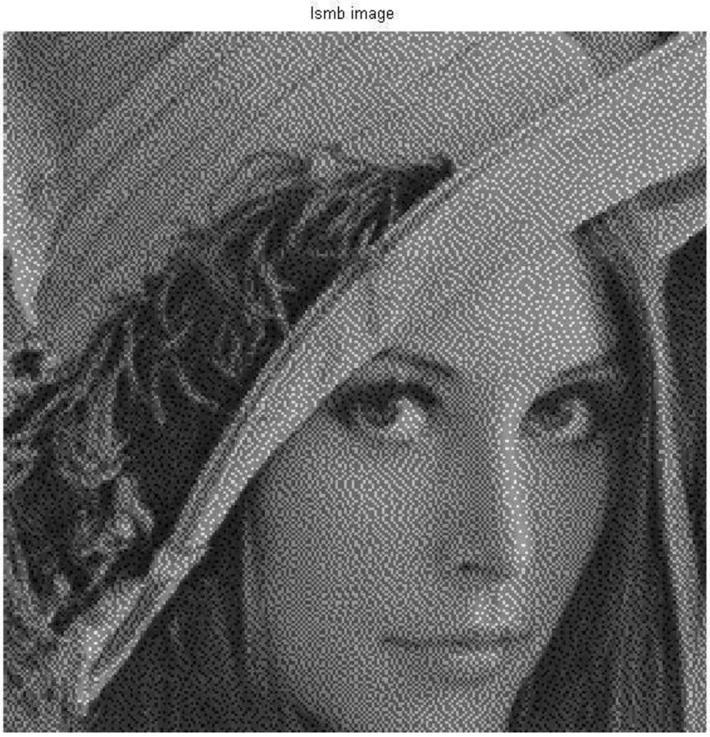


Figure 30 : LSMB Halftoned image using Gaussian filter of frequency 100 and Stucki Filter

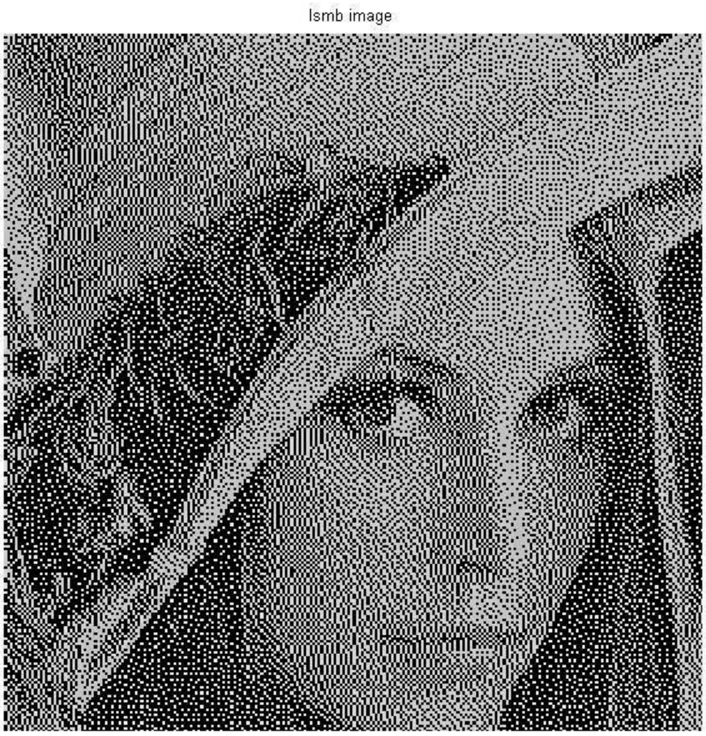


Figure 31 : LSMB Halftoned image using Gaussian filter of frequency 100 and butterworth filter of order 4 with FS Filter

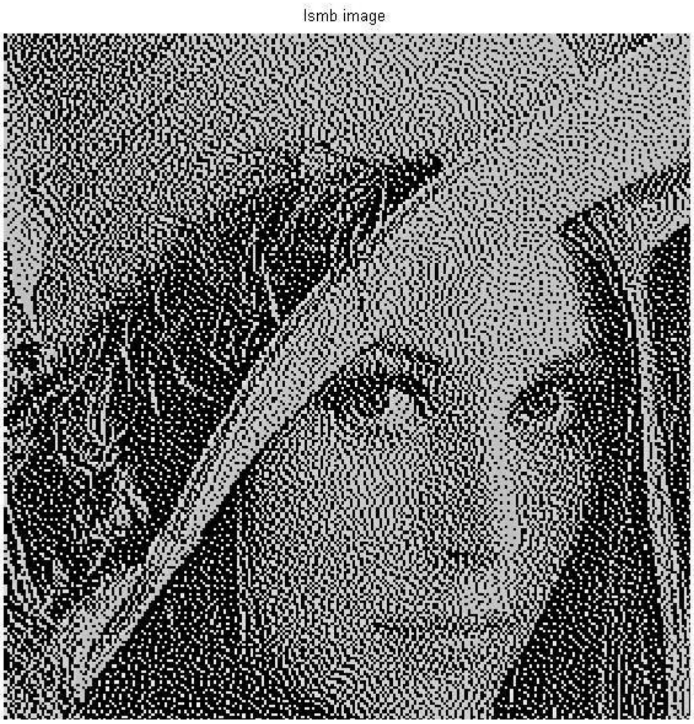


Figure 32 : LSMB Halftoned image using Gaussian filter of frequency 100 and butterworth filter of order 4 with JJN Filter

Figure 33 : LSMB Halftoned image using Gaussian filter of frequency 100 and butterworth filter of order 4 with Stucki Filter

Note that we have used two different filters with two different impulse responses for the eye channels relating to the ceaseless tone and halftone pictures. We found that when we don't filter the gray scale picture, the subsequent halftone pictures are more sharper than the previous ones [10].

Table 3 : Table showing the PSNR Values for LSMB

Method	Filter used(cut off frequency,order)	PSNR (in dB)
LSMB(FS Filter)	Gaussian (100)	11.357884
LSMB(Stucki Filter)	Gaussian (100)	11.356560

LSMB(JJN Filter)	Gaussian(100)	11.355995
LSMB(FS Filter)	Butterworth(100,4)	11.137186
LSMB(Stucki Filter)	Butterworth(100,4)	11.154804
LSMB(JJN Filter)	Butterworth(100,4)	11.161841

4.6 Weighted Least Squares Halftoning

We introduced another least squares model-based [10] methodology to advanced halftoning called as the weighted least squares method. It describes both a visual and a printer model to create an "ideal" halftoned image. The 2-D least squares arrangement is acquired by continuous iterations. Our examinations show that LSMB halftoning can deliver pictures with high dim scale and spatial determination and satisfying surfaces. We demonstrated that the visual nature of the subsequent halftone pictures relies on upon the beginning stage and the streamlining procedure. We considered the execution of the LSMB calculations over a scope of review separations. General the least squares model-based methodology offers a considerable change over ordinary halftoning procedures, furthermore takes out the issues connected with Error diffusion.

Weighted least squares model based Halftoning (WLS) [13] strategy is helpful for computing the estimations of model parameters when the reaction qualities having tremendous distinction in degrees of varieties over the blends of the anticipated qualities. Ideal results that will minimize the vulnerability in the parameter estimators are gotten when the weights used to gauge the estimations of the obscure parameters are contrarily corresponding to the differences at every mix of the indicator variable qualities [13] . The mathematical statements relating to the weighted least squares are demonstrated as follows.

Let f [m,n] be the continuous-tone image and f (x,y) be the haltoning of this continuous-tone image by the printer. Let g[m,n] =0 or 1 represent the halftone image. Then, the following equations hold for all the conditions [11]. In this chapter we develop the relationship between the Human vision system(HVS) or the printer model and the halftoning algorithm.

$$g (x , y) = \sum g [m, n] p (x - mX , y - nY) \quad (7)$$

$$f (x , y) = \sum f [m, n] p (x - mX , y - nY) \quad (8)$$

$$p(x, y) = rect(x / X , y / Y) \quad (10)$$

The goal of least-squares halftoning is to find the optimal halftone image which minimizes the total squared error.

$$E_{x,y} = \sum (g_{x,y} - f_{x,y})^2 \quad (11)$$

Weighted least squares (WLS) [13] relapse is valuable for assessing the estimations of the model parameters when the reaction qualities have varying degrees of variability over the combinations of the indicator values. Ideal results that minimize the vulnerability in weights used to gauge the estimations of the obscure parameters are conversely relative to the fluctuations at every mix of indicator variable.

In the proposed approach, we will get the halftone image that reduces the weighted squared error [12]

$$E_{x,y} = \lambda_k \sum (g_{x,y} - f_{x,y})^2 \quad (12)$$

The output images got through the WLSMB halftoning are shown below

Figure 34 : WLSMB Halftoned image using FS Filter and Gaussian FIR Filter of frequency 100

Figure 35 : WLSMB Halftoned image using JJN Filter and Gaussian FIR Filter of frequency 100

Figure 36 : WLSMB Halftoned image using Stucki Filter and Gaussian FIR Filter of frequency 100

Figure 37 : WLSMB Halftoned image using Stucki Filter and Gaussian FIR Filter of frequency 100,butterworth filter of order 4

Figure 38 : WLSMB Halftoned image using JJN Filter and Gaussian FIR Filter of frequency 100,butterworth filter of order 4

Figure 39 : WLSMB Halftoned image using Stucki Filter and Gaussian FIR Filter of frequency 100,butterworth filter of order 4

The Table showing the PSNR Values of the WLSMB Haftoning is shown

Table 4 : Table showing the PSNR values for WLSMB halftoning

Method	Filter Used(cutoff frequency,order)	PSNR (in dB)
WLSMB(FS Filter)	Gaussian (100)	12.570160
WLSMB(Stucki Filter)	Gaussian(100)	12.436827
WLSMB(JJN Filter)	Gaussian(100)	12.364745
WLSMB(FS Filter)	Butterworth(100,4)	12.969933
WLSMB(Stucki Filter)	Butterworth(100,4)	12.988819
WLSMB(JJN Filter)	Butterworth(100,4)	12.792683

A detailed analysis on the proposed calculation was exhibited. Examination results demonstrate that the proposed calculation creates better dim scale halftone picture quality when we expand the quantity of grouping, specifically subtle elements of the picture. Reproduction comes about additionally exhibited that the proposed calculation attains to reliably lower estimations of MSE than the LSMB calculation. As the bunch part expands, the estimation of MSE reductions. What's more, the proposed calculation attains to reliably higher estimations of PSNR than the LSMB calculation. As the bunch parcel builds, the estimation of PSNR abatements.

The proposed calculation can further diminish the quantity of emphases. The principle substance of cells in gravure barrel are concentrate picture highlight esteem and sorting. We view the machine vision as the hypothetical premise for making the sorting arrangement of cells in gravure chamber. Firstly, the phones pictures are picked up in the pictures catching gadget.

Drawbacks

Least Squares Model based Halftoning even though takes into account the printer model and visual model into consideration is deterministic in nature and does not give a better halftone image.

Summary

Least Squares Model based Halftoning and weighted least squares model halftoning even though takes into account the printer model and visual model into consideration is deterministic in nature and does not give a better halftone image. That’s why iterative techniques involving the evolutionary algorithms are taken into account thinking that we get a pleasing halftone image of high PSNR and Structural Similarity Index Measure(SSIM).

CHAPTER - 5

HALFTONING USING EVOLUTINARY ALGORITHMS

5.1 Evolutionary Algorithms

In neural networks or artificial intelligence an evolutionary algorithm (EA) is a subset of evolutionary processing, a non specific population based metaheuristic optimization algorithm. An EA utilizes systems motivated by natural evolution, for example, multiplication, transformation, recombination, and determination. Hopeful answers for the optimization issue assume the part of people in a populace, and the wellness capacity decides the nature of the arrangements. Evolution of the populace then happens after the rehashed use of the above administrators. Artificial evolution (AE) depicts a methodology including individual evolutionary algorithms; EAs are singular segments that take part in an Artificial Evolution.

Systems from evolutionary algorithms connected to the demonstrating of natural evolution are by and large restricted to investigations of micro evolutionary methodologies and arranging models based upon cell forms.

Steps in the Implementation of the Biological Processes

1. Generate the initial random population called as individuals. This is the first generation of the process
2. Evaluate the fitness value of all individuals
3. Repeat the below steps until specific iterations and time limit.
    - Amongst the population of the individuals select the best individual with best fitness value.
    - Breed these selected individuals using mutation and cross over operations to give birth to new individuals
    - Evaluate the fitness value for the above individuals
    - If the fitness value of the new individuals are better than the previous one, replace the previous population individuals.

Such algoithms used in this work are

- Particle Swarm Optimization
- Genetic Algorithm

5.2 Particle Swarm Optimization

In software engineering, particle swarm optimization (PSO) is a computational strategy that upgrades an issue by its iterative nature attempting to enhance an applicant arrangement with respect to a given measure of value. PSO advances an issue by having a populace of competitor arrangements, here named particles, and moving these particular particles around in the empty space as per straightforward numerical formulae over the particle's known position and known speed. Each particle's development is affected by its nearby best known position but at the same time, is guided toward the best known positions in the inquiry space, which are overhauled as better positions are found by different particles. This is required to move the swarm toward the best arrangements.

The velocity diagram of the particle swarm optimization shown below

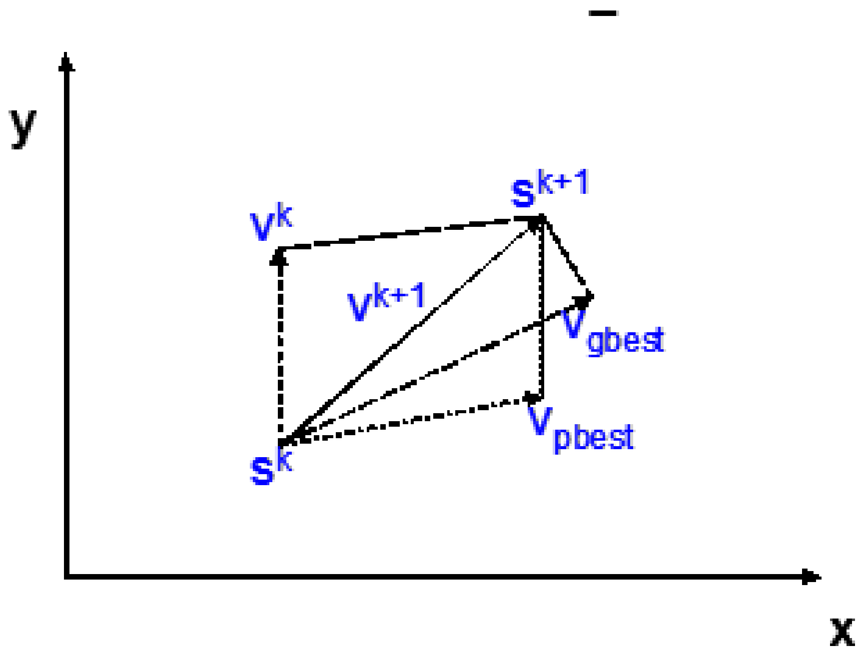


Figure 40 : Velocity update diagram of PSO

Where s^k : current searching point.

s^{k+1}: modified searching point.

v^k: current velocity.

v^{k+1}: modified velocity.

v_{pbest} : velocity based on pbest.

v_{gbest} : velocity based on gbest

Each particle will try to modify its position using the following information :

- The particles current position ,
- The particles current velocity,
- the distance between the pbest(personal best),and the current position.
- the distance between the gbest(global best) and the current position.

The modification of the particle's position can be mathematically modeled according the following equations :

$$\mathbf{V_i^{k+1} = \mathit{w}V_i^k + c_1 * rand_1 * x\ (pbest_i - s_i^k) + c_2 * rand_2 * x\ (gbest - s_i^k)} \qquad (13)$$

$$\mathbf{s_i^{k+1} = s_i^k + V_i^{k+1}} \qquad (14)$$

where, v_i^k : velocity of particle i at iteration k,

w : weighting function, (default 0.95)

c_j : weighting factor, (default 2)

rand : random number between 0 and 1,

s_i^k : current position of particle i at iteration k,

$pbest_i$: pbest of particle i,

gbest : gbest of the group.

The flowchart of the Particle Swarm Optimization is Shown below

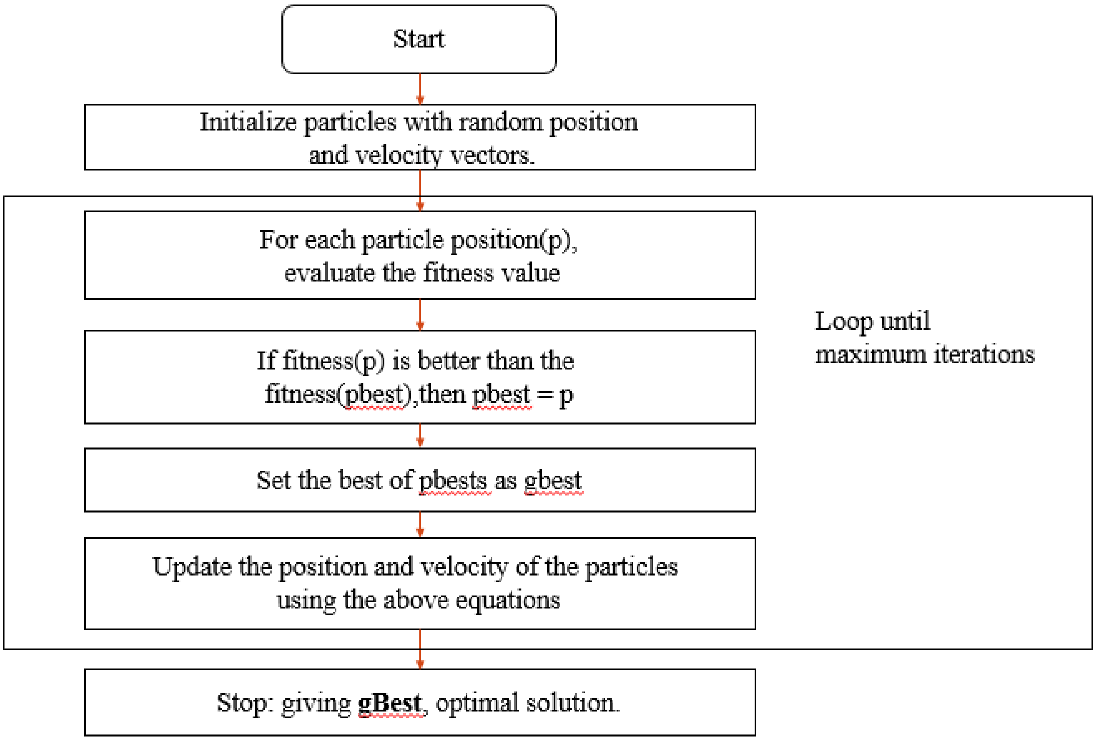


Figure 41 : Flow Chart Of Particle Swarm Optimization

Application of Particle Swarm Optimization To Halftoning

Particle swarm optimization used in the haftoning in the way as described. The image is divided into sub blocks such that we are got to solve a 2-D problem. Generate a random population in the dimension of the image. Calculate the fitness value of the random population. Update the velocity and position of each particle using above equations and at the new position calculate the fitness value. If the calculated fitness value is better than that of the previous one mark it as ‘pbest’ and the best of all the pbest is called as ‘gbest’. Such that we got the improved 2-D block which can be used as the filter for the sub block of the original image.

5.3 Genetic Algorithm

In the field of artificial intelligence, a genetic algorithm (GA) is an inquiry heuristic that impersonates the procedure of characteristic choice. This heuristic (likewise in some cases called a metaheuristic) is routinely used to create valuable answers for enhancement and inquiry problems. Genetic algorithms have a place with the bigger class of developmental algorithms (EA), which produce answers for advancement issues utilizing methods motivated by regular development, for example, legacy, transformation, determination, and hybrid.

Outline of the Genetic Algorithm

1. Generate a random population of n chromosomes which are the individuals and when totally taken is called as population
2. Evaluate the fitness value for all the individuals.
3. Create the new population using the following steps until specific iterations and time limt
    - Based on the fitness value of the total population available select two chromosomes with higher fitness values. This is called as selection.
    - Crossover the two chromosomes to give rise to the newer off springs. This is called as the crossover operation
    - Mutate a new off spring according to the higher probability. This is called as mutation.
    - Place new off spring in the population creating new population. This is called as accepting.
4. Use the generated population as the new population
5. If all the conditions are satisfied end the loop
6. Go to Step 2.

Application of Genetic algorithm to Halftoning

Application for halftoning of genetic algorithm is nothing but we are dividing the image into sub images and we are creating filter for each sub image. For example if we give take the block size as 8 and divide the image into sub image of size 8x8 . we are creating the filters for the gray levels of 0-63 and compare the image sub block with the 8x8 block we get.

5.4 Halftoning using PSO

Cost Function Formulation

For the application of the PSO to the Halftoning we have to first formulate a cost function which is to be minimized or maximized according to the problem. The Halftoning of the grayscale image relies on 2 facts importantly they are Structural Silarity index measure (SSIM) and the Average Minority Pixel Distance (AMD) [13] [14] .

The below are the things related to the cost function formulation

$$SSIM_{gh} = \frac{(2\mu g\mu h+c1)(2\sigma_g \sigma_h+c_2)(\sigma gh+c3)}{(\mu g2+\mu h2+c1)(\sigma g2+\sigma h2+c2)(\sigma g \sigma h+c3)} \quad (15)$$

Where μg= local average pixel intensity in g [13]

μh= local average pixel intensity in h [13]

σ_g=local standard deviation of the matrix in g [13]

σ_h=local standard deviation of the matrix in h [13]

σ_{gh}=cross correlation function between g and h [13]

The SSIM is the measure used to measure the similarity between two images based on structure similarity and the contrast similarity etc., The SSIM measures from 1 and -1 and the maximum value of that is 1 [13]. Thus the cost function formulated using SSIM is

$$\Phi_1=1-SSIM_{gh} \quad (16)$$

The cost function 2 is formulated using the average minority pixel distance

$$\Phi_2 =\left(\frac{Ddes - Damd}{Ddes} \right)^2 \quad (17)$$

where des is the desired distance

The complete cost function formulated is [13]

$$\Phi=w_1\Phi_1+w_2\Phi_2 \quad (18)$$

where w_1 and w_2 are the weighting functions usually $w_1 + w_2 =1$ [13].

Steps in Performing Halftoning

The Halftoned image was achieved through minimizing the cost funtion Φ ascertained by the above comparison .The first dark scale pictures of size p x q are filtered with HVS channel which was examined above and the separated grayscale pictures I were divided into s x s blocks .Individual squares which are acquired are subjected to PSO Optimization . In a solitary run s^2 pixels are Halftoned [16] .

The progressions of producing Optimized halftones utilizing PSO can be abridged as takes after:

Step1: Filtering through HVS channel

Step2 : Dividing The picture into squares.

Step3 : Specifying the parameters of PSO.

Step4 : Generation of Initial Random population and assessment of expense capacity to gauge fitness .Searching at the region of individual answers for indicated number of cycles to discover arrangements with higher wellness contrasted with the current [16] .

Step5 : Finding nearby best and worldwide best arrangements toward the end of every emphasis.

Step6 : Declaring the worldwide best arrangement toward the end of emphasess and recreating the whole picture once halftone for all the picture blocks are produced.

In this Paper the block size picked was 8 x 8

Intial population of size 30 and 300 iterations are taken

5.5 Halftoning Using Genetic Algorithm

Genetic Algorithm is an evolutionary computation technique which is based on natural selection in which the cost function is minimized using the biological terms such as production, calculation, reproduction, cross over and mutation.

In this method of halftoning using genetic algorithm [15] the cost function is formulated and minimized of maximized using the genetic algorithm. In this method the spatial and gray level resolutions of the images are calculated and the calculated function is optimized using Genetic Algorithm. First Generate the random strings which are to be minimized or maximized. After that Calculate the fitness values of the strings . Generate the off springs using the initial population using cross over operator and mutation. Then

Calculate fitness values of the new individuals . If the fitness values of the offsprings are better than that of the older ones replace the older ones with the newer ones. Repeat the procedure for many iterations until the limit is reached.

The flow chart of the genetic algorithm is given below

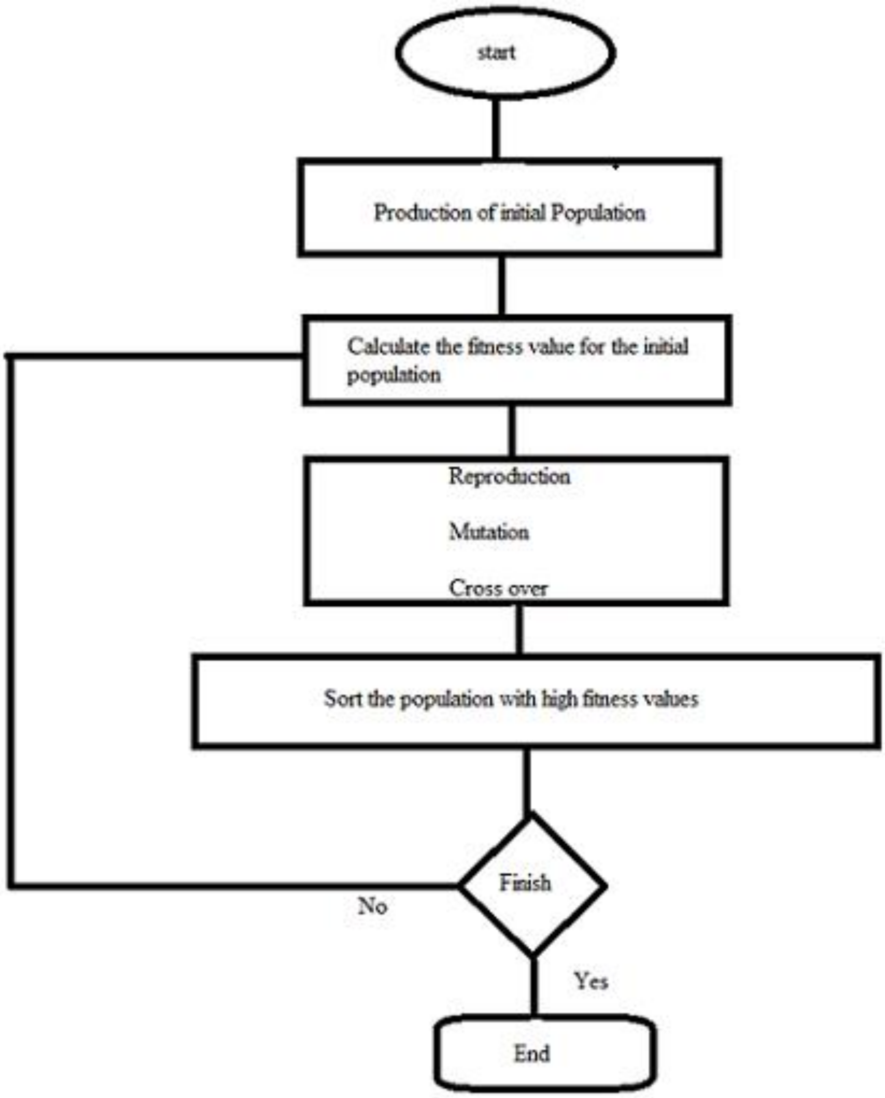


Figure 42 : Flow chart of Genetic Algorithm

Steps in Performing Halftoning using Genetic algorithm

A cost function is formulated using the following equations

The First evaluation function E_m is defined as [15]

$$E_m = (1/s) \sum g(i,j) – b_g(i,j) \quad (19)$$

Where b_g (i,j) is the Gaussian filtered binary image

g(i,j) is the original image

s is the product of the number of rows and columns

The second evaluation function is defined as [15]

$$E_c = (1/s) \sum (g(i,j)+(M/2) – g_s(i,j) – b(i,j)) \quad (20)$$

M is the number of rows

gs(i,j) is the smoothened image of the original image

b(i,j) is the binary image.

The combined cost function is

$$E_t = w_m E_m + w_c E_c \quad (21)$$

Where w_m and w_c are the weighting functions

The fitness value of the cost function is formulated is calculated using the function

$$F = E_f – E_t \quad (22)$$

Where E_f is the number associated with the E_t value for the worst string

Step 1: Divide the image into overlapping blocks of 5 x 5 and filtered using the Gaussian filter and smoothing filter

Step 2: The fitness value is calculated using the above function.

Step 3: The genetic algorithm is used to sort the greater value using genetic algorithm

Step 4: Calculate the MSE values by generating the difference of the original image block and the generated matrix.

Step 5: Sort the MSE values in Decreasing order.

Step 6: Then remove the last half lower values and replace them with the upper half values.

Step 7: Repeat the procedure for many iterations for all the blocks.

Step 8: Reconstruct the whole image

Drawbacks

- These evolutionary algorithms are iterative in nature consumes more time.
- We may not get the result as wanted by taking the less iterations.
- The Results when run at different times may be different because of the random initial population taken.

Summary

This is the algorithm which gave the higher PSNR value and high similarity index measure. However improvements can be made in these also by combining the two methods. This is shown in the results and discussion chapter and also the future work has also been discussed in the following chapters.

CHAPTER – 6

RESULTS AND ANALYSIS

6.1 Results and Analysis

The results obtained using different halftoning techniques are shown in the above figures. The final result in which we have used evolutionary computation techniques such as Particle Swarm Optimization and Genetic Algorithm we get a better halftoned image with high PSNR and SSIM than the previous adapted techniques. Here for all the research work we have used Lena image which is of size 512 X 512 in size . For PSO the block size chosen was 8 X 8 and the intial particles chosen in number are 30. The process ran for around 300 iterations.

The final image obtained using PSO is Shown below in Figure 6.1

Figure 43 : Halftoned Image using PSO

The image obtained using the genetic Algorithm is shown in the below **Figure**

Figure 44 : Halftoned Image using Genetic Algorithm

The evaluation of the image comparison metrics is also done using the parameters called as PSNR and SSIM. The Evaluation of these parameters for different methods employed for halftoning are shown in the **Table 5** and **Table 6.**

Table 5 : Objective Evaluation of PSNR (in dB)

Technique	MED	LSMB	PSO	Genetic Algorithm
Lena	7.712	11.7685	13.3593	13.1552

Table 6 : Objective Evaluation of SSIM

Technique	MED	LSMB	PSO	Genetic Algorithm
Lena	0.9867	0.9959	0.9967	0.9961

Summary

The above Results show that the image obtained by the method of PSO is having high PSNR and SSIM close to one when compared to other deterministic techniques. The Evolutionary Algorithms on the other hand give best quality images because the error minimization goes through an evolutionary process until it becomes zero.

CHAPTER – 7

CONCLUSION AND FUTURE WORK

7.1 Conclusion

The methods which we have employed for the halftoning technique without using the evolutionary processes are deterministic in nature that they are undergoing a constant thresholding for comparison. This does not give us better quality images. As shown in the previous Tables in the evaluation of comparison metrics we came to know that they doesn't give a best quality image where as by employing the Evolutionary process we get best quality images. Here the Evolutionary processes also involved the cost function which is the measurement of PSNR and SSIM . In Genetic algorithm we have formulated a cost function by the conditions that local mean gray levels are closer to the gray levels in the original image and the the contrats for human vision.The major drawback of the Evolutionary process is that as it is going through an evolutionary process it is time consuming of more iterations . Even Genetic algorithm has a drawback of more time consuming nature.

7.2 Future Work

The Conclusion shows that employing evolutionary algorithms even though they are time consuming can give us better quality Halftone images . The cost function employed here is based on the average minority pixel distance and the Contrast sensitivity. The future work includes the below Improvements

- The cost function formulation using other metrics such as parameters related to sharpness, edge enhancement etc., This methods can be further used to halftone colour images.
- The Combination of the techniques such as Particle swarm optimization and Genetic algorithm may be employed to get a pleasing halftoned image.
- The Halftoned image using PSO shows so many block artifacts, So a method improving this is to be implemented.

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