Development Of Digital Half toning Techniques For Grayscale Image

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MASTER OF TECHNOLGY

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Dedicated to…,

My parents , Priyanka , Abhishek & Archana……

Abstract

In this paper a complete overview of digital halftoning is given. This paper concludes all about haftoning from its definition to different methods which is used to achieve it. Also drawback of each method is given in this paper. How a new method is better than previous one it is also explained theoretically and mathematically. Floyd & Steinberg's error diffusion technique is a well-known approach to digital halftoning. Its main drawback is that it is inherently serial. This paper is briefly discussing about the method and a complete process to achieve error diffusion and thus to achieve halftoning. 'Any model which is designed for the human visual system (HVS) is an important component of many halftoning algorithms. Also by using the iterative direct binary search (DBS) algorithm, we have compared the halftone texture quality which is provided by the four HVS models'. We design filter for the four different HVS model and tried to compare these models. Using the different HVS model we have calculated the MSE and thus got the best HVS model.

DEPT. OF ELECTRONICS AND COMMUNICATION ENGINEERING

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Certificate

This is to certify that the work in the thesis entitled ***Development Of Digital Half toning Techniques For Grayscale Image*** by ***Avinash Giri*** is a record of an original research work carried out by him during 2013 - 2014 under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of Master of Technology in Electronics and Communication Engineering (Communication and Networks), National Institute of Technology, Rourkela. Neither this thesis nor any part of it, to the best of my knowledge, has been submitted for any degree or diploma elsewhere.

Place: NIT Rourkela

Date: 26th May 2014

Prof A. K. Sahoo

Nit Rourkela

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I certify that

a) The work contained in the thesis is original and has been done by myself under the general supervision of my supervisor.

b) The work has not been submitted to any other Institute for any degree or diploma.

c) I have followed the guidelines provided by the Institute in writing the thesis.

d) Whenever I have used materials (data, theoretical analysis, and text) from other sources, I have given due credit to them by citing them in the text of the thesis and giving their details in the references.

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Avinash Giri

26th May 2014

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At last but not the least I am in debt to my father Mr. Kailash Giri and my mother Mrs. Ambika Giri to support me regularly during my hard times.

AVINASH GIRI

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CHAPTER 1

Introduction

Introduction

In our modern world, we are constantly exposed to different images produced by books, television, magazines, poster newspapers, etc. As a part of daily life, images have evolved into many valuable commercial endeavours. Printing industry is one of the case. In recent years enormous economic powers is generated by printing industry businesses due to the increasing demand for high quality printing high fidelity gray scale images such as photographs , design rendering art work, magazine layout etc.

Digital halftoning reffered to as " spatial dithering ", is a major technology used in printing images. In general , it is a process of creating a binary approximation to a sampled gray scale image that create the illusion of a continuous ton image. Currently, there are various method to halftone an image. To achieve high quality halftone image ,the conventional approach is to use a high resolution printer . However these kinds of printers are often slow and expensive. Therefore the research of new halftoning techniques which produces a much better quality halftoning by using low resolution standards printers, has been a popular topic in the past three decades or so [1].

Task of the project is to implement an algorithm, which must be fast and printed image must look good based on human visual perception.

Motivation

Halftone is necessary in the production of the photographic images. This is because most printing press are not able to print continuous tone , therefore photographic images must be first converted into a series of dots in order to get effective printing. Halftone can be generated electronically by using digital data. With the growing interests in the field computer vision, active vision, researcher have been concerned with the mechanism of attention. This is why, a number of visual attention computational model, inspired by Human Vision System (HVS), have been developed. These model aim to detect regions of interest in image. In recent decade, psychologists, neurobiologists and engineers have investigated visual attention and their cooperation has been resulted in considerable benefits. However, the interdisciplinary of the subject has not only benefit but also difficulties, since the concepts of different field are often difficult to access due to difference in vocabulary and lack of knowledge of the relevant literature. The purpose of this paper is to bring together concept and ideas from these different research area. It provides an extensive survey of biological research on HVS and the state-of-art on computational models of visual attention .The methods are presented which depend on their classification: computational, biological plausible or hybrid. A discussion on the interdisciplinary knowledge of HVS is also included.

CHAPTER 2

Halftoning

Introduction

In many of the image rendering technologies we have output in the binary format only. For example, any printer can either " fire a dot " or not. Basically halftoning is a method that is used for creating the illusion of a continuous tone output with any binary device [6].

Any effective digital halftoning technique can be substantially improves the quality of rendered image at minimum cost.

Definition

"Halftone is the reprographic technique that simulates continuous tone imagery through the use of dots, varying either in size, in shape or in spacing, thus generating a gradient like effect [1]".

How it works

The grayscale digital image consists of 256 gray level, but any black and white printers can only have one coloured ink. Therefore it is required to replace the wide range of grayscale pixels for printers. The 256 levels of the gray should somehow to be represented by just placing the black ink on the white paper. Halftoning is a representation techniques for the transformation of the original continuous tone digital image into binary image only of 1's and 0's consisting.

Meaning of these two values are as follows:-

1 » Fire a dot in current position

0 » Keep the corresponding position empty.

As we know that the human eyes have the low pass filter property, human eyes thus can perceive patches of black and white spot as some kind of the average gray when viewed from large distance. Our eyes cannot be distinguish the dots patterns if they are very small. Instead, our eyes will integrate the black dots and non -printed areas as a varying shades of grey[2].

(a) (b) (c)

Figure 1: Effect of halftoning

(a) Original image; (b) Halftoned image ; (c) An enlargement of (b)

Figure 1(b) shows a typical halftoning image and if we zoom in a part of the halftoning image, we can see that the image is actually structured by certain strategy of distributed black dots.

Halftoning Method

There are many in number of advanced halftoning methods. The algorithm can be categorized into three categories, based on their computational complexity [2]. The first and one of the simplest method is to operate on each pixel individually, without taking into account neighbour. The second method is region based method which quantifies each pixel using a neighbourhood operation instead of the simple point wise operation. The last method is an iterative method. Unlike the previous two method , this iterative method normally operate over the entire original image and iteratively try to minimize the errors. However, the last type of methods are time demanding even for the images of small sizes. In this section a brief introduction of some common halftoning method as representative of the above mentioned types of techniques.

1) Constant threshold halftoning

2) Ordered dithering

3) Block replacement

4) Error diffusion

Constant threshold halftoning

The constant threshold halftoning method is the simplest and straightforward halftoning method. We can understand it by taking following data into consideration. Assume that the image falls in the range of 0 to 255. Where 255 represent black and 0 represent white as:

255 ⟶ black

0 ⟶ white

Let I={(i, j),i, j= 1,2,3,4,……..255} describe the pixel position in the image . The pixel values at the position (i, j) in I is compared with some already chosen threshold value T. If it is bigger or equal to the threshold value than 1 is set at the corresponding position in the halftoning image i.e the printers fires ink and if it is less than threshold value than 0 is set there i.e the printer does nothing. It can be illustrated by following table.

INPUT: image I, threshold T= 127

OUTPUT: halftoned image H

For each pixel (i ,j) in I , set H(i,j)= $\begin{cases} 1 & if\ I(i,j) \geq T; \\ 0 & if\ I(i,j) < T. \end{cases}$

Figure 2: The threshold algorithm

This table shows how the method works and image below represents the result got by using this method.

Figure 3: Halftoning image by constant threshold algorithm

It is obvious by analysing the image after constant threshold halftoned is that the result is not satisfactory. It produces a poor rendering of a continuous toned image, losing most of the details.

Ordered Dithering

Ordered dithering is an techniques that provides a fixed patterns of number to indicate the order of the turning pixels on within a selected screen before thresholding to binary.[3]. In this method the threshold matrix which is also called screen , is tiled over the image using periodic replication. The pixel value at each position in I is threshold by the threshold matrix T. It can be more understand by following figure[4].

INPUT: Image I, threshold matrix T of size R*C

OUTPUT: Halftone image H

For each pixel (i,j) in I , set H(i,j)= { $\begin{matrix} 1 & if\ I(i,j) \geq T(i\ mod\ R, j\ mod\ C); \\ 0 & otherwise \end{matrix}$ }

Figure 4: The dithering algorithm

According to the arrangement of the threshold values, the ordered dithering techniques are mainy divided into two groups[4],

1) Clustered dot dithering and
2) Dispersed dot dithering.

1) Clustered dot dithering

In clustered dot dithering the consecutive threshold values are located in spatial proximity. For a constant threshold halftoning patch, this method turns pixel on that are adjacent to one another ,and thus forming a cluster. Thus the final halftoning dots will be clustered in the centre of each screen. The final halftoned image using two different threshold matrices as shown in figure 5 are shown in figure 6. As on comparing the two images in figure 6, the larger threshold matrix has worst resolution. The clustered dot dithering method requires a trade-off between number of the gray level and the resolution. Because of the dot centered criterion and the limited gray levels, final halftoning image has poor details rendition and obvious countouring artifacts.

Whereas on the other hand , there is no additive spot overlap. This method efficiently decreases the effects that the ink spread to neighboring pixel.

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

(a)

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

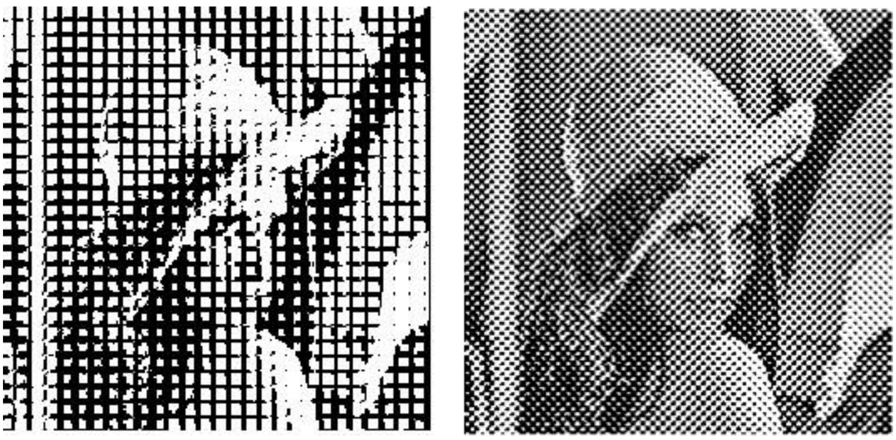
(b)

Figure 5 : Two threshold matrices

Threshold values are arranged to build a spiral kind of shape.

(a) Threshold value are representing 65 levels of gray.

(b) Threshold values are showing 17 level of gray.



(a) *(b)*

Figure 6: Halftoned image by clustered dot ordered dithering

Fig 6:-. (a), the threshold matrix shown in figure 5(a) is used . In (b), the threshold matrix shown in figure 5(b) is used.

Properties of Clustered Dot Screens

• Requires a trade-off between variety of grey levels and resolution.

• Relatively visible texture

• Relatively poor detail rendition

• Uniform texture across entire grey scale.

• Robust performance with non-ideal output devices

1) Non – additive spot overlap
2) Spot to spot variability
3) Noise

2) Dispersed dot dithering

In the dispersed dot dithering method, threshold matrices are arranged in such a way that the value of threshold grow separately. In the figure 7 example of an 8*8 matrix has been shown.

This turns pixels on one by one while not grouping them into cluster, thus build the ultimate halftone dots disperse in every screen. Figure eight shows the halftoning pictures ensuing from the brink matrix shown in Figure seven. The four × four case doesn't look a lot of totally different from the eight × eight case. There is no need for considering the trade – off between the number of gray levels and the resolution. As compared to the clustered dot dithering , this method shows improved details rendition.

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

(a)

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

(b)

Figure 7: Two threshold matrix .

In (a) threshold values are representing 65 levels of gray. In (b) threshold values are representing 17 levels of gray.

Dispersed dot dithering yields better amplitude quantization for larger area and maintains good details presentation within smaller area. Also there is no trade- off between resolution and number of grey levels.

Properties of dispersed Dot Screens:-

• Eliminate the trade-off between range of grey levels and backbone.

• Within any region containing K dots, the K thresholds ought to be distributed as uniformly as potential.

• Textures wont to represent individual grey levels have low visibility.

• Improved detail rendition.

• Transitions between textures adore completely different grey levels could also be a lot of visible.

• Not strong to non-ideal output devices

– needs stable formation of isolated single dots.

Block Replacement

Block replacement halftoning is commonly used halftoning technique. In this technique each pixel in the original picture is replaced by one of a predetermined sets of binary patterns . The dimensions of the patterns is determined by screen frequency and the print resolutions. [5]. To make it simple ,assume that each pixel is going to be replaced by 2*2 matrix. As the dimensions of matrix is 2*2 therefore only five different gray levels can be represented by the set of matrices, as it is shown in figure.

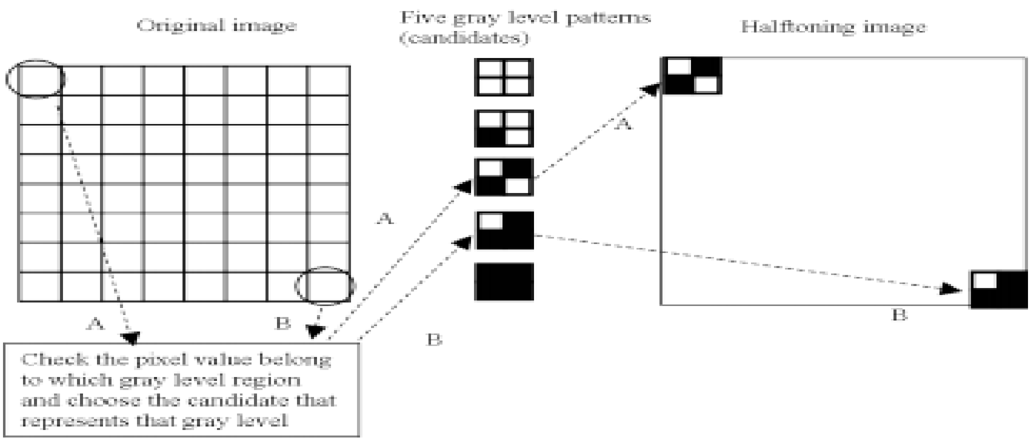


Figure 8 : Block replacement halftone

The pixel belong to one of the 5 grey level regions is replaced by the corresponding already known candidate. Fig 8 shows how this method works. In this illustration only the representation of the first and last pixels are shown and the same is done for the rest of the image. In figure 9 it is clear that the left one is image halftoned by a 2 by 2 block replacement and the right one is image halftoned by 3 by 3 block replacement.

As 3*3 block replacement can represent ten different grey level. On comparing the two image (a) and (b).We see that the 3 *3 block replacement can keep more details than 2*2 replacement, which represent the bigger number of grey levels, i.e. higher resolution.

Figure 9: Halftone images by block replacement

In (a.), the candidates are 2 x 2, hence five levels of grey. In (.b), the candidates are 3 x 3. hence 10 levels of gray.

In distinction to the ordered video digitizing technique, the arrangement of the black small dots within the patterns doesn't have essentially to be clustered or to be distributed. Due to the low-pass abstraction frequency property of the human eye, identical grey level may be represent by 2 different patterns, any of which may presumably be organized as a clustered dot and another as a distributed dot. The choice of the patterns has an effect on the characteristics of the half toning image.

Error Diffusion

1) Definition

a) Error diffusion is the process of quantizing each and every pixel using a neighbourhood operation. It do not use simple point wise operation.

b) In error diffusion method process moves through an image in raster order, that is it quantize the result and "pushing" the error forward.

c) Error diffusion method can produce better quality images than it is possible with screen.

It can be more understand by using the following diagram:-

Filter View of Error Diffusion

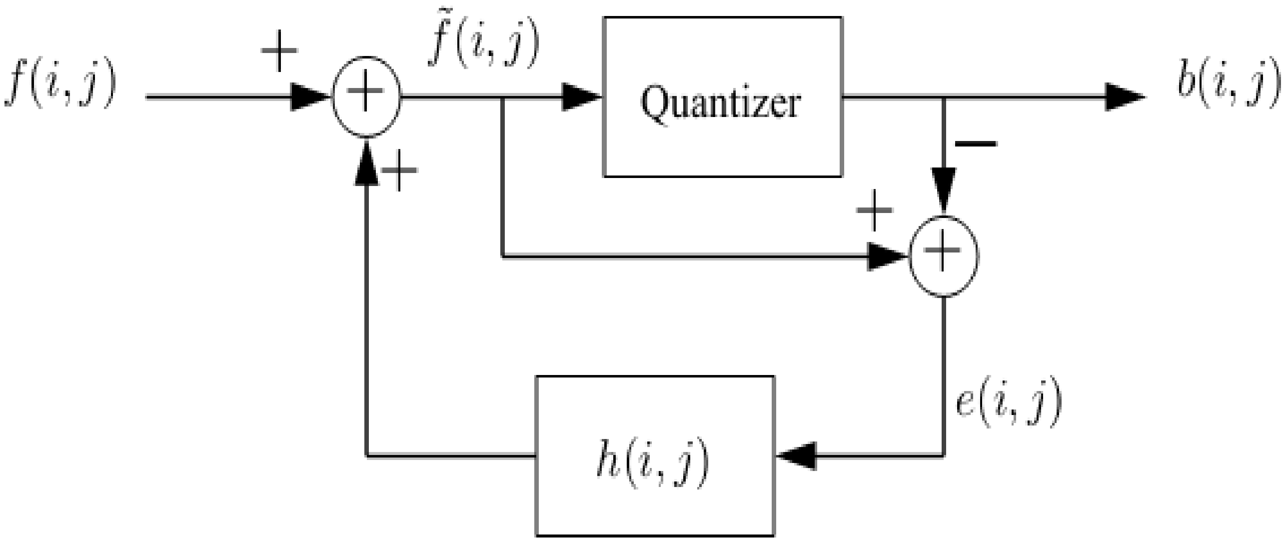


Figure 10: Filter view of error diffusion

As from the above figure we can see that what is happening throughout the error diffusion process. Above picture can be summarized into equation form as.

- Equations are

$$b(i,j) = \begin{cases} 255 & \text{if } \tilde{f}(i,j) > T \\ 0 & \text{otherwise} \end{cases}$$

$$e(i,j) = \tilde{f}(i,j) - b(i,j)$$

$$\tilde{f}(i,j) = f(i,j) + \sum_{k,l \in S} h(k,l) e(i-k, j-l)$$

Parameters are as follow:-

a) Threshold value is typically T=127

b) h (k,l) are typically choosen to be +ve and sum equal to 1.

As from the Fig 10 it can be shown that the pixel which is to be processed is equal to the value of current pixel sum with the error arises in the last pixel & error is calculated by the value of any pixel originally minus the value which become after thresholding. Also we have already discussed that how thresholding is done by comparing the particular pixel value with the threshold value which we set according to our wish and requirement[3].

Overall error diffusion can be understand by analysing following presentation:

In the Fig 11 we have assume that the threshold value is 0.5. Using this value we apply the process of error diffusion as explained above and we will get the layout as drawn in the fig11.

1-D Error Diffusion Example

- $\tilde{f}(i) \Rightarrow$ circles
- $b(i) \Rightarrow$ boxes

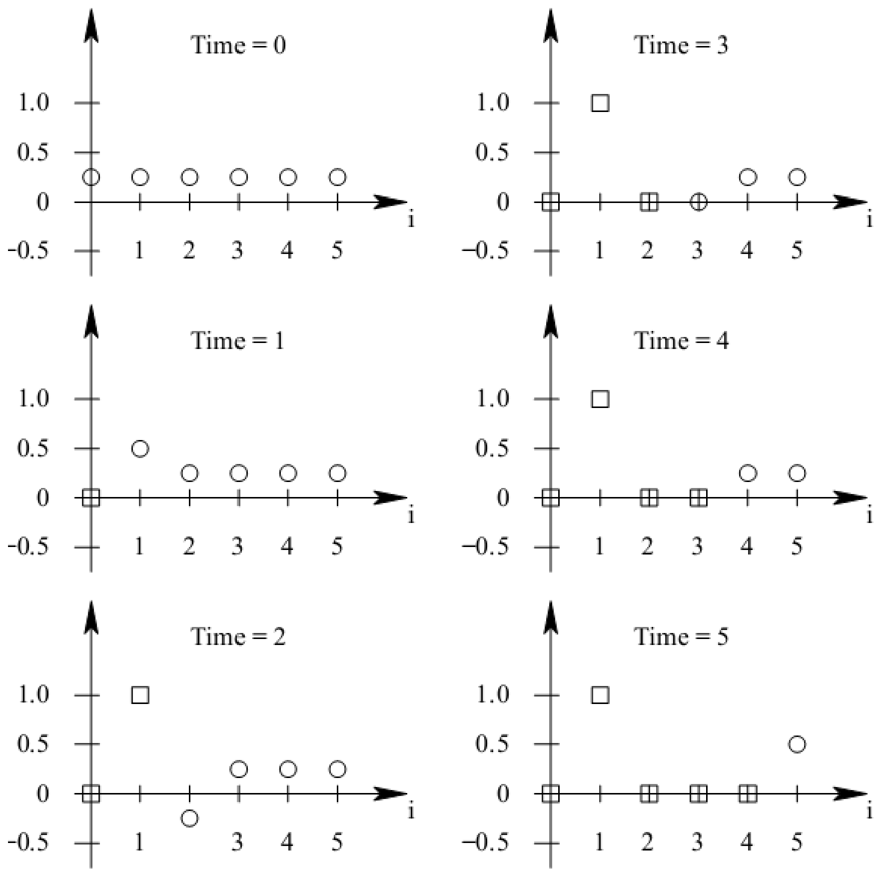


Figure 11: Process of error diffusion on pixel level

This example can give the brief description why noise is not concentrated on single point.But it is distributed or dispersed to neighbouring pixel by using some proper and predefined structure of filters.

Therefore error diffusion helps us to find output which is much more free to noise and resolution of picture becomes better.

There is two views of error diffusion. They are as follows:

1) Pulling error forward
2) Pushing error ahead.

These two views helps to achieve error diffusion and thus helping us out to get better output.

Pulling Error Forward: This method is more similar to common views of IIR filters. Also it has advantages while achieving error diffusion. As the name suggest pulling error forward means is to disperse error of one pixel to its neighbouring pixels but in forward direction. It can be explained better by following pictorial representation.

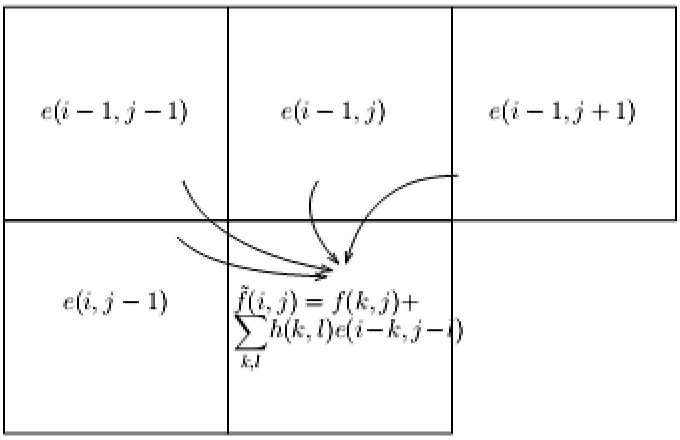


Figure 12: Pulling error forward

It is clear from the figure 12 that how the error arises in one position is dispersed to other position and this happens with each and every pixels and thus averaging the error throughout the image. Thus forming a better quality image.

The process of pulling error forward and the steps involved is described by following equations: For each pixel in the image

(a) Pull error forward

$$\tilde{f}(i,j) = f(i,j) + \sum_{k,l \in S} h(k,l)e(i-k, j-l)$$

(b) Compute binary output

$$b(i,j) = \begin{cases} 255 & \text{if } \tilde{f}(i,j) > T \\ 0 & \text{otherwise} \end{cases}$$

(c) Compute pixel's error

$$e(i,j) = \tilde{f}(i,j) - b(i,j)$$

And finally display the binary image b(i,j).

Pushing Errors Ahead:- This method is also same as pulling error forward.This method is also based on spreading the error of a single pixels to its neighbouring pixels in a ratio which vary from filter to filter.As a whole it can be described by using following pictorial presentation.

1. Initialize $\tilde{f}(i,j) \leftarrow f(i,j)$
2. For each pixel in the image (in raster order)
   (a) Compute

$$b(i,j) = \begin{cases} 255 & \text{if } \tilde{f}(i,j) > T \\ 0 & \text{otherwise} \end{cases}$$

   (b) Diffuse error forward using the following scheme

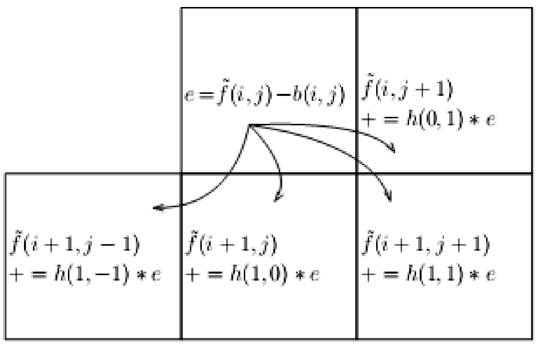


Figure 13: Pushing error ahead

3. Display binary image $b(i,j)$

As from the figure 13 it is clear that how the error generated in the first pixel is distributed to its neighbouring pixels. In this type of error diffusion technique error aroused at any pixel is given to its neighbouring pixel in some particular ratio.

This ratio must be defined in decreasing order as we move away from the error aroused pixel. Distance is not calculated by pixel number but it is the physical distance between the two pixel.

Commonly used error diffusion weight:-

1) Floyd and Steinberg (1976)

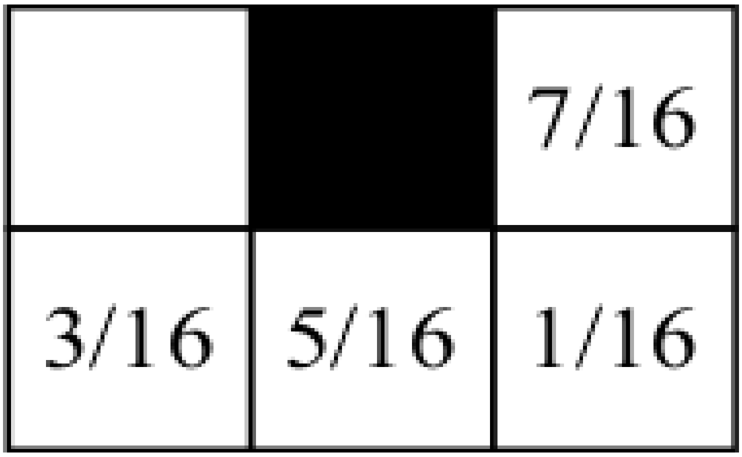


Figure 14: Filter coefficients used by Floyd and Steinberg

From the above table we can predict the following property of the filter weights:

1) Pixel with black colour is the position of error found.
2) Sum of all the weights is equal to 1.
3) Closer the pixel with black colour more the ratio of error we get. As we move away from the marked position portion or effect of error decreases.

Result Obtained by Using Floyd and Steinberg Code:-

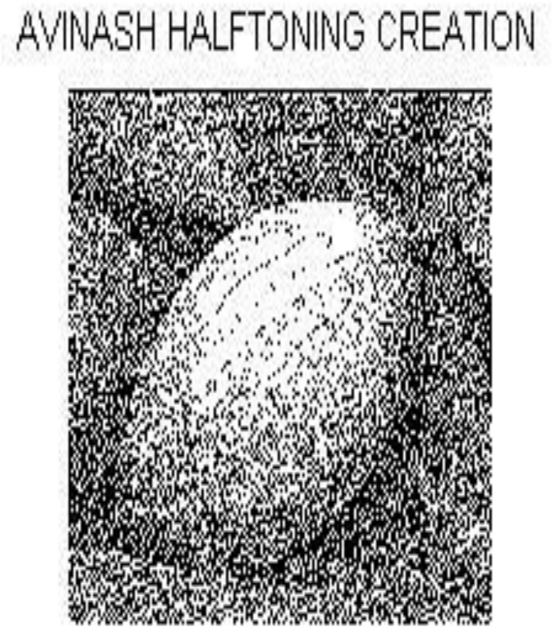


Figure 15:Halftone creation using Floyd and Steinberg filter weight

2) Jarvis, Judice and Ninke (1976)

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

Figure 16: Filter weight used by Jarvis, Judice and Ninke.

Now using these weight we can change the image to such a quality so that it will be change into discret form in such a manner so that quality of original image do not change much from its value and printing cost decrease. It can be clear by using following result which is perform on an image using Jarvis, Judice and Ninke weight.

From the above figure reffering the weight we can conclude that:-

1) Sum of all the weight to the Jarvis, Judice and Ninke model is equal to 1.
2) Black shaded area is a point of operation i.e we get error at that position and try to diffuse it in its neighbouring pixels in the particular ratio.
3) Those pixels are nearer to the shaded area have higher value than others, it is because nearer the pixel to the shaded area more the effect is measured.

2) Result Using Jarvis, Judice and Ninke weights

Figure 17:Halftone creation using Floyd and Steinberg filter weight

Quantization Error Modelling for Error Diffusion

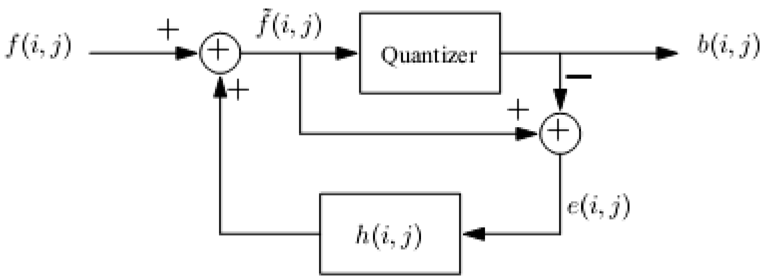


Figure 18: Model for calculating quantization error in error diffusion

Quantization error is assumed to be uniformly distributed on [-0.5,0.5]. Also it is uncorrelated in space i.e it do not mix with space noise. It is also independent of the signal $\tilde{f}(i,j)$.

Modified Error Diffusion Block Diagram:-

The error diffusion block diagram may be rearranged as following…

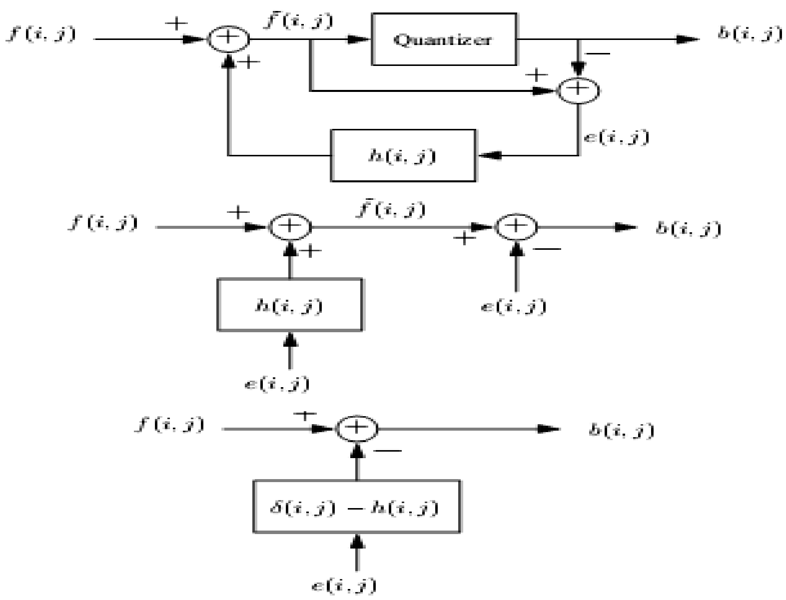


Figure 19: Rearrangement of error diffusion block diagram

Error Diffusion Spectral Analysis:

We can see that

$$b(i,j) = f(i,j) - (\delta(i,j) - h(i,j)) * e(i,j)$$

On rewriting ….

$$f(i,j) - b(i,j) = \underbrace{(\delta(i,j) - h(i,j))}_{\text{high pass filter}} * \underbrace{e(i,j)}_{\substack{\text{quantization}\\ \text{error}}}$$

With these equation we can conclude that …

Display error is :-

$$f(i,j) - b(i,j)$$

And quantization error is e(i,j). Also display error is high pass version of quantization error and human visual system is less sensitive for high spatial frequencies.

Correlation Of Quantization Error and Image:-

Quantization error model can be given as..

$$\begin{aligned} E(\mu,\nu) &= \rho F(\mu,\nu) + R(\mu,\nu) \\ &= \rho(\text{Image}) + (\text{Residual}) \end{aligned}$$

Where ρ represents the correlation between quantization error and the image

Table 1: correlation between the quantization error and the image

Weight	ρ
1-D	0.0
Floyd and Steinberg	0.55
Jarvis,Judice,and Ninke	0.8

Figure 20: correlation between quantization error and the image

Using this model we have,

$$B(\mu,\nu) = F(\mu,\nu) - (1 - H(\mu,\nu))\,E(\mu,\nu)$$
$$= [1 - \rho(1 - H(\mu,\nu))]\,F(\mu,\nu) + \text{noise}$$

This behaves as a unsharp masking.

Chapter 3: The impact of HVS model on the model based halftoning.

Introduction

HVS model is an very important tool for halftoning . If we are using the Direct Binary Search Method (DBS) we can compare many models for the best for halftoning. Once choosing the best HVS model we then design for the best techniques so that on increasing the complexity of the system device work efficiently and this we get by varying the parameters of the system. As we change the parameters of the model we can see that it is possible to tune the grey level which has been changed and thus get a best halftone quality among all the tone scale. After this we will design a full metric DBS algorithm which provides a tone dependent human vision system(HVS)model without having any large increase in the computational complexity.

Classification of Halftoning algorithm based on the type of computation involved

As we know that halftoning is a technique which is used to change or rendered an image with a large set of possible pixel value into other image which is comparatively less number or limited number of output levels such as monitors and printers. As we know that HVS acts as a low pass filter. On this assumption halftoning is based and this is why it is possible to create an image of different shades of grey with an exact dot size and exact dot density.

On the basis of total number of computation involved in the halftoning algorithm is mainly categorised into three categories:-

1) Point processes

2) Neighbourhood processes and

3) Iterative processes.

Point processes includes thresholding and lookup table based algorithm and it requires pixel by pixel comparison with a varying threshold value to determine the halftoned value in the output of the current pixel.

On the opposite side error diffusion that is associate degree neighbourhood method, compare the total weight of the present pixels and weighted error in the neighbour with a threshold to see the halftone values. Throughout the past twenty five year, particularly within the last decade an excellent deal of researches has been directed towards up the standard of the screening & error diffusion.

Iterative or we can say search based primarily techniques needs many passes of process to urge the ultimate halftone pictures. These techniques do try to minimize the error between the continuous image and the halftoned image picture simply by looking for the most suitable configuration of the binary values in the halftoned image. Though the iterative method is the most computational intensive among the three catogaries , but it yield significantly better output quality than screening or error diffusion.

Direct Binary Search Method (DBS)

DBS is an algorithm which is used to decrease the error between the perceived continuous image and the perceived halftone image the by changing the parameters of the halftone image based on the minimum square error (MSE) that we calculate in the process simultaneously [7][10][16].

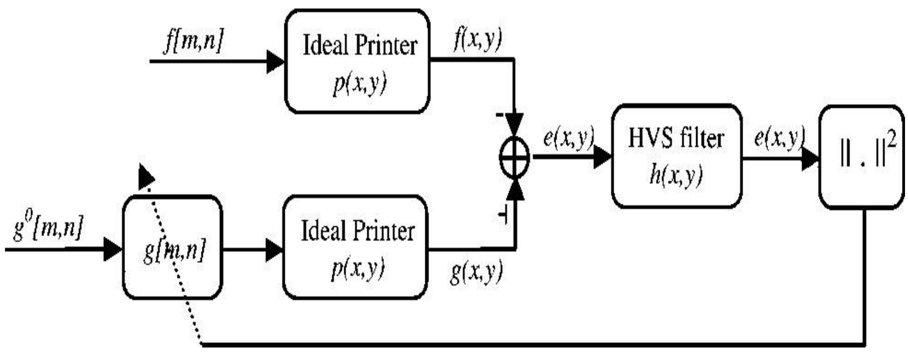


Figure 21: Block diagram for the direct binary search (DBS) algorithm

Error perceived between the original image or continuous tone image and the halftone image can be given by:-

e(x, y) = g(x, y) –f(x, y);

and the mean squared error (MSE) is given by

$$\mathcal{E} = \sum_{m,n} e[m,n] c_{ep}[m,n]$$

Where

e[m, n]=g[m, n]-f[m, n];

where g[m, n] is continuous tone image and f[m, n] is halftone image whose value is either 0 or 1 depending on condition it satisfy[13].

and

c_{ep}[m,n]= e[m,n] ** c_{pp}[m,n]

In Direct Binary Serch method there are two kind of pixels changes,

1) **Toggle**

   In this type there is only change in the current pixels status and that is from 0 to 1 or 1 to 0.

2) **Swap**

   In swapping we swap the value of any pixel by the value of its eight nearest neighbouring pixels that has a different value .

Change in halftone image g[m,n] is represented by

$$g'[m,n] = g[m,n] + a_0\delta[m - m_0, n - n_0] + a_1\delta[m - m_1, n - n_1]$$

After toggling or on swapping the change in the MSE value is given by:

$$\Delta\mathcal{E} = (a_0^2 + a_1^2)\, c_{\tilde{p}\tilde{p}}[0,0] + 2a_0a_1c_{\tilde{p}\tilde{p}}[m_1 - m_0, n_1 - n_0] + 2a_0c_{\tilde{e}\tilde{p}}[m_0, n_0] + 2a_1c_{\tilde{e}\tilde{p}}[m_1, n_1].$$

This is the equation which is used by DBS algorithm to search for pixel change in the halftoned image. If Δ€< 0 ,this implies that the change in the direction to decrease the mean square error which is profitable and this is why this change is acceptable[16].

If Δ€ >0 then this implies that the change in halftoning pixel is in the direction to increase the MSE which is not acceptable. If the change is accepted than g[m,n] will be changed according to the following equation;

$$g'[m,n] = g[m,n] + a_0\delta[m - m_0, n - n_0] + a_1\delta[m - m_1, n - n_1]$$

On assuming that cc_{pp} [m,n] has a support over N*N pixel then the total number of update requre is about N^2 addition. However updates are performed only when the trial change is accpted according to the equation of change in error given above as Δ€[15].

Different Model of Human Vision System (HVS)

There are many scientist who have given their own mathematical equation to model the human vision system mathematically. These model helps to design such a device using which we can improves the quality of halftoning[5][16].

Some of these models are tabulated below:

Table 2: Contrast Sensitivity Function of Four HVS model

Author	Contrast senstivity function $\bar{H}(\bar{\rho})$	Constants
Campbell	$k(e^{-2\pi\alpha\bar{\rho}} - e^{-2\pi\beta\bar{\rho}})$	$\alpha = 0.012$, $\beta = 0.046$
Mannos	$a(b + c\bar{\rho})\exp(-(c\bar{\rho})^d)$	$a = 2.6$, $b = 0.0192$, $c = 0.114$, $d = 1.1$
Näsänen	$\exp(\frac{-\bar{\rho}}{c \log L + d})$	$c = 0.525$, $d = 3.91$, $L = 11$
Daly	$a(b + c\bar{\rho})\exp(-(c\bar{\rho})^d)$, $\bar{\rho} > \bar{\rho}_{max}$, 1, else.	$a = 2.2$, $b = 0.192$, $c = 0.114$, $d = 1.1$, $\bar{\rho}_{max} = 6.6$

These are the mathematical formula which actually gives the mask or screen . We pass the image through these mask and also the halftoned image and then compare the result of both.

According to the difference we change the parameter in the halftoned image to minimize the overall error.

Comparison of Different HVS model On The Basis of Contrast Sensitivity Function

When we draw the graph of these equation and compare their performances on the basis of DBS halftoning algorithm and thus we will choose the one of the best model for the use with DBS[16].

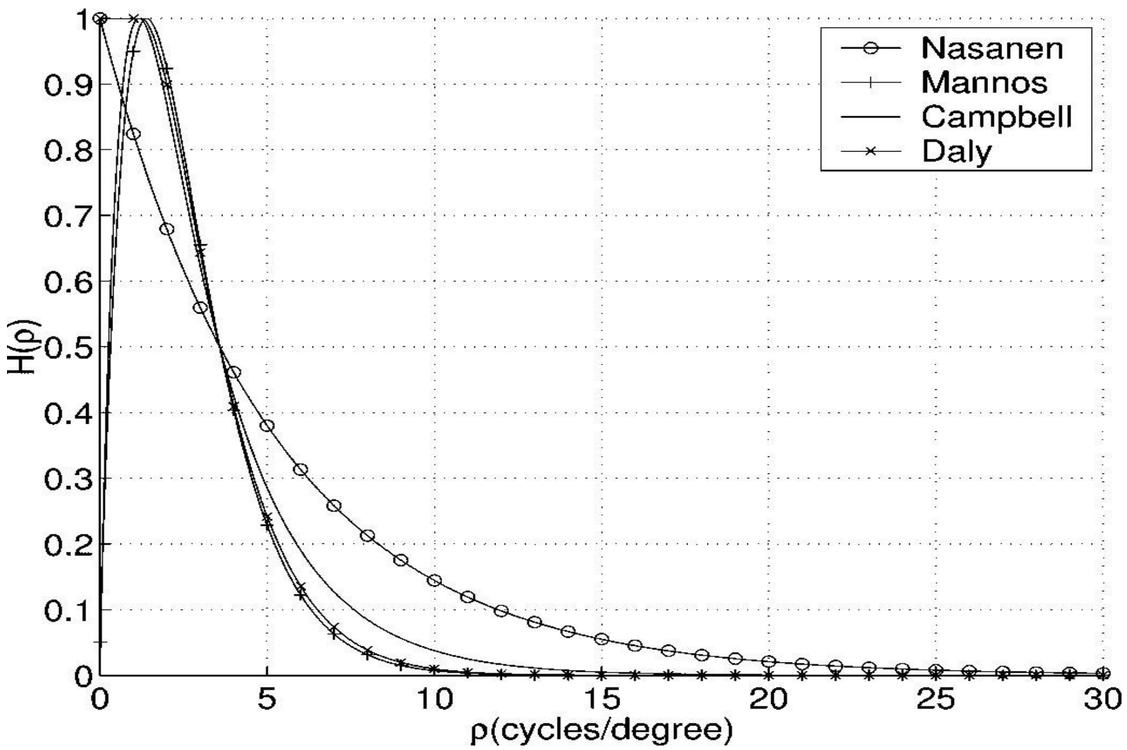


Figure 22: Comparison Of Different HVS model On The Basis of Contrast Sensitivity Function

Mask Creation by HVS model

Using the four model equation we develop a screen .We can develop it of any matrix size.

But here we have develop it of 3 *3.

1) NASANEN

0.6791	0.8241	0.6791
0.8241	1.0000	0.8241
0.67910.8241	0.6791	

2) **CAMPBELL**

0.2989	0.1783	0.2989
0.1783	0	0.1783
0.2989	0.1783	0.2989

3) **MANNAS**

0.0711	0.1332	0.0711
0.1332	0.3055	0.1332
0.0711	0.1332	0.0711

4) DALY

0.0711	0.1332	0.0711
0.1332	0.3055	0.1332
0.0711	0.1332	1.0000

So once they form we pass our original image and halftoned image through these mask. Once they pass through it then we calculate the output at both the places & calculate the minimum square error (MSE)[4]. Again get the difference of two MSE which we have got earlier. This MSE gives the overall MSE of the system. In this way we can calculate the MSE of each models and thus can compare each one. The model with minimum MSE will be best and thus choosen for the DBS algorithm to reduce the error from halftoning method [2][16].

Chapter 4: Result & Analysis

Using Nasanen Model of HVS we have designed a mask. After passing the original image and halftoned image through this mask we get two output. Now we have calculated MSE at both the position and difference of them gives the overall MSE of the model.

Using NASANEN model of HVS…….

Figure 23: Original Image

Figure 24: Original Image Using Nasanen Model

Figure 25: Original image after passing through Nansen model

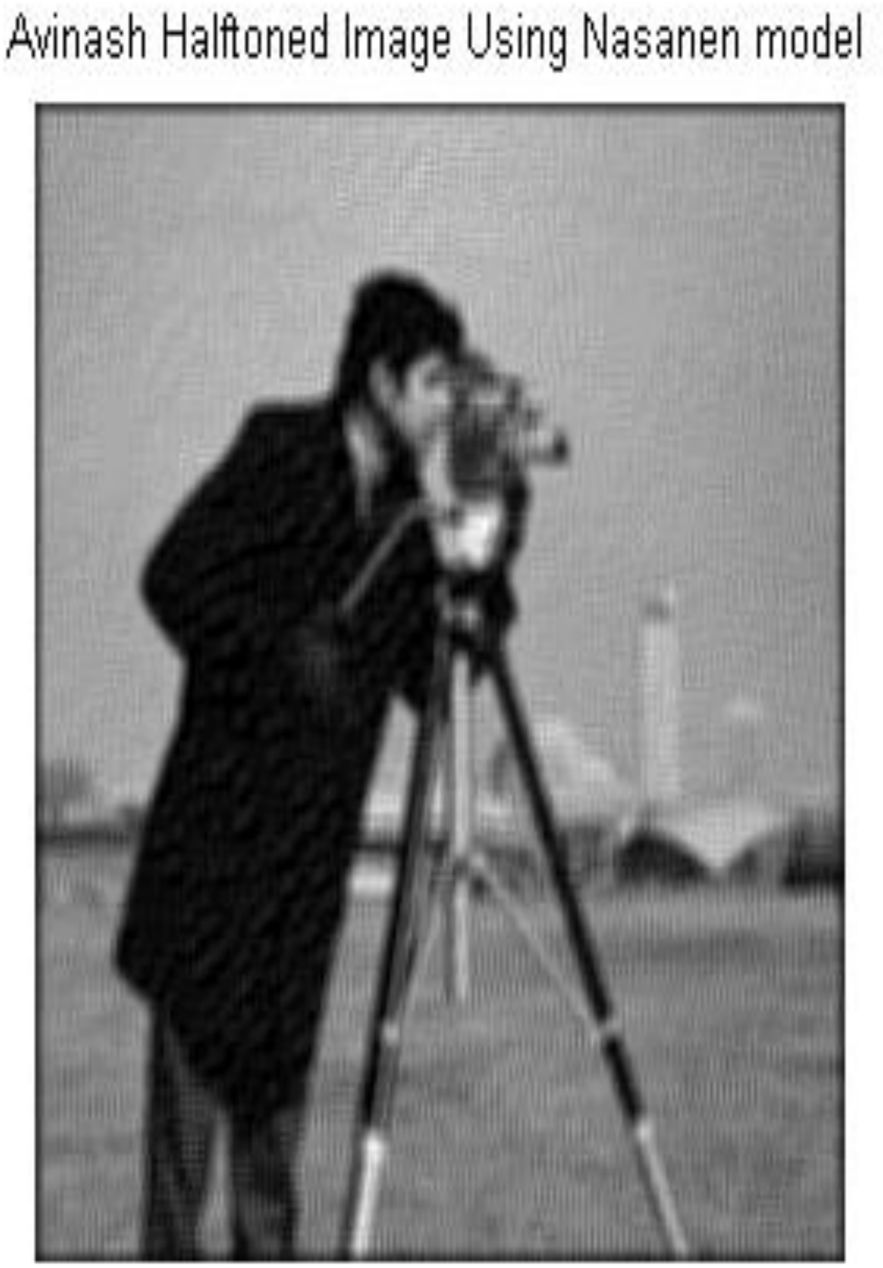


Figure 26: Halftoned image of original image

In this example we calculate the MSE and compare the performance of the different model. According to the MSE a feedback is given to the halftoned image in the input part and thus we make some proper shift in the parameter to reduce the MSE in the output and thus form a better halftoned output.

We have shown output only for Nansen model but this can be applied for all other models as well. As we compare after applying DBS algorithm to all the model we find that the minimum MSE we got in the case of Nansen & thus it is the best model.

Chapter 5: Future Work, Conclusion & Improvement

Future Work

1) After designing all the model we have compare them on the basis of MSE, but in future I would compare them on the basis of complexity & resolution.
2) I would like to develop a dual matrix DBS algorithm that will facilitates a tone dependent HVS model without any large increase in the computational complexity.

Conclusion

1) Several digital halftoning algorithms are surveyed and compared on the basis of their performances.
2) Of the four HVS models that we compared, Näsänen's model yielded the best overall halftone quality when used with the DBS algorithm as we got the minimum square error (MSE) equal to 0.1815.
3) By varying the parameters of the Gaussian model it could be tuned to provide a better quality at each and every grey level.

Improvement

In this report, many digital half toning algorithms area unit surveyed and that we specialise in 2-by-2 block replacement technique. we advise the subsequent enhancements of the initial 2-by-2 block replacement technique,

(1) Neighbouring Analysis,

(2) Decomposition of the grayscale regions for a much better visual look,

(3) Parallelization.

Improvement 1: Within the close Analysis approach, the plan is to think about every pixel's nearest neighbours (up, right, down, left) and compare their grey level intensities. Once the comparison, the stencil is turned in order to imitate the native changes in the image.Once victimization this approach, additional details is preserved within the output image relatively to the prevailing technique. .

Improvement 2: Instead of using fixed regions of equal length, the adaptive gray level range analysis defines grey level intervals according to the peaks of intensity histogram. The corresponding regions of the peaks area unit adjusted. Victimization the adaptive gray level intervals, we will distinguish additional details pixels from the background pixels, leading to a much better haftoning toning.

Improvement 3: Each the prevailing and therefore the new technique area unit parallelized and their performance is compared. because the new technique needs comparatively additional operations per picture element, its parallel performance is best than that of the initial technique and therefore the discovered acceleration is sort of ideal.

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