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# An Approach to Digital Halftone Processing Using Error Diffusion in Forward and Backward Direction.

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***Abstract— Digital halftoning is an important technique to convert an image having several bits for brightness levels into a binary image consisting of black and white dots which looks similar to an input image. The similarity between two images is measured by the total sum of differences in the weighted sums of brightness levels of pixels in a neighbourhood surrounding each pixel. In this paper, we proposed a new modified approach to error diffusion halftoning by diffusing the error in both forward and backward direction in the image.***

***Keywords: Halftoning, dithering, Error-Diffusion, Block replacement, PSNR, WSNR, UQI***

## I. INTRODUCTION

Halftoning is one of the oldest applications of image processing, since it is essential for the printing process. With the evolution of computers and their gradual introduction to typesetting, printing, and publishing, the field of halftoning that was previously limited to the so-called halftoning screen evolved into its successor digital halftoning [1]. Today, digital halftoning plays a key role in almost every discipline that involves printing and displaying. All newspapers, magazines, and books are printed with digital halftoning. It is used in image display devices capable of reproducing two-level outputs such as scientific workstations, laser printers, and digital typesetters. The grayscale digital image consists of 256 gray levels, while the black and white printers only have one colored ink. So, there is a need to replace wide range of grayscale pixels for printers. These 256 levels of gray should somehow be represented by placing black marks on white paper. Halftoning is a representation technique to transform the original continuous tone digital image into a binary image only of 1's and 0's consisting [2][3]. The value 1 means to fire a dot in the current position and 0 means to keep the corresponding position empty Since the human eyes have the low pass spatial frequency prosperity, human eyes perceive patches of black and white marks as some kind of average grey when viewed from sufficiently far away. Our eyes cannot distinguish the dots patterns if they are small enough. Instead, our eyes integrate the black dots and the non-printed areas as varying shades of gray.

## II. ERROR DIFFUSION

Since its introduction Floyd and Steinberg, the error diffusion (E-D) algorithm has attracted much attention .The main advantage of the initial version of the algorithm is its simplicity and its good overall visual quality of the produced binary images. For all these reasons, it became very popular in various graphics applications [4]. Unlike the block replacement and ordered dithering methods, which treat each pixel individually, error diffusion quantities each pixel using a neighbourhood operation. In this case, the value of each output point depends no longer only on the value of the corresponding input point

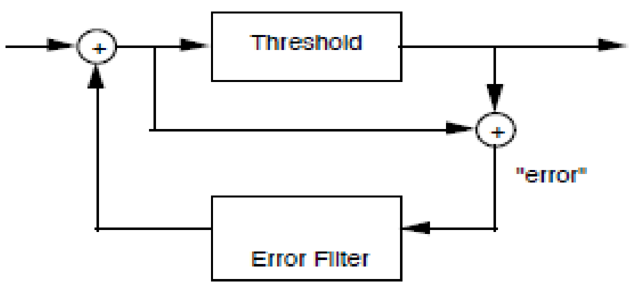



Fig 1: Error Diffusion halftoning method

A schematic diagram of error diffusion method is given in A simple error diffusion system shown in Figure 1 consists of a digital filter, commonly known as the error diffusion kernel and a binary quantizer embedded in a feedback loop [5]. At each step, the input sample is adjusted by a filtered version of the binary quantizer error, and then the result is quantized. This method moves through the original image in raster order, normally starting from the pixel up to the left (i.e. the first element of the matrix) and then goes through all pixels from left to right until the end. Pixels of the continuous-tone digital image are processes in a linear fashion, left-to-right and top-to-bottom. At every step, the algorithm compares the grayscale value of the current pixel, represented by an integer between 0 and 255, to some threshold value (typically 128). If the grayscale value is greater than the threshold, the pixel is considered black and its output value is set to 1, else it is considered white and is set to 0. The difference between the pixel's original grayscale value and the threshold is considered as *error*. To achieve the effect of continuous-tone illusion without the diagonal visual artifacts, this error is distributed to four neighboring pixels that have not been processed yet, according to the matrix shown graphically in Figure 2, proposed by Floyd and Steinberg [6]

| | | |
|---|---|---|
| | ■ | 7/16 |
| 3/16 | 5/16 | 1/16 |

Fig 2: Floyd and Steinberg Error filter

The result of the Floyd and Steinberg algorithm is shown in Figure 3 given below.

(a) (b)

Fig 3: (a) The original image; (b) The halftoning image using Floyd and Steinberg Error filter algorithm

The Floyd-Steinberg E-D algorithm contains a number of inherent drawbacks. First, this algorithm produces clearly identifiable visually harmful artifacts in highlights and in dark areas referred to as worm artifacts Second, patches of regular structure may appear. Not only are such patches visually disturbing, but also the uneven transition between "structured" and "unstructured" areas may be clearly visible and undesirable harmful visual perturbations due to uneven patches of regular structures should be avoided whenever possible. To overcome these drawbacks two methods are suggested.

- First is to change the scanning path from raster to serpentine
- Second is to use modified error weights

In order to reduce these artifacts [7], modified error weights were suggested that diffuse the error to a large number of pixels Jarvis, Judice and Ninke [2] introduced 12-element error filter shown in Figure 4.

| | | | | |
|---|---|---|---|---|
| | | ■ | 7/48 | 5/48 |
| 3/48 | 5/48 | 7/48 | 5/48 | 3/48 |
| 1/48 | 3/48 | 5/48 | 3/48 | 1/48 |

Fig 4: Error weight filter matrix given by Jarvis, Judice and Ninke

Stucki also proposed a 12-element error filter to reduce the worm like artifacts. Figure 5 shows the error weight filter matrix given by Stucki

| | | | | |
|---|---|---|---|---|
| | | ■ | 8/42 | 4/42 |
| 2/42 | 4/42 | 8/42 | 4/42 | 2/42 |
| 1/42 | 3/42 | 4/42 | 2/42 | 1/42 |

Fig 5 : Error weight filter matrix given by Stucki

The result of both the Jarvis, Judice and Ninke and Stucki algorithm is given in the Figure 6 and Figure 7 respectively.

(a) (b)

Fig 6: (a) The original image; (b) The halftoned image using Jarvis, Judice and Ninke Error filter algorithm

(a) (b)

Fig 7: (a) The original image; (b) The halftoned image using Stucki error filter algorithm

## III. PROPOSED METHOD

All the methods described above shows that the performance of the error diffusion techniques is based on the error filter. The quantization error is filtered through the error filter. We see that the error is transferred in the forward direction only, which means that the error is distributed to pixels that are yet to be scanned. The proposed method suggests a method in which the errors are distributed in both forward and direction [8] [9]. Thus the halftone image to be produce may contain the error distributed uniformly to each of the neighbouring pixels. We propose a method where the quantization error of one iteration (pass) is collected and used during the next iteration as quantization error of the future pixels .The error filter is causal FIR with the coefficient at (0, 0) = 0. The magnitude response of the error filter should be low pass, since this would result in the low frequency spectrum of the halftone resembling so that the error feedback is added to the input image in phase to retain the sharp edges All the methods described earlier pushes the error in forward direction, we uses an error filter that also distribute the error in backward direction too.

| | | | | |
|---|---|---|---|---|
| .015 | .030 | .050 | .030 | .015 |
| .030 | .050 | .075 | .050 | .030 |
| .050 | .075 | | .075 | .050 |
| .030 | .050 | .075 | .050 | .015 |
| .015 | .030 | .050 | .030 | .015 |

Fig 8: A 5x 5 non causal error filter

Using this non causal filter we uses a straight forward implementation of the error diffusion algorithm is detailed in the following steps, performed on each pixel in raster order:

1. Initialize an output image matrix with zeros.
2. Quantize the current pixel to 0 or 255 using the threshold T, and place the result in the output matrix
3. Compute the quantization error by subtracting the binary pixel from the grayscale pixel.
4. Diffuse the scaled versions of this error to the forward and backward pixels of the original image, according to the diffusion filter of Figure 8

The result of proposed algorithm is shown in figure 9

(a) (b)

Figure 9: (a) The original image; (b) The halftoned image using the new proposed algorithm.

Both the input original image and the output halftoned image is analysed using various quality and visual quality parameters. Quality measures should vary monotonically with visual quality. The linear quality measures which weight the noise in frequency according to a model of the frequency response of the HVS. The various parameters that we use for evaluating the image quality are briefly explained as under

**PSNR**: The simplest and most widely used pixel wise error based measures are mean squared error (MSE) and peak signal-to-noise ratio (PSNR). The MSE is the squared intensity differences between the reference and the test image pixels, which defined by:

$$\text{MSE} = \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}[f(m,n) - f'(m,n)]^2$$

$$PSNR = 10\log_{10}\frac{255^2}{MSE}$$

Where f (m, n) is the original image and f' (m, n) is the halftoned image.

**Universal Image Quality Index (UQI);** Let X and Y be the original and test image signal respectively where

$$X = \{x_i \mid i = 1, 2..N\}\text{;}\quad Y = \{y_i \mid i = 1, 2,..N\}$$

$$UQI = \frac{4\sigma_{XY}\,\overline{xy}}{(\overline{x}^2 + \overline{y}^2)(\sigma_X^2 + \sigma_y^2)}$$

Where

$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad \& \quad \overline{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$$

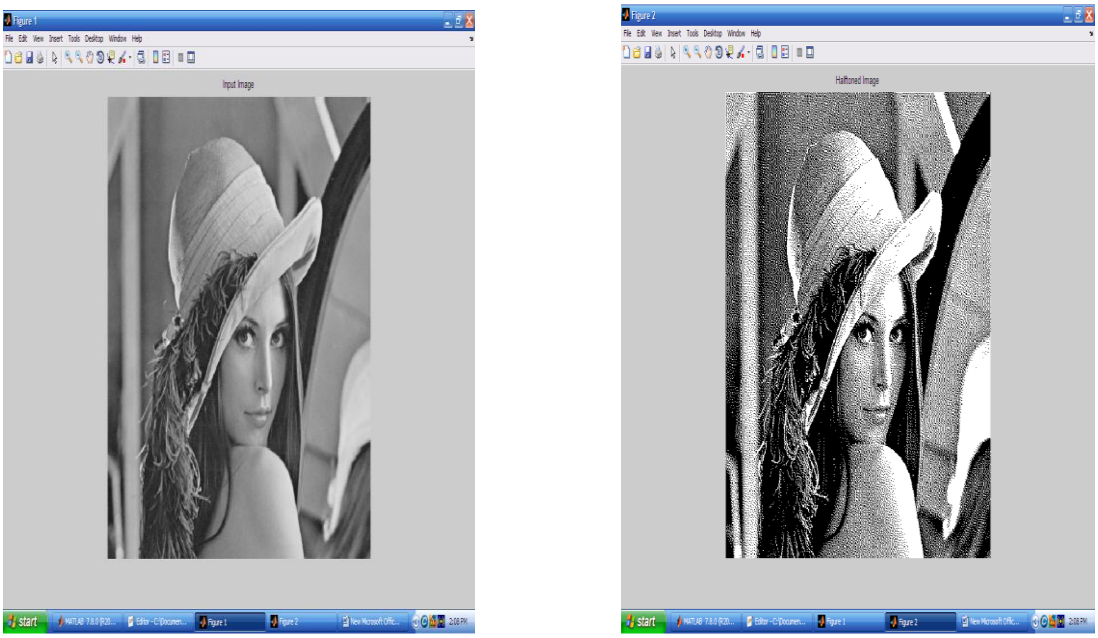
 

**Weighted Signal-to-Noise Ratio (WSNR)**: WSNR is calculated in the spatial frequency domain and it is defined as follows.

$$WSNR = 10\log 10 \frac{255^2}{\sum_{m=1}^{M}\sum_{n=1}^{N}[\mathrm{X(m,n)} - \mathrm{B(m,n)}]^2 . W(m,n)}$$

Where $W(m,n)$ is the is a weighting function represents the discrete Fourier transform (DFT) of a grayscale image with size $M \times N$ , and $B(m, n)$ is the DFT of the bi-level halftone image.
The following table shows the result of the various qualitative parameters described above

TABLE I
Result of various qualitative parameters for various algorithms




(a) (b)

Figure 10: (a) The original image; (b) The halftoned image using the new proposed algorithm in MATLAB .

| Type of algorithm | PSNR(dB) | WSNR(dB) | UQI |
|---|---|---|---|
| Floyd | 6.75054 | 30.1316 | .0783243 |
| Jarvis, | 6.89729 | 24.5358 | .106034 |
| Stucki | 6.8656 | 25.6308 | .100091 |
| New Method | 7.67766 | 19.0333 | .543334 |

## IV CONCLUSIONS

The presented work is the implementation of improved error diffusion technique. Results shows the halftone obtained after using this proposed error diffusion method and errors as the starting error and diffusing errors in forward and backward direction values produces better results. All the regions which have finer details in the images are visible so the proposed method is truthful in reproducing the fine details of the actual image. These quantitative results also reaffirm the results obtained from our visual assessment. From all these we can conclude that our proposed modification to error diffusion method produces substantially better halftones that retains all the edges and their sharpness and gives a better visual perception. These quantitative results reaffirm the results obtained from our visual assessment.

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