National Taiwan University of Science and Technology

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REPORT 1

Multimedia Signal Processing

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Contents

1. Problem statement

- **Point Process – Ordered Dithering using the Classical-4 && Bayer-5 Dither Array**

Write an algorithm to convert the Gray Scale Image (0-255 Range) to Binary Image (0-1 Range) using the mentioned dither array.

- **Neighborhood Process – Error Diffusion**

In error-diffusion, three kernels are widely used Stucki (1981), Jarvis (1976), and Floyd-Steinberg (1975).

Write an algorithm to convert the Gray Scale Image (0-255 Range) to Binary Image (0-1 Range) based on the mentioned error diffusion kernels.

2. Proposed solution

There are many methods to convert the Gray Scale Image to Binary Image such as ordered dithering, error diffusion, thresholding and so on. The simplest way is "Thresholding" which differentiates the pixels we are interested in from the rest.

2.1. Deterministic thresholding

a) Title

In the first part, I am going to apply the "Deterministic Thresholding" method to convert a grayscale image to binary image. One application example of thresholding is to separate out regions of an image corresponding the objects which we want to analyze.

Thresholding method differentiates the pixels we are interested in from the rest (which will eventually be rejected), we perform a comparison of each pixel intensity value with respect to a threshold. Once we have separated properly the important pixels, we can set them with a determined value to identify them. For example, we can assign them a value of 0 (black), 255 (white) or any value that suits our needs.

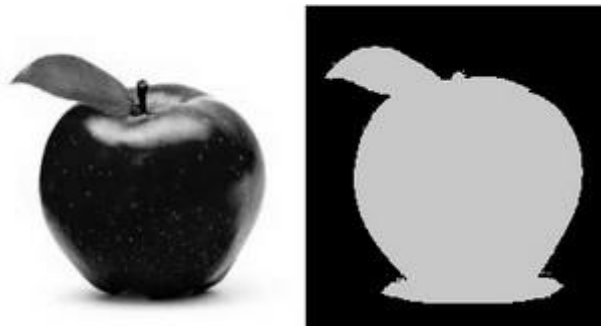


Figure 1. Applying thresholding method to differentiate the image of an apple

There are 5 types of thresholding operations:

- Threshold Binary
- Threshold Binary and Inverted
- Truncate
- Threshold to Zero
- Threshold to Zero and Inverted

For easier demonstration purpose, I would like to use the Threshold Binary operation applying to Lena image file. The Threshold Binary operation can be easily expressed as:

$$\texttt{dst}(x,y) = \begin{cases} \texttt{maxVal} & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ 0 & \text{otherwise} \end{cases}$$

Therefore, if the intensity of the pixel src(x,y) is higher than thresh, then the new pixel intensity is set to a MaxVal. Otherwise, the pixels are set to 0.

b) Code

```
clc
clear all

%Read the image and change to gray scale image
I = imread('lena.JPG');
G = rgb2gray(I);

%Show the image
figure
imshow(G);
title('Grayscale Image')

figure
imshow( G > 128)
title('Binary Image with threshold 128')
```

c) Result

Figure 2. Binary image with thresholding 128

d) Discussion

We should not use the threshold because the quality of image does not look good. The picture is unreadable and looks terrible. Therefore, we will move on to the concept of Dithering.

2.2. Ordered Dithering

a) Title

We will consider two dithering methods that are applied widely: Ordered dither and error diffusion dither.

The human visual system usually average a region around a pixel instead of sensing each pixel individually, we can create the illusion of many gray levels in a binary image in actuality only contains two gray levels. For example, using 2 x 2 binary pixel grids, we can represent 5 different "effective" intensity levels, as illustrated in Figure 3.

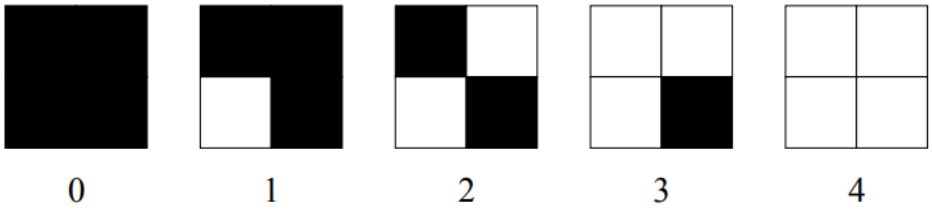


Figure 3. Five different patterns of 2 x 2 binary pixel grids.

In dithering, we replace the blocks of original image with these types of binary grid patterns. Ordered dithering consists of comparing blocks of the original image to a 2-D grid of thresholds called a dither pattern. In the report, I will take classical-4 and bayer-5 dither arrays as an example of dither pattern.

.567	.635	.608	.514	.424	.365	.392	.486
.847	.878	.910	.698	.153	.122	.090	.302
.820	.969	.941	.667	.180	.031	.059	.333
.725	.788	.757	.545	.275	.212	.243	.455
.424	.365	.392	.486	.567	.635	.608	.514
.153	.122	.090	.302	.847	.878	.910	.698
.180	.031	.059	.333	.820	.969	.941	.667
.275	.212	.243	.455	.725	.788	.757	.545

.513	.272	.724	.483	.543	.302	.694	.453
.151	.755	.091	.966	.181	.758	.121	.936
.634	.392	.574	.332	.664	.423	.604	.362
.060	.875	.211	.815	.030	.906	.241	.845
.543	.302	.694	.453	.513	.272	.724	.483
.181	.758	.121	.936	.151	.755	.091	.966
.664	.423	.604	.362	.634	.392	.574	.332
.030	.906	.241	.845	.060	.875	.211	.815

Figure 4. Classical-4 dither array and bayer-5 dither array

The values in the dither matrix are floating-fixed numbers, but are typically different from each other. Some decorrelation from the quantization error is achieved because the threshold changes between adjacent pixels.

Methods:

At the beginning, the Bayer-5 array and Classical-4 are floating-point matrices, so we need to multiply the whole matrices to 255 and round them into integer matrices, which mean that the matrix consists of all integer values.

```
%Create bayer array
bayer=[.513 .272 .724 .483 .543 .302 .694 .453;
 .151 .755 .091 .966 .181 .758 .121 .936;
.634 .392 .574 .332 .664 .423 .604 .362;
.060 .875 .211 .815 .030 .906 .241 .845;
.543 .302 .694 .453 .513 .272 .724 .483;
.181 .758 .121 .936 .151 .755 .091 .966;
.664 .423 .604 .362 .634 .392 .574 .332;
.030 .906 .241 .845 .060 .875 .211 .815]*255;
```

bayer

8x8 double

	1	2	3	4	5	6	7	8
1	130.8150	69.3600	184.6200	123.1650	138.4650	77.0100	176.9700	115.5150
2	38.5050	192.5250	23.2050	246.3300	46.1550	193.2900	30.8550	238.6800
3	161.6700	99.9600	146.3700	84.6600	169.3200	107.8650	154.0200	92.3100
4	15.3000	223.1250	53.8050	207.8250	7.6500	231.0300	61.4550	215.4750
5	138.4650	77.0100	176.9700	115.5150	130.8150	69.3600	184.6200	123.1650
6	46.1550	193.2900	30.8550	238.6800	38.5050	192.5250	23.2050	246.3300
7	169.3200	107.8650	154.0200	92.3100	161.6700	99.9600	146.3700	84.6600
8	7.6500	231.0300	61.4550	215.4750	15.3000	223.1250	53.8050	207.8250

Figure 5. Bayer-5 matrix

```
%Round the values
bayer = round(bayer);
```

bayer

8x8 double

	1	2	3	4	5	6	7	8
1	131	69	185	123	138	77	177	116
2	39	193	23	246	46	193	31	239
3	162	100	146	85	169	108	154	92
4	15	223	54	208	8	231	61	215
5	138	77	177	116	131	69	185	123
6	46	193	31	239	39	193	23	246
7	169	108	154	92	162	100	146	85
8	8	231	61	215	15	223	54	208

Figure 6. Bayer-5 matrix with integer values

Because ordered dithering is using the point-process that means every pixel of original image will be compared to specified value of Dither array. To be easier for implementing the algorithm, I am going to use to Raster Scan technique to process all the pixel of original image.

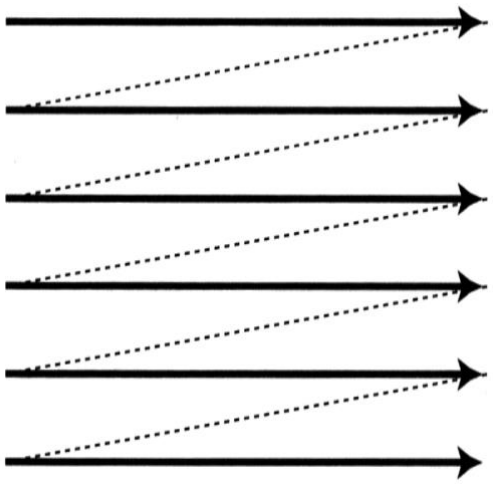


Figure 7. Raster scan – processing path

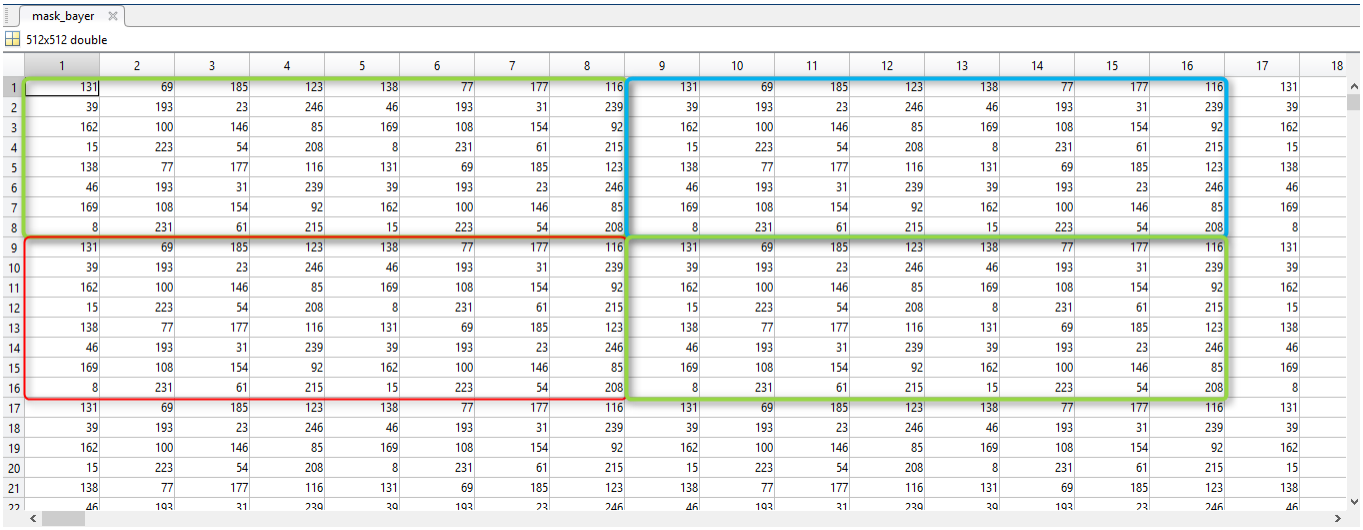
I will use 2 for-loop the access every pixel from left to right, from top to bottom.

```
for R=1:row
     for C=1:col
            if G(R,C) > mask_bayer(R,C)
                Bayer_Image(R,C) = 255;
            else
                Bayer_Image(R,C) = 0;
            end
     end
 end
```

The “Lena.jpg” image has size 512 x 512 but the Classical-4 and Bayer-5 Dither arrays are 8x8 matrices. The fastest way to solve the problem is repeat copies of Classical-4 and Bayer-5 arrays.

```
mask_bayer=repmat(bayer,row/8,col/8);
```

“Mask_bayer” returns an array containing 512/8 = 64 copies of array in the row and column dimensions which means the Bayer-5 arrays will have size of 512 x 512.

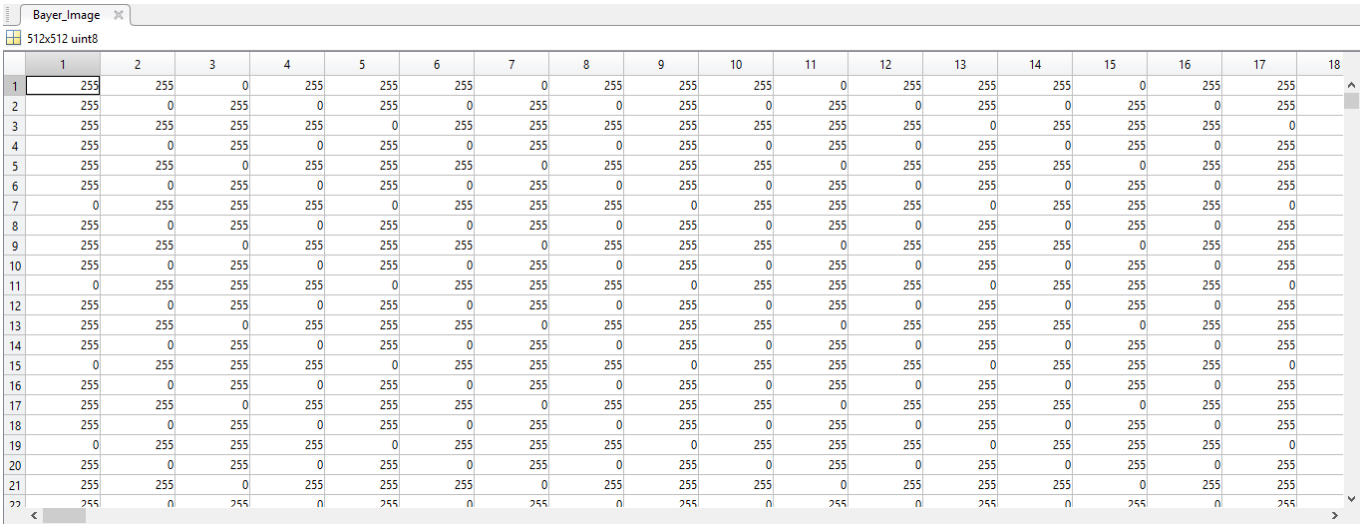


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	131	69	185	123	138	77	177	116	131	69	185	123	138	77	177	116	131	
2	39	193	23	246	46	193	31	239	39	193	23	246	46	193	31	239	39	
3	162	100	146	85	169	108	154	92	162	100	146	85	169	108	154	92	162	
4	15	223	54	208	8	231	61	215	15	223	54	208	8	231	61	215	15	
5	138	77	177	116	131	69	185	123	138	77	177	116	131	69	185	123	138	
6	46	193	31	239	39	193	23	246	46	193	31	239	39	193	23	246	46	
7	169	108	154	92	162	100	146	85	169	108	154	92	162	100	146	85	169	
8	8	231	61	215	15	223	54	208	8	231	61	215	15	223	54	208	8	
9	131	69	185	123	138	77	177	116	131	69	185	123	138	77	177	116	131	
10	39	193	23	246	46	193	31	239	39	193	23	246	46	193	31	239	39	
11	162	100	146	85	169	108	154	92	162	100	146	85	169	108	154	92	162	
12	15	223	54	208	8	231	61	215	15	223	54	208	8	231	61	215	15	
13	138	77	177	116	131	69	185	123	138	77	177	116	131	69	185	123	138	
14	46	193	31	239	39	193	23	246	46	193	31	239	39	193	23	246	46	
15	169	108	154	92	162	100	146	85	169	108	154	92	162	100	146	85	169	
16	8	231	61	215	15	223	54	208	8	231	61	215	15	223	54	208	8	
17	131	69	185	123	138	77	177	116	131	69	185	123	138	77	177	116	131	
18	39	193	23	246	46	193	31	239	39	193	23	246	46	193	31	239	39	
19	162	100	146	85	169	108	154	92	162	100	146	85	169	108	154	92	162	
20	15	223	54	208	8	231	61	215	15	223	54	208	8	231	61	215	15	
21	138	77	177	116	131	69	185	123	138	77	177	116	131	69	185	123	138	
22	46	193	31	239	39	193	23	246	46	193	31	239	39	193	23	246	46	

Figure 8. Bayer-5 arrays after duplicating matrix

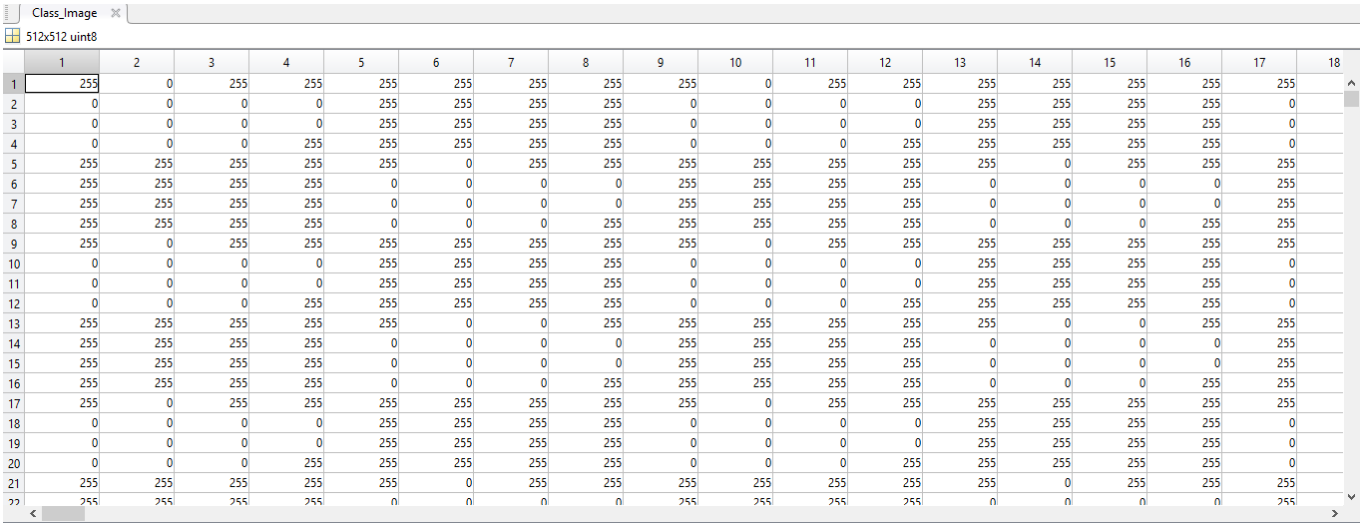
The crucial ordered dither algorithm is that comparing the gray level of a pixel to a level in a dither matrix, depending on this comparison, the pixel is set to either black or white. In the real case, if gray level of a pixel is larger than value in dither matrix then the pixel is set to 255, else set to 0. The whole process is applied from left to right, from top to bottom of matrix.

Finally, we will get a new matrix including only 2 values 0 or 255. “0” means print out black ink, 255 means print out white ink.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	
2	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
3	255	255	255	255	0	255	255	255	255	255	255	255	0	255	255	255	0	
4	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
5	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	
6	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
7	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	
8	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
9	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	
10	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
11	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	
12	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
13	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	
14	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
15	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	
16	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
17	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	
18	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
19	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	
20	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	
21	255	255	0	255	255	255	0	255	255	255	0	255	255	255	0	255	255	
22	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	0	255	

Figure 9. The matrix of original image with Bayer-5 dither array



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	255	0	255	255	255	255	255	255	255	0	255	255	255	255	255	255	255	
2	0	0	0	0	255	255	255	255	0	0	0	0	255	255	255	255	0	
3	0	0	0	0	255	255	255	255	0	0	0	0	255	255	255	255	0	
4	0	0	0	255	255	255	255	255	0	0	0	255	255	255	255	255	0	
5	255	255	255	255	255	0	255	255	255	255	255	255	255	0	255	255	255	
6	255	255	255	255	0	0	0	0	255	255	255	255	0	0	0	0	255	
7	255	255	255	255	0	0	0	0	255	255	255	255	0	0	0	0	255	
8	255	255	255	255	0	0	0	255	255	255	255	255	0	0	0	255	255	
9	255	0	255	255	255	255	255	255	255	0	255	255	255	255	255	255	255	
10	0	0	0	0	255	255	255	255	0	0	0	0	255	255	255	255	0	
11	0	0	0	0	255	255	255	255	0	0	0	0	255	255	255	255	0	
12	0	0	0	255	255	255	255	255	0	0	0	255	255	255	255	255	0	
13	255	255	255	255	255	0	0	255	255	255	255	255	255	0	0	255	255	
14	255	255	255	255	0	0	0	0	255	255	255	255	0	0	0	0	255	
15	255	255	255	255	0	0	0	0	255	255	255	255	0	0	0	0	255	
16	255	255	255	255	0	0	0	255	255	255	255	255	0	0	0	255	255	
17	255	0	255	255	255	255	255	255	255	0	255	255	255	255	255	255	255	
18	0	0	0	0	255	255	255	255	0	0	0	0	255	255	255	255	0	
19	0	0	0	0	255	255	255	255	0	0	0	0	255	255	255	255	0	
20	0	0	0	255	255	255	255	255	0	0	0	255	255	255	255	255	0	
21	255	255	255	255	255	0	255	255	255	255	255	255	255	0	255	255	255	
22	255	255	255	255	0	0	0	0	255	255	255	255	0	0	0	0	255	

Figure 10. The matrix of original image with Classical-4 dither array

b) Code

```
clc
clear all

%Read the image and change to gray scale image
I = imread('lena.JPG');
G = rgb2gray(I);

%Create bayer array
bayer=[.513 .272 .724 .483 .543 .302 .694 .453;
 .151 .755 .091 .966 .181 .758 .121 .936;
.634 .392 .574 .332 .664 .423 .604 .362;
.060 .875 .211 .815 .030 .906 .241 .845;
.543 .302 .694 .453 .513 .272 .724 .483;
.181 .758 .121 .936 .151 .755 .091 .966;
.664 .423 .604 .362 .634 .392 .574 .332;
.030 .906 .241 .845 .060 .875 .211 .815]*255;

%Classical-4 Dither Array
classical = [.567 .635 .608 .514 .424 .365 .392 .486;
.847 .878 .910 .698 .153 .122 .090 .302;
.820 .969 .941 .667 .180 .031 .059 .333;
.725 .788 .757 .545 .275 .212 .243 .455;
.424 .365 .392 .486 .567 .635 .608 .514;
.153 .122 .090 .302 .847 .878 .910 .698;
.180 .031 .059 .333 .820 .969 .941 .667;
.275 .212 .243 .455 .725 .788 .757 .545]*255;



%Round the values
bayer = round(bayer);
classical = round(classical);

%Get the value of row and column of image then assign to variable 'row',
%'col'
[row col] = size(G);
```

```
mask_bayer=repmat(bayer,row/8,col/8);

mask_classical=repmat(classical,row/8,col/8);


 for R=1:row
     for C=1:col
            if G(R,C) > mask_bayer(R,C)
                Bayer_Image(R,C) = 255;
            else
                Bayer_Image(R,C) = 0;
            end
     end
 end

  for R=1:row
     for C=1:col
            if G(R,C) > mask_classical(R,C)
                Class_Image(R,C) = 255;
            else
                Class_Image(R,C) = 0;
            end
     end
 end


%Show the desired image
figure
imshow(G);
title('Gray Scale Image')

figure
imshow(Bayer_Image);
title('Ordered Dithering | Halftone Image by using Bayer-5 Dither Array')

figure
imshow(Class_Image);
title('Ordered Dithering | Halftone Image by using Classical-4 Dither Array')
```

c) Results

Figure 11. Grayscale image and halftone image by using classical-4 dither array

Figure 12. Grayscale image and halftone image by using bayer-5 dither array

d) Discussion

At the beginning, I tried to convert gray scale image into binary image with simple method “Half toning” buy comparing each pixel of image to a certain thresholding value, for example 128. I finally got a very bad result due to bad distribution of numbers.

Figure 13. Grayscale image and halftone image with constant thresholding 128

It is clear that the halftone image created by bayer-5 dither array provides more decent detail rendition than created by classical-4 dither array. At normal viewing distances, the picture (left) is visibly noisier than the right one.

Figure 11. Half toning image creating by using classical-4 (left) and bayer-5 (right)

2.3. Error Diffusion

a) Title

Error diffusion dither algorithms spread the error (caused by quantizing a pixel) over neighboring pixels; the best known example of error diffusion dither is the "Floyd Steinberg" dither.

In error diffusion, the value of a pixel is compared to a single threshold of 50% gray. When black is 0 and white is 255, each pixel is compared to 128. The pixel is set to either black or white, based on that comparison. After outputting the dithered pixel, the algorithm calculates the difference between the source pixel and the output pixel (a simple subtraction), and then it spreads this difference (the "error") over neighboring pixels.

```
if (OLD(R,C) < T)            %T: Thresholding = 128
    NEW(R,C) = 0;            %R: row, C: Column
else
    NEW(R,C) = 255;          %OLD: the source pixel
end;                         %NEW: the output pixel
error = OLD(R,C)-NEW(R,C);   %error: calculate the difference by simple subtraction
```

In other words, the algorithm changes the source image as it goes through it. The error is partitioned between pixels to the right of the current pixel and pixels below the current pixel. The "diffusion" part of the error diffusion algorithm is thus two-dimensional.

	x	7/16
3/16	5/16	1/16

Floyd-Steinberg, 1975

```
OLD(R,C+1)   = round(((7/16* error) + OLD(R,C+1)));
OLD(R+1,C-1) = round(OLD(R+1,C-1) + (3/16 *error));
OLD(R+1,C)   = round(OLD(R+1,C)   + (5/16 *error));
OLD(R+1,C+1) = round(OLD(R+1,C+1) + (1/16 *error));
```

		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

Jarvis et al., 1976

```
OLD(R,C+1) = round(OLD(R,C+1) + (7/48 *error));
OLD(R,C+2) = round(OLD(R,C+2) + (5/48 *error));

OLD(R+1,C-2) = round(OLD(R+1,C-2) + (3/48 *error));
OLD(R+1,C-1) = round(OLD(R+1,C-1) + (5/48 *error));
OLD(R+1,C+0) = round(OLD(R+1,C+0) + (7/48 *error));
OLD(R+1,C+1) = round(OLD(R+1,C+1) + (5/48 *error));
OLD(R+1,C+2) = round(OLD(R+1,C+2) + (3/48 *error));

OLD(R+2,C-2) = round(OLD(R+2,C-2) + (1/48 *error));
OLD(R+2,C-1) = round(OLD(R+2,C-1) + (3/48 *error));
OLD(R+2,C+0) = round(OLD(R+2,C+0) + (5/48 *error));
OLD(R+2,C+1) = round(OLD(R+2,C+1) + (3/48 *error));
OLD(R+2,C+2) = round(OLD(R+2,C+2) + (1/48 *error));
```

		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

Stucki, 1981

```
OLD(R,C+1) = round(OLD(R,C+1) + (8/42 *error));
OLD(R,C+2) = round(OLD(R,C+2) + (4/42 *error));

OLD(R+1,C-2) = round(OLD(R+1,C-2) + (2/42 *error));
OLD(R+1,C-1) = round(OLD(R+1,C-1) + (4/42 *error));
OLD(R+1,C+0) = round(OLD(R+1,C+0) + (8/42 *error));
OLD(R+1,C+1) = round(OLD(R+1,C+1) + (4/42 *error));
OLD(R+1,C+2) = round(OLD(R+1,C+2) + (2/42 *error));

OLD(R+2,C-2) = round(OLD(R+2,C-2) + (1/42 *error));
OLD(R+2,C-1) = round(OLD(R+2,C-1) + (2/42 *error));
OLD(R+2,C+0) = round(OLD(R+2,C+0) + (4/42 *error));
OLD(R+2,C+1) = round(OLD(R+2,C+1) + (2/42 *error));
OLD(R+2,C+2) = round(OLD(R+2,C+2) + (1/42 *error));
```

Figure 12. Implementing three kernels with code

b) Code

- Matlab Implementation of Error diffusion using Floyd's and Steinberg's

```
% Matlab Implementation of Error diffusion using Floyd's and Steinberg's...
clc
clear all

%Read the image and change to gray scale image
I = imread('lena.JPG');
G = rgb2gray(I);
```

```
%Declare some variables
T = 128 % Thresholding

%Apply Zeropadding to matrix
OLD = Zeropadding_Floyd(G);


%Get the value of row and column of image then assign to variable 'row',
%'col'
[row col] = size(OLD);
NEW = zeros(size(OLD));

 for R=2: (row-1)
     for C=2 : (col-1)
            if (OLD(R,C) < T)
                 NEW(R,C) = 0;
            else
                 NEW(R,C) = 255;
            end;
            error = OLD(R,C) - NEW(R,C);

            OLD(R,C+1)   = round(((7/16* error) + OLD(R,C+1)));
            OLD(R+1,C-1) = round(OLD(R+1,C-1) + (3/16 *error));
            OLD(R+1,C)   = round(OLD(R+1,C)   + (5/16 *error));
            OLD(R+1,C+1) = round(OLD(R+1,C+1) + (1/16 *error));
     end
 end

%De-Padding Image
NEW = DePadding_Floyd(NEW);

%Show the desired image
figure
imshow(G);
title('Gray Scale Image')

%Show the halftoning image
figure
imshow(NEW);
title('Error diffusion using Floyd and Steinberg');
```

- Matlab Implementation of Error diffusion using Jarvis

```
% Matlab Implementation of Error diffusion using Jarvis
clc
clear all

%Read the image and change to gray scale image
I = imread('lena.JPG');
G = rgb2gray(I);

T = 128; % Threshold

%Apply Zeropadding to matrix
OLD = ZeroPadding_Jarvis(G);
```

```
%Get the value of row and column of image then assign to variable 'row',
%'col'
[row col] = size(OLD);
NEW = zeros(size(OLD));


 for R =3: (row-2)
     for C = 3: (col-2)
            if (OLD(R,C) < T)
                 NEW(R,C) = 0;
            else
                 NEW(R,C) = 255;
            end;

            error = OLD(R,C) - NEW(R,C);

             OLD(R,C+1) = round(OLD(R,C+1) + (7/48 *error));
             OLD(R,C+2) = round(OLD(R,C+2) + (5/48 *error));

             OLD(R+1,C-2) = round(OLD(R+1,C-2) + (3/48 *error));
             OLD(R+1,C-1) = round(OLD(R+1,C-1) + (5/48 *error));
             OLD(R+1,C+0) = round(OLD(R+1,C+0) + (7/48 *error));
             OLD(R+1,C+1) = round(OLD(R+1,C+1) + (5/48 *error));
             OLD(R+1,C+2) = round(OLD(R+1,C+2) + (3/48 *error));

             OLD(R+2,C-2) = round(OLD(R+2,C-2) + (1/48 *error));
             OLD(R+2,C-1) = round(OLD(R+2,C-1) + (3/48 *error));
             OLD(R+2,C+0) = round(OLD(R+2,C+0) + (5/48 *error));
             OLD(R+2,C+1) = round(OLD(R+2,C+1) + (3/48 *error));
             OLD(R+2,C+2) = round(OLD(R+2,C+2) + (1/48 *error));

     end
 end

%DePadding Jarvis
NEW = DePadding_Jarvis(NEW);

%Show the desired image
figure
imshow(G);
title('Gray Scale Image')

%Show the halftoning image
figure
imshow(NEW);
title('Error diffusion using Jarvis');
```

- Matlab Implementation of Error diffusion using Stucki

```
% Matlab Implementation of Error diffusion using Stucki
clc
clear all

%Read the image and change to gray scale image
I = imread('lena.JPG');
G = rgb2gray(I);
```

```
T = 128; % Threshold

%Apply Zeropadding to matrix
OLD = ZeroPadding_Jarvis(G);


%Get the value of row and column of image then assign to variable
'row',
%'col'
[row col] = size(OLD);
NEW = zeros(size(OLD));


 for R =3: (row-2)
     for C = 3: (col-2)
            if (OLD(R,C) < T)
                 NEW(R,C) = 0;
            else
                 NEW(R,C) = 255;
            end;

            error = OLD(R,C) - NEW(R,C);

             OLD(R,C+1) = round(OLD(R,C+1) + (8/42 *error));
             OLD(R,C+2) = round(OLD(R,C+2) + (4/42 *error));

             OLD(R+1,C-2) = round(OLD(R+1,C-2) + (2/42 *error));
             OLD(R+1,C-1) = round(OLD(R+1,C-1) + (4/42 *error));
             OLD(R+1,C+0) = round(OLD(R+1,C+0) + (8/42 *error));
             OLD(R+1,C+1) = round(OLD(R+1,C+1) + (4/42 *error));
             OLD(R+1,C+2) = round(OLD(R+1,C+2) + (2/42 *error));

             OLD(R+2,C-2) = round(OLD(R+2,C-2) + (1/42 *error));
             OLD(R+2,C-1) = round(OLD(R+2,C-1) + (2/42 *error));
             OLD(R+2,C+0) = round(OLD(R+2,C+0) + (4/42 *error));
             OLD(R+2,C+1) = round(OLD(R+2,C+1) + (2/42 *error));
             OLD(R+2,C+2) = round(OLD(R+2,C+2) + (1/42 *error));

     end
 end

%DePadding Jarvis
NEW = DePadding_Jarvis(NEW);

%Show the desired image
figure
imshow(G);
title('Gray Scale Image')

%Show the halftoning image
figure
```

```
imshow(NEW);
title('Error diffusion using Stucki');
```

c) Results

Figure 13. Half toning image using kernels Floyd (left), Jarvis (middle) and Stucki(right)

d) Discussion

After apply three kernels Floyd-Steinberg, Jarvis and Stucki, three desired images have very good visual quality.

There are many traditional approaches to assess the image quality based on error-sensitivity such as mean squared error (MSE) and peak signal-to-noise- ration (PSNR). However, these metrics has several limitations because these methods are based on pixel differences and do not take into account the spatial structure and human visual characteristics [1], so I will use the structural similarity (SSIM) as a widely used concept of image quality assessment.

STT	Kernels	SSIM Index
1	Floyd-Steinberg	0.0289
2	Jarvis	0.0371
3	Stucki	0.0347

By using the SSIM index, in the “lena” image, the Jarvis kernel gives a better image quality than the others one with the highest index – 0.0371. Floyd-Steinberg kernel produces a little lower image quality than Stucki kernel. Therefore, in the “lena” picture, we can apply the Jarvis kernel to convert gray scale image into binary image with the improved image quality.

3. References

[1] L. L. Zhengyou Wang , Shuang Wu, Yanhui Xia, Zheng Wan and Cong Cai, "A New Image Quality Assessment Algorithm based on SSIM and Multiple Regressions,"

International Journal of Signal Processing, Image Processing and Pattern Recognition, vol. 8, pp. 221-230, 2004.

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[3] https://engineering.purdue.edu/~bouman/grad-labs/Image-Halftoning/pdf/lab.pdf

[4] https://www.cs.princeton.edu/courses/archive/fall00/cs426/lectures/dither/dither.pdf