Purdue University

ECE 637 Laboratory Exercise 8
Image Halftoning

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March 3, 2017

1 Introduction

Nothing to report for this section.

2 Image Fidelity Metrics

Nothing to report for this section.

3 Thresholding and Random Noise Binarization

The simplest method of converting a grayscale image to a binary image is by thresholding, it is a two-level (one-bit) quantization process.

3.1 RESULT RISPLAY

Figure 3.1: The original image

Figure 3.2: The halftoning image with a threhold of 127

And the RMSE and Fidelity Values are as follows:

$$\begin{aligned} RMSE &= 87.3933 \\ Fidelity &= 77.3371 \end{aligned} \tag{3.1}$$

3.2 FIDELITY.M

```
function d = fidelity(img,b)
img = 255*(img/255).^2.2;

h = zeros(7);
```

```
    temp = 0;
    for i = -3:3
    for j = -3:3
    h(i+4,j+4) = exp(-(i^2+j^2)/4);
    temp = temp + h(i+4,j+4);
    end
    end
    h = h/temp;

    img = imfilter(img,h);
    b = imfilter(b,h);
    img = 255*(img/255).^(1/3);
    b = 255*(b/255).^(1/3);

    c = sum(sum((img - b).^2));
    [m n] = size(img);
    d = sqrt(c/(m*n));

    end
```

4 Ordered Dithering

The goal in halftoning is to give the impression of grayscale tones while using only black and white pixels. Although the random thresholding technique described before can produce this effect, it is not often used in real applications since it yields very noisy results. In this section, we will learn and utilize a better class of halftoning techniques known as ordered dithering. The Bayer index matrices of size 2X2 is:

$$Bayer_2 = \begin{bmatrix} 1 & 2 \\ 3 & 0 \end{bmatrix}$$

The Bayer index matrices of size 4X4 is:

$$Bayer_4 = \begin{bmatrix} 5 & 9 & 6 & 10 \\ 13 & 1 & 14 & 2 \\ 7 & 11 & 4 & 8 \\ 15 & 3 & 12 & 0 \end{bmatrix}$$

The Bayer index matrices of size 8X8 is:

$$Bayer_8 = \begin{bmatrix} 21 & 37 & 25 & 41 & 22 & 38 & 26 & 42 \\ 53 & 5 & 57 & 9 & 54 & 6 & 58 & 10 \\ 29 & 45 & 17 & 33 & 30 & 46 & 18 & 34 \\ 61 & 13 & 49 & 1 & 62 & 14 & 50 & 2 \\ 23 & 39 & 27 & 43 & 20 & 36 & 24 & 40 \\ 55 & 7 & 59 & 11 & 52 & 4 & 56 & 8 \\ 31 & 47 & 19 & 35 & 28 & 44 & 16 & 32 \\ 63 & 15 & 51 & 3 & 60 & 12 & 48 & 0 \end{bmatrix}$$

Figure 4.1: Result of Bayer 2X2 matrix

Figure 4.2: Result of Bayer 4X4 matrix

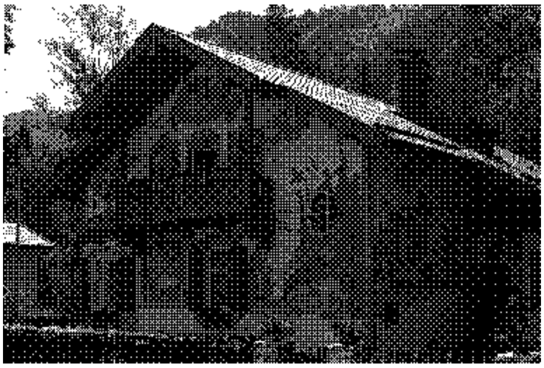

Figure 4.3: Result of Bayer 8X8 matrix

And the RMSE and Fidelity Values are as follows:

$$\begin{aligned} RMSE_2 &= 97.6690 \\ Fidelity_2 &= 50.0569 \end{aligned} \tag{4.1}$$

$$\begin{aligned} RMSE_4 &= 101.0069 \\ Fidelity_4 &= 16.5583 \end{aligned} \tag{4.2}$$

$$\begin{aligned} RMSE_8 &= 100.9145 \\ Fidelity_8 &= 14.6918 \end{aligned} \tag{4.3}$$

5 Error Diffusion

Another class of halftoning techniques are called error diffusion. In this method, the pixels are quantized in a specific order , and the residual quantization error for the current pixel is propagated forward to local unquantized pixels. This keeps the local average intensity of the binary image close to the original grayscale image. In this section, we will be to display a calibrated color image from a known illuminant spectrum and the reflectance coefficients at each point in the image.

5.1 Code Listing

```
clc
clear
I0 = imread('house.tif');
I0 = double(I0);
I = (I0/255).^(2.2)*255;
```

```
[r,c] = size(I);


for i = 2:r-1
for j = 2:c-1
if I(i,j) > 127
diff = - 255 + I(i,j);
I(i,j) = 255;
else
diff = I(i,j);
I(i,j) = 0;
end
I(i+1,j) = 5/16*diff + I(i+1,j);
I(i,j+1) = 7/16*diff + I(i,j+1);
I(i+1,j+1) = 1/16*diff + I(i+1,j+1);
I(i+1,j-1) = 3/16*diff + I(i+1,j-1);
end
end

imshow(I(2:r-1,2:c-1))
truesize
imwrite(I,'i.tif')

temp = 0;
for i = 1:r
for j = 1:c
temp = temp + (I0(i,j) - I(i,j))^2/(r*c);
end
end
RMSE = sqrt(temp)
fidelity(I0,I)
```

5.2 Result Display

Figure 5.1: The original image

Figure 5.2: The Error Diffusion Image

And the RMSE and Fidelity Values are as follows:

$$\begin{aligned} RMSE &= 98.4725 \\ Fidelity &= 12.8448 \end{aligned} \tag{5.1}$$

5.3 RMSE AND FIDELITY COMPARISON

	RMSE	Fidelity
Simple Threhold	87.3933	77.3371
2×2 Ordered Dithering	97.6690	50.0569
4×4 Ordered Dithering	101.0069	16.5583
8×8 Ordered Dithering	100.9145	14.6918
Error Diffusion	98.4725	12.8448

Table 5.1: List of Region of Image with different T

According to the results, the RMSE values do not change with different method, while the fidelity values change a lot through different method. And we can also conclude that the fidelity values is related to the halftoning quality. The halftoning images with lower fidelity value looks more realistic and have higher resolution.