ECE 637 Digital Image Processing Laboratory: Image Halftoning

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1 Introduction

Nothing due for report.

2 Image Fidelity Metrics

Nothing due for report.

3 Thresholding and Random Noise Binarization

In this section, the technique of using thresholding to convert a grayscale image to a binary image is explored. Using a single threshold value, a grayscale image is converted to a binary image associated with root mean square error (RMSE) and fidelity value. These values are also calculated.

3.1 Original Image vs. Threshold Image

(a) Original house.tif (b) Threshold Image using T = 127

Figure 1: Original and Threshold Image

3.2 Compute RMSE and Fidelity Values

$$RMSE = 87.3933$$
$$fidelity = 77.3371$$

3.3 Code listing

3.3.1 fidelity.m

```
function [fid] = fidelity(f,b)
  f = double(f);
  b = double(b);

  fl = 255 * (f / 255).^2.2;

  sigma = 2;
  [I J] = meshgrid(-3:1:3, -3:1:3);
  h = exp(-(I.^2 + J.^2)/2/sigma);
  h = h / sum(h(:));

  flh = conv2(fl, h, 'same');
  blh = conv2(b, h, 'same');

  flt = 255 * (flh / 255).^(1/3);
  blt = 255 * (blh / 255).^(1/3);

  [m, n] = size(flt);

  fid = sqrt((1 / (n * m)) * sum(sum((flt - blt).^2)));

end
```

3.3.2 sec31.m

```
% Section 3.1 %

clear all;
close all;

img = imread('house.tif');
[m, n] = size(img);

graymap = [0:255;0:255;0:255]'/255;
colormap(graymap);
img_thres = (img > 127) * 255;
image(img_thres);
truesize
imwrite(img_thres, '../report/house_t_127.tif');

img_d = double(img);
img_thres_d = double(img_thres);

rmse = sqrt((1 / (n * m)) * sum(sum((img_d - img_thres_d).^2)));

fid = fidelity(img, img_thres);
```

4 Ordered Dithering

In this section, the method of using ordered dithering is explored.

4.1 Compute Bayer Index Matrices

$$I_2 = \begin{bmatrix} 1 & 2 \\ 3 & 0 \end{bmatrix}$$

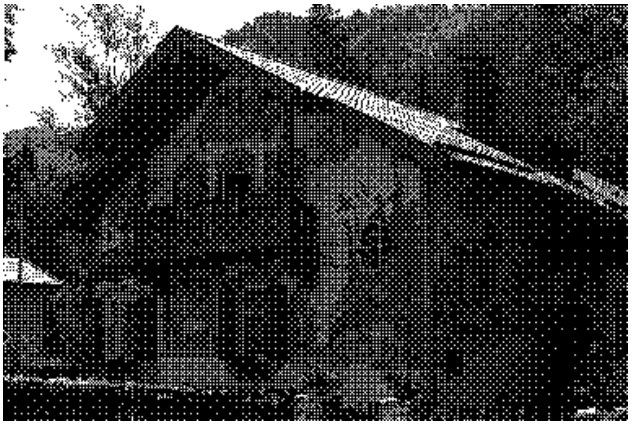
$$I_4 = \begin{bmatrix} 5 & 9 & 6 & 10 \\ 13 & 1 & 14 & 2 \\ 7 & 11 & 4 & 8 \\ 15 & 3 & 12 & 0 \end{bmatrix}$$

$$I_8 = \begin{bmatrix} 21 & 37 & 25 & 41 & 22 & 38 & 26 & 42 \\ 53 & 5 & 57 & 9 & 54 & 6 & 58 & 10 \\ 29 & 45 & 17 & 33 & 30 & 46 & 18 & 34 \\ 61 & 13 & 49 & 1 & 62 & 14 & 50 & 2 \\ 23 & 39 & 27 & 43 & 20 & 36 & 24 & 40 \\ 55 & 7 & 59 & 11 & 52 & 4 & 56 & 8 \\ 31 & 47 & 19 & 35 & 28 & 44 & 16 & 32 \\ 63 & 15 & 51 & 3 & 60 & 12 & 48 & 0 \end{bmatrix}$$

4.2 Three Halftoned Imaged by Three Dither Patterns

(a) Halftoned Image by 2 by 2 Bayer Index Matrix

(b) Halftoned Image by 4 by 4 Bayer Index Matrix



(c) Halftoned Image by 8 by 8 Bayer Index Matrix

Figure 2: Halftoned Image by Dither Patterns

4.3 Compute RMSE and Fidelity Values

$$RMSE_{22} = 97.6690$$
$$fidelity_{22} = 50.0569$$

$$RMSE_{44} = 101.0069$$
$$fidelity_{44} = 16.5583$$

$$RMSE_{88} = 100.9145$$
$$fidelity_{88} = 14.6918$$

5 Error Diffusion

5.1 Code listing

5.1.1 errDiffusion.m

```
function [out] = errDiffusion(in)
  inl = 255 * (double(in) / 255).^2.2;
  out = padarray(inl, [1 1]);

  for i = 2:size(out,1) - 1
    for j = 2:size(out,2) - 1
      orig = out(i,j);
      out(i,j) = (out(i,j) > 127) * 255;
      e = orig - out(i,j);
      out(i,j+1) = out(i,j+1) + e*(7/16);
      out(i+1,j+1) = out(i+1,j+1) + e*(1/16);
      out(i+1,j) = out(i+1,j) + e*(5/16);
      out(i+1,j-1) = out(i+1,j-1) + e*(3/16);
    end
  end

  out = out(2:end-1, 2:end-1);

end
```

5.1.2 sec51.m

```
% Section 5.1 %

clear all;
close all;

fg = imread('house.tif');
fo = errDiffusion(fg);
[m, n] = size(fg);

graymap = [0:255;0:255;0:255]'/255;
colormap(graymap);
image(fo);
truesize
```

```
imwrite(fo, '../report/house_ed.tif');

rmse = sqrt((1 / (n * m)) * sum(sum((double(fg) - fo).^2)));
fid = fidelity(double(fg), fo);
```

5.2 Original Image vs. Error Diffused Image

(a) Original house.tif

(b) Error Diffusion Image

Figure 3: Orignal and Error Diffusion Image

5.3 Compute RMSE and Fidelity Values

$$RMSE = 98.8471$$
$$fidelity = 13.4273$$

5.4 RMSE and Fidelity Comparison

	Threshold	2x2 Dithering	4x4 Dithering	8x8 Dithering	Error Diffusion
RMSE	87.3933	97.6690	101.0069	100.9145	98.8471
Fidelity	77.3371	50.0569	16.5583	14.6918	13.4273

Table 1: RMSE and Fidelity Comparison Table

Observation: it is clear from the table that the RMSE does not change significantly for different methods. However, fidelity does change and it can be observed that the threshold method has the highest fidelity value which is counter-intuitive since visually speaking, it's the worst.