ME5405 Machine Vision

Exercise 1: Fundamentals of Digital Imaging

The questions are intended for your exercises. You are encouraged to discuss your solution and any question you may have on this exercise in IVLE forum. – CK Chui

Question 1.
Suppose that the resolution of a high-definition TV system is 1125 lines in the vertical direction. The width-to-height aspect ratio of the image is 16:9. The system displays a full color image every 1/30 sec for each of the red, green, and blue component images. Each pixel in the color image has 24 bits of intensity resolution, 8 bits each for a red, a green, and a blue image. How many bits are required to store a 120-minute movie?

Question 2.
Suppose that a flat area with center at (x_0, y_0) is illuminated by a light source with intensity distribution:

$$i(x, y) = Ke^{-[(x - x0)2 + (y - y0)2]}.$$

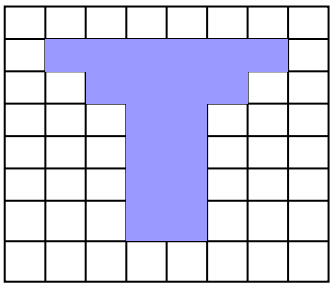
Assume for simplicity that the reflectance of the area is constant and equal to 1.0, and let $K = 255$. The resulting image is digitalized with k bits of intensity resolution.

Sketch the image if the image is quantized into 4 intensity levels.

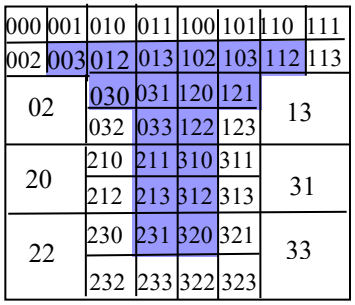
False contouring is quantization noise. It refers to the creation of false edges or outlines not present in the original scene. It is reasonable to assume that human eye can detect an abrupt change of 8 intensity levels between adjacent pixels, what value of k will cause visible false contouring?

Question 3.
Image data can be represented by a list of rectangular spatial cells. The most common method of representing an image space is by a 2D array (or a matrix) of pixels (rectangular cells with fixed size). Quadtree is a generalized form of spatial enumeration in which the disjoint cells are not necessary rectangular or identical.

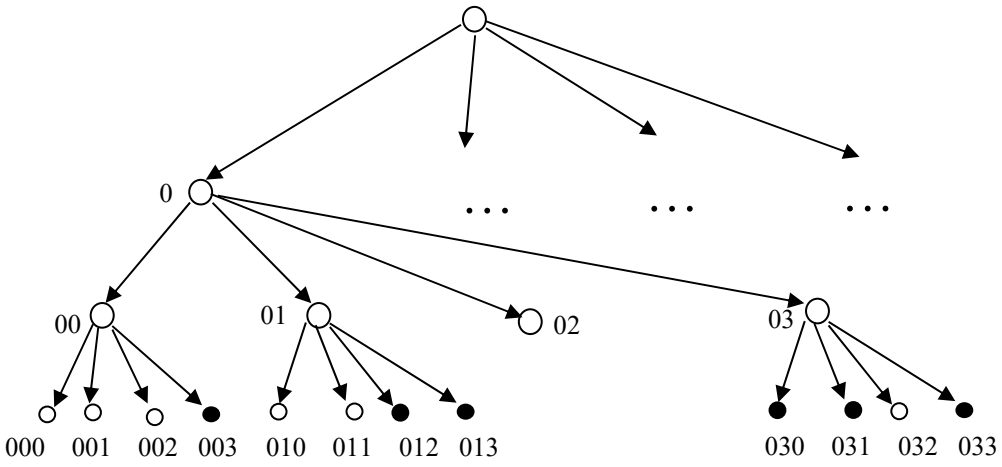
Compare the memory usage in representing the image of Figure 1(a) using matrix and quadtree. You may assume any type of implementation.
A quadtree can be viewed as a collection of rectangles that approximates an object in the image. Figure 1 is an example of the quadtree of a simple object.



(a) A simple image with an object



(b) Recursive subdivision of the image



(c) A segment of the quadtree for the object in (a)

Figure 1. Quadtree image representation

The resultant quadtree has three types of nodes:

(a) black or occupied node
(b) white or empty node
(c) gray or intermediate node

Question 4.
Write an algorithm to determine the histogram of an image represented using quadtree. Compare the performance of this algorithm with that of image representation using matrix.

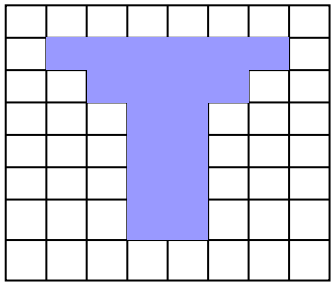
Question 5.
Given that the intensities of the image in Figure 1(a) is as follows (Figure 2). Perform histogram equalization on the image.

1	0	0	0	0	0	0	1
0	2	2	3	3	3	2	0
0	0	2	4	4	2	0	1
0	0	0	4	4	0	0	0
0	1	0	4	4	0	1	0
0	0	0	3	3	0	0	0
1	0	1	2	2	0	1	0
0	0	0	1	1	0	0	1

Figure 2. Intensities of the image in Figure 1(a)

Question 6.
Given the following image (Image A) with gray levels between 0 (black) and 15 (white) as shown in Figure 3.

Determine the histograms of Image A and the negative of Image A. Can gray level transforms be determined to bring these two histograms into each other? Briefly explain your answer.



(a) A simple image with an object

1	0	0	0	0	0	0	1
0	8	8	9	9	9	8	0
0	0	8	9	9	8	0	1
0	0	0	9	9	0	0	0
0	1	0	9	9	0	1	0
0	0	0	8	8	0	0	0
1	0	1	7	7	0	1	0
0	0	0	5	5	0	0	1

(b) Pixel intensities of the image

Figure 3. Image A

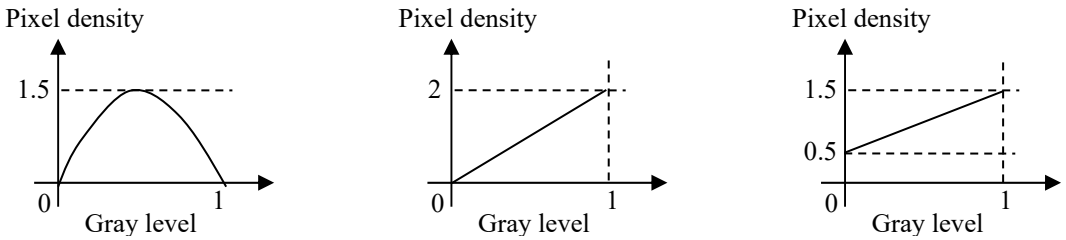
Question 7.
Design a point processing transform to convert pixels with gray level less than 6 to black, and leave the pixels within the object unchanged. Determine the histogram of this transformed image.

Question 8.
Design a linear point processing transform to stretch the gray levels in the object to cover the whole available range. Has the contrast of the image improved? Briefly explain your answer.

Question 9. The following matlab codes will display Image A as a gray level image with gray level between 0 (black) and 255 (white). Briefly explain how this could affect the contrast of the original image with gray level between 0 and 16.

```
image(ImageA);
colormap(gray);
```

Given the three histograms defined as continuous functions in the interval [0,1] as shown in Figure 4. Two gray level transforms can be determined to bring the two histograms (Figure 4(a) and Figure 4(b)) into each other. This is equivalent to finding the functions z=z(r) and r=r(z).



(a) $p(r) = \frac{\pi}{2}\sin(\pi r)$ (b) $p(z) = 2z$ (c)

Figure 4. Histograms defined as continuous functions in the interval [0,1].

Question 10. Determine the two gray level transforms that can bring the histograms in Figure 4(a) and Figure 4(b) into each other.

(Hints: $\int_0^r \frac{\pi}{2}\sin(\pi w)dw = \frac{1}{2}(1-\cos(\pi r))$, $\int x dx = \frac{x^2}{2}$)

Question 11. The histograms in Figure 4(b) can also be converted to the histogram in Figure 4(c). Design the point processing transform that can achieve that.

(Hints: $\int x dx = \frac{x^2}{2}$, $\int \frac{1}{2} dx = \frac{x}{2}$)

Question 12.
The following photo has 4 different shades indicated as (a), (b), (c) and (d) in Figure 5. Suppose that the segment indicated as (b) has the right exposure. Explain how by transforming the pixel intensities of the image, we can obtained the shades indicated in segments (a), (c) and (d).

(a) (b) (c) (d)

Figure 5. Photo image with different shades.