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EXAMINER SECTION
Sheet code: ______________________________

61FIT4IPR
Image Processing & Recognition – Fall 2021
Midterm Exam (SAQ)– Form A1 (Online)

Time: 90 Minutes

<u>Instructions:</u>

- **The exam consists of 6 problems on 3 pages. Most problems are subdivided**

  into sections like 1(a), 1(b), etc. Make sure your exam is complete before you begin.
- **Turn on your camera. Stay in a private room during the exam. Prepare**

  student ID card with you.
- **Use Microsoft Word/LibreOffice Writer/AbiWord as your typesetting. For**

  your submission, please convert your answer sheet to PDF file (*.pdf), and change its name to "student id.pdf".
- **Add your fullname, class, and student ID to your answer sheet.**

Honor Statement:
By signing below you confirm that you have neither given nor received any unauthorized assistance on this exam. Furthermore, you agree not to discuss this exam (or chat in any messaging platforms) with anyone until the exam testing period is over. In addition, your student ID card may be checked at any time (show to your camera) by any testing center proctor or FIT's instructor.

STUDENT SECTION

- NAME: Nguyễn Thị Kim Oanh
- ID: 1701040130
- CLASS: 4C-17
- SIGNATURE: Oanh

1 Question 1

A CCD camera chip of dimension 7 × 7 mm and 1024 × 1024 sensing elements, is focused on a square, flat area, located 0.5 away. The camera is equipped with a 35-mm lens. How many line pairs per mm will this camera be able to resolve? (*Hint:* Model the imaging process as in Figure 1, with the focal length of the camera lens substituting for the focal length of the
eye.)

⇨ **Answer:**

We have distance: 0.5 m = 500 mm

Because dimension 7 × 7 mm and camera is equipped with a 35-mm lens

$\frac{7\text{mm}}{35\text{mm}} = \frac{z}{500\text{mm}}$ => z = 100 mm. (The target size is 100 mm on the side)

Thus total of 1024 elements per line => The resolution of 1 line is: $\frac{1024}{100}$or approximately 10 elements/mm.

For line pairs they are divided by 2.

Therefore, number of line pairs per mm = 5 line pairs/mm.

2 Question 2

Suppose that a given automated imaging application requires a minimum resolution of 5 line pairs per mm to be able to detect features of interest in objects viewed by the camera. The distance between the focal center of the camera lens and the area to be imaged is 1 m. The area being imaged is 0.5 × 0.5 m. You have available a 200 mm lens, and your job is to pick an appropriate CCD imaging chip. What is the minimum number of sensing elements and square size, *d*×*d*, of the CCD chip that will meet the requirements of this application? (*Hint:* Model the imaging process as in the Figure 1, and assume for simplicity that the imaged area is square.)

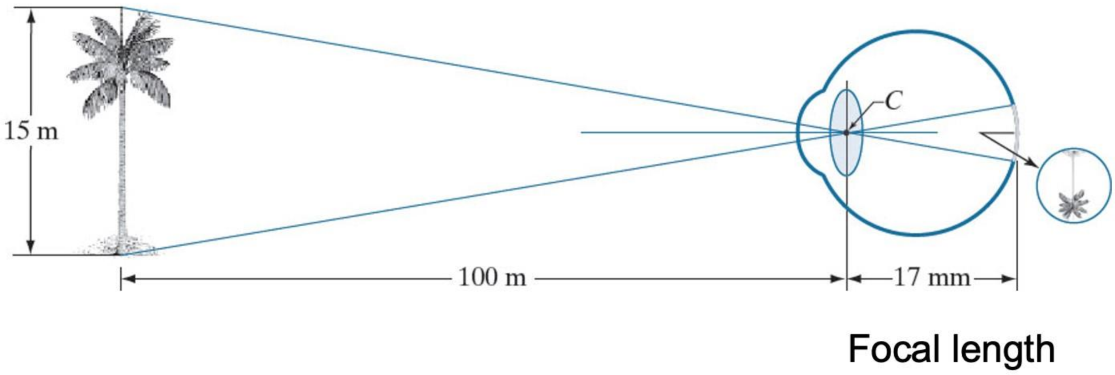

Figure 1: Graphical representation of the eye looking at a palm tree. Point C is the focal center of the lens.

⇨ **Answer:**

The minimum resolution of the camera is 5 lines pairs/mm

⇨ the solutions of a line = $\frac{\text{number of element per line}}{\text{target size}}$

<=> 5 x 2 = $\frac{\text{number of element per line}}{\text{500mm}}$ (given target size = 0.5m = 500mm)

We have the number of element per line = 10 x 500 = 5000 elements/ line.

⇨ The minimum number of sensing element of the CCD chip = 5000

Given that:

The size of the CCD chip = d x d and the camera is equipped with a 200mm lens.

The distance between the focal center of camera, lens and the area to be image is 1m = 1000mm

So, from the geometry, $\frac{d}{200} = \frac{\text{Target size}}{\text{Distance}} = \frac{500}{1000}$

⇨ d = $\frac{500\text{x}200}{1000}$ = 100mm.

As a result, the CCD camera chip's dimensions are 100mmx100mm.

3 Question 3

Propose a method for extracting the bit planes of an image based on converting the value of its pixels to binary. Find all the bit planes of the following 4-bit image:

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$$I_{4bit} = \begin{pmatrix} 0 & 1 & 8 & 6 \\ 2 & 2 & 1 & 1 \\ 1 & 15 & 14 & 12 \\ 3 & 6 & 9 & 10 \end{pmatrix}.$$

Answer:

We need to convert each number to binary, and to form the plans by looking at the least significant bit (LSB) as following:

0 1 0 0	0 0 0 1	0 0 0 1	0 1 1 0
0 0 1 1	1 1 0 0	0 0 0 0	0 0 0 0
1 1 0 0	0 1 1 0	0 1 1 1	0 1 1 1
1 0 1 0	1 1 0 1	0 1 0 0	0 0 1 1
LSB plane			MSB plane

Where the rightmost bit plan contains the most significant bit (MSB). Let look at the example: the 4^{th} element in the first row of each plan corresponds to the sequence: 1 1 0 0 from the LSB to MSB. This is the binary of decimal number 3, which is the value of the pixel at that location in the given image.

4 Question 4

Use the histogram equalization to enhance the following image:

$$I = \begin{pmatrix} 0 & 2 & 1 & 6 & 5 & 3 \\ 1 & 4 & 3 & 1 & 10 & 7 \\ 2 & 7 & 8 & 0 & 1 & 9 \\ 5 & 4 & 6 & 5 & 2 & 7 \\ 2 & 0 & 4 & 2 & 7 & 5 \end{pmatrix}.$$

8 10 9 0 6 3

Show all derivation steps and the enhanced image.

Answer:

The enhance image

1	2	1	5	4	3
1	3	3	1	7	5
2	5	6	1	1	6
4	3	5	4	2	5
2	1	3	2	5	4
6	7	6	1	5	3

Grey level	0	1	2	3	4	5	6	7	8	9	10
Frequency	4	4	5	3	3	4	3	4	2	2	2

Total number of pixels: N = 36

Grey level (r)	Frequency	PDF (P() = /N)	CDF	CDF * 7	Round off (s)
0	4	0.1	0.1	0.7	1

1	4	0.1	0.2	1.4	1
2	5	0.138	0.338	2.366	2
3	3	0.08	0.418	2.926	3
4	3	0.08	0.498	3.486	3
5	4	0.1	0.598	4.186	4
6	3	0.08	0.678	4.746	5
7	4	0.1	0.778	5.446	5
8	2	0.05	0.828	5.796	6
9	2	0.05	0.878	6.146	6
10	2	0.05	0.958	6.706	7

5 Question 5

Given the following kernel and image:

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$$w = \begin{pmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{pmatrix}, f = \begin{pmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}.$$

Find the convolution of the two.

Answer:

To calculate the convolution of kernel w and image f, we have to rotate kernel w 180° to apply matrix multiple rule.

k	sk	nk	P(sk)
0	0	4	0.11
1	1/10	4	0.11
2	2/10	5	0.14
3	3/10	3	0.08
4	4/10	3	0.08
5	5/10	4	0.11
6	6/10	3	0.08
7	7/10	4	0.11
8	8/10	2	0.06
9	9/10	2	0.06
10	1	2	0.06

⇨ Total = 36

Applying the transformation, we have

S0 = 0.11 -> 1/10

S1 = 0.11 + 0.11 = 0.22 -> 2/10

S2 = 0.22 + 0.14 = 0.36 -> 4/10

S3 = 0.36 + 0.08 = 0.44 -> 4/10

S4 = 0.44 + 0.08 = 0.52 -> 5/10

S5 = 0.52 + 0.11 = 0.63 -> 6/10

S6 = 0.63 + 0.08 = 0.71 -> 7/10

S7 = 0.71 + 0.11 = 0.82 -> 8/10

S8 = 0.82 + 0.06 = 0.88 -> 9/10

S9 = 0.88 + 0.06 = 0.94 -> 1

S10 = 0.94 + 0.06 = 1 -> 1

With this transformation, the output image will have histogram:

K	Sk	nk	P(rk)
0	1/10	4	0.11
1	2/10	4	0.11
2	4/10	8	0.22
3	5/10	3	0.08
4	6/10	4	0.11
5	7/10	3	0.08
6	8/10	4	0.11
7	9/10	2	0.06
8	1	4	0.11

So we got the result matix below:

(9 12 12 12 9
12 16 16 16 12
12 16 16 16 12
12 16 16 16 12
9 12 12 12 9)

6 Question 6

The white bars in the test pattern shown in Figure 2, are 7 pixels wide and 210 pixels high. The separation between bars is 17 pixels. What would this image look like after application of

1. A 3 × 3 arithmetic mean filter?
2. A 7 × 7 arithmetic mean filter?
3. A 9 × 9 arithmetic mean filter?

Answer:
Explain.

Note: This problem and the ones that follow it, related to filtering this image, may seem a bit tedious. However, they are worth the effort, as they help develop a real understanding of how these filters work. After you understand how a particular filter affects the image, your answer can be a brief verbal description of the result. For example, "the resulting image will consist of vertical bars 3 pixels wide and 206 pixels high." Be sure to describe any deformation of the bars, such as rounded corners. You may ignore image border effects, in which the filter neighborhoods only partially contain image pixels.

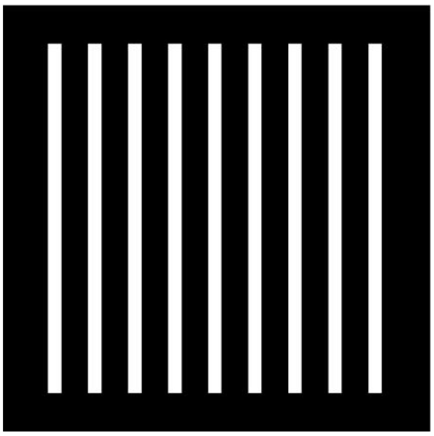

Figure 2: Test pattern

7 Note

Simulation in any languages (MATLAB, Python, C, Java) will get bonus marks.