THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
LEVEL 05
FINAL EXAMINATION 2010/2011

# MEX5271 – MACHINE VISION

DATE: 10TH MARCH 2011
TIME: 0930-1230 HRS
DURATION: THREE HOURS

**READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THE QUESTION PAPER**

The question paper has **eight** questions
Answer **five** questions only.

## Question 01

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | 10 | 09 | 08 | 01 | 01 | 00 |
| 15 | 14 | 13 | 15 | 02 | 02 | 02 |
| 14 | 01 | 12 | 14 | 00 | 03 | 00 |
| 13 | 15 | 11 | 12 | 01 | 02 | 01 |
| 14 | 15 | 01 | 13 | 01 | 00 | 04 |

Fig. 1

Consider the 5 x 7 image shown in Fig. 1 above, with grey levels from 0 to 15. This image is composed of a bright 5 x 4 part on the left and a dark 5 x 3 part on the right.

(a) Plot the histogram of this image and that of its inverse.

(b) Design a point processing to transform the left part of the image to white and the right part to black, and show the resulting image (round the numbers to the closest integer).

(c) After step (b) above, the left part of the image is not completely white due to the presence of noise. Use a 3 x 3 average mask to filter this noise.

(d) Threshold the image resulting from step (c) above to make the left part completely white and the right part completely black. Show the resulting image.

(e) Process the image resulting from step (b) above using a 3 x 3 median filter. Compare your result with the result from (c). Is step (d) also needed in this case?

(f) Design a 3 x 3 mask and describe how you can use it to detect the "vertical edge" separating the left and right parts of the image resulting from step (e). What mask would you use to detect horizontal edges?

**Question 02**

(a) Describe how one could determine, with structured lighting, the depth of the groove of a channel shown in Fig. 2. Use an appropriate sketch to illustrate your method.

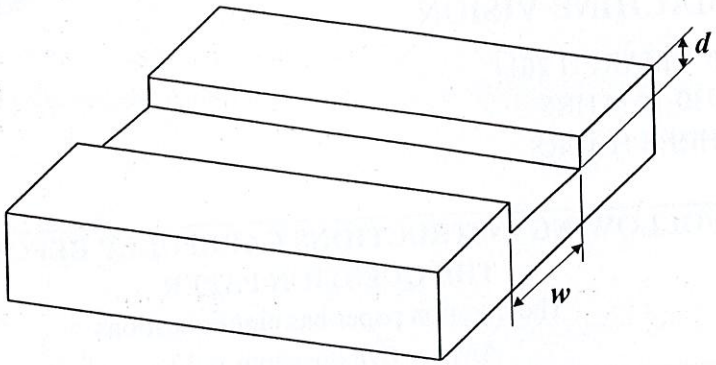



Fig. 2

(b) Consider an automated vision-based system for dimensional measurement. The system setup has an object view is a 4 cm by 4 cm square. The solid state sensor is a 512 by 512 array arranged in a 0.8 cm by 0.8 square. If the required tolerance of the measurement is 20 μm, determine whether this system setup is suitable. Explain.

(c) Consider a surface inspection system using a microscope. The vision system has a 256 by 256 sensor array, arranged in a 0.8 cm by 0.8 cm square, the lens has an $f$–stop of 16 and a magnification of 10. Determine whether the system can be used to inspect surface irregularities with maximum height of 0.05 mm. Explain.

**Question 03**

(a) A partial 2-gray level digital image is shown in Fig. 3(a), and the gray levels $a > b$. Design a 3 by 3 mask, **G**, to detect the bright line with gray level $a$, and produce an output image shown in Fig. 3(b).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $b$ | $b$ | $b$ | $a$ | $b$ | $b$ | $b$ | |
| ... | $b$ | $b$ | $b$ | $a$ | $b$ | $b$ | $b$ | ... |
| ... | $b$ | $b$ | $b$ | $a$ | $b$ | $b$ | $b$ | ... |
| ... | $b$ | $b$ | $b$ | $a$ | $b$ | $b$ | $b$ | ... |
| | $b$ | $b$ | $b$ | $a$ | $b$ | $b$ | $b$ | |

Fig. 3(a)

| | | | | | | |
|---|---|---|---|---|---|---|
| | .. | .. | .. | .. | .. | |
| ... | $0$ | $3(b-a)/2$ | $3(a-b)$ | $3(b-a)/2$ | $0$ | ... |
| ... | $0$ | $3(b-a)/2$ | $3(a-b)$ | $3(b-a)/2$ | $0$ | ... |
| ... | $0$ | $3(b-a)/2$ | $3(a-b)$ | $3(b-a)/2$ | $0$ | ... |
| | .. | . | . | .. | .. | |

Fig. 3 (b)

(b) Use the mask **G** developed in part (a) to process the partial digital images shown in Fig. 3(c) and 3(d), and show the respective output.

| | | | | | |
|---|---|---|---|---|---|
| *a* | *a* | *a* | *b* | *b* | *b* |
| *a* | *a* | *a* | *b* | *b* | *b* |
| *a* | *a* | *a* | *b* | *b* | *b* |
| *a* | *a* | *a* | *b* | *b* | *b* |
| *a* | *a* | *a* | *b* | *b* | *b* |

Fig. 3(c)

| | | | | | | |
|---|---|---|---|---|---|---|
| ... | *b* | *b* | *b* | *b* | *b* | ... |
| ... | *b* | *b* | *b* | *b* | *b* | ... |
| ... | *b* | *b* | *a* | *b* | *b* | ... |
| ... | *b* | *b* | *b* | *b* | *b* | ... |
| ... | *b* | *b* | *b* | *b* | *b* | ... |

Fig. 3(d)

Comment on the effectiveness of the mask **G** that you developed in relation to the results obtained here.

(c) Carry out the following processing:

(i) Interchange the rows and columns of mask **G** to produce a new mask **H.**
(ii) Convolve the partial image shown in Fig. 3(d), with the mask **H.**
(iii) Convolve the partial image shown in Fig. 3(d) with the mask **G.**
(iv) Do a point wise subtraction between the results of steps (ii) and (iii).

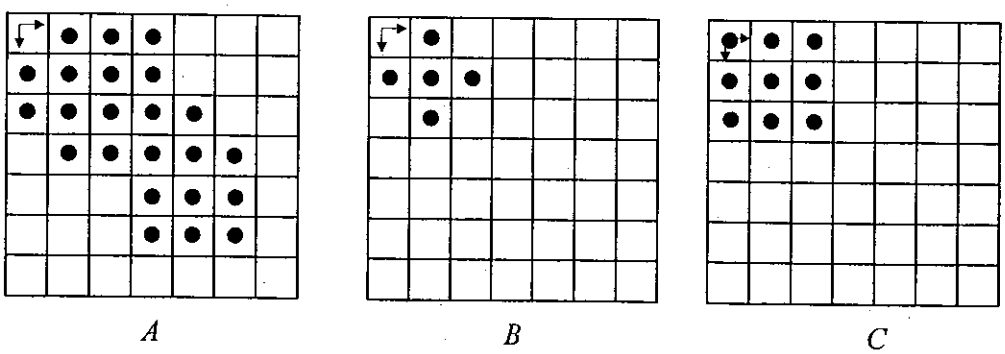
Show and discuss the result of step (iv). Can you suggest an application for this processing?

**Question 04**

(a) Fig. 4(a) Shows a digital binary image $A$, and two structural elements $B$ and $C$. Determine the results of the following morphological operations:

i. $A \circ B$
ii. $A \circ C$

What conclusion can you draw from the resulting images after the above operations.



*A* *B* *C*

Fig. 4(a)

(b) In a image noise cleaning operation, a single pixel which does not have any 8-connected neighbour is considered as a noise spot. Design a morphological operation for the noise-cleaning operation. Show clearly the structure element used in the operation.

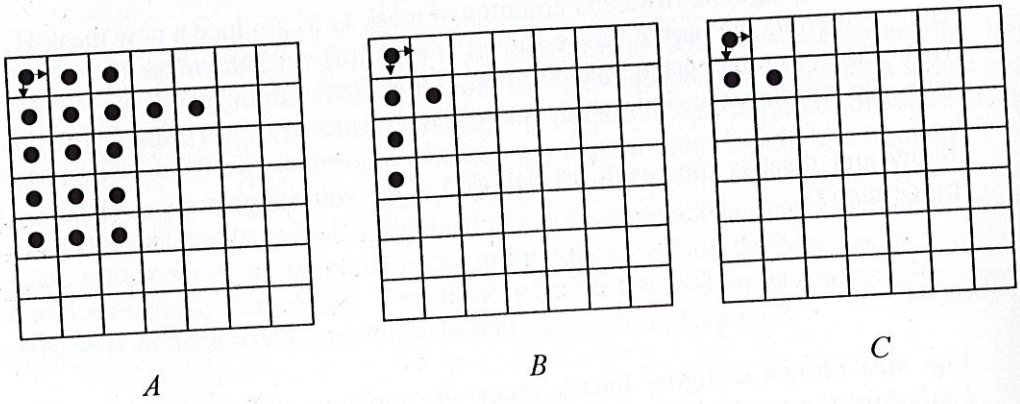
(c) Fig. 4(c) shows a digital binary image $A$, and two structural elements $B$ and $C$. Determine the results of the following morphological operations:

(i) $(A \ominus B) \ominus C$

(ii) $A \ominus (B \oplus C)$

(iii) What conclusions can be drawn from the results of parts (i) and (ii)?

(iv) Show that $A \ominus C = (A \ominus C) \bullet C$. Explain whether this result is expected?



*A* *B* *C*

Fig. 4(c)

**Question 05**

(a) Sketch the dilation of a circle of radius $r$ by a circular structuring element of radius $r/4$.

Use the same structure element to dilate a square of size $r$ x $r$, and an equilateral triangle with sides of size $r$.

(b) Repeat part (b) for erosion.

(c) For the image of a C-channel shown in Fig 5(c), determine the morphological operations that will extract its outer and inner edges with thickness $d$. Hence, derive a method which will yield an edge of thickness $2d$. Assume the thickness of every branch of the channel is much larger than $2d$.

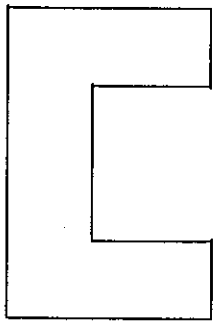


Fig. 5(c)

**Question 06**

(a) For a spatially discretised $M$ x $N$ image, denoted by $f(i, j)$, the $p^{th}$, $q^{th}$ moment is given by:

$$m_{pq} = \sum_{i=0}^{M} \sum_{j=0}^{N} i^p j^q f(i, j)$$

Fig. 6(a) and 6(b) show images of a certain geometrical shape in 2 orientations formed by arrays of gray or white pixels. For each orientation, determine the moment $m_{00}$, $m_{10}$ and $m_{01}$ and comment on your results. Use an intensity of 1 for gray pixels and 0 for white pixels. The '+' in the diagrams indicates the origin.

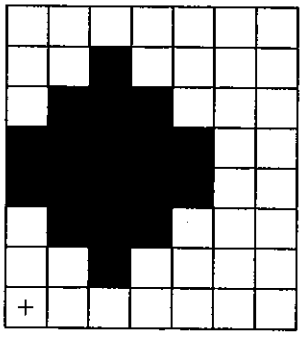



Fig. 6(a)

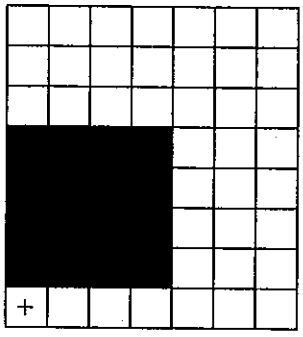



Fig.6(b)

(b) The central moments of the images shown in Fig. 6(a) and 6(b) are given below:

| | $\mu_{20}$ | $\mu_{02}$ | $\mu_{11}$ |
|---|---|---|---|
| Fig. 6(a) | 24 | 28.5 | 0 |
| Fig. 6(b) | 20 | 23 | 0 |

An invariant moment $\phi_1$ is defined as $\phi_1 = \eta_{20} + \eta_{02}$ and

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\gamma}}, \gamma = 0.5*(p+q)+1$$

Calculate the invariant parameter $\phi_1$ for each image shown in Fig. 6(a) and Fig. 6(b), and give your comments on the results.

(c) Calculate the areas and perimeters of the two images shown in Fig. 6(a) and Fig. 6(b), and hence determine the ratio Area/(Perimeter)$^2$ in each case. Comment on your results.

**Question 07**

Consider a given image $f(x, y)$, the gray level $z$ of which lies within the interval $[a, b]$. Mathematically:

$$a \leq z = f(x, y) \leq b$$

for all $x, y$ where $[a, b]$ is a sub-interval of the available range of gray level ($[z_1, z_k]$) of the system used.

(a) Find a simple linear gray level transformation expression that allows the stretching and shifting of the existing gray level interval $[a, b]$ to occupy the full available range ($[z_1, z_k]$).

(b) Determine an expression that will stretch the gray level interval $[a, b]$ to the full available range $[z_1, z_k]$, but compress the intervals $[z_1, a]$and $[b, z_k]$.

(c) Given a gray-level image, we wish to compress the gray level intervals [0, 80] and [160, 240] by a factor of 2, and expand the gray level in the interval [80, 160] by a factor of 2. Find the expressions for the required transformation. Be sure to indicate the validity of each expression.

(d) Suppose now we have an image with gray level ranges in the interval [0, 30]. Give the equations for the transformation that:

i. stretches the gray level interval [0, 10] into [0,15],
ii. shifts the interval [10, 20] to [15, 25], and
iii. compresses the interval [20, 30] into [25, 30].

Be sure to indicate the validity of each equation.

**Question 08**

(a) An engineer is asked to inspect a certain class of images generated by a machine vision system. He has decided to use digital image enhancement and has examined a set of representative images. He has found the following problems:

i. bright and isolated dots are of no interest;
ii. lack of sharpness;
iii. insufficient contrast in some images;
iv. shifts in the average gray-level value from a pre-determined value.

He wishes to correct these problems and then colour in constant red all gray levels between a given band between I1 and I2, while keeping normal tonality in the remaining gray levels. Propose a sequence of processing steps that the engineer can follow to achieve the desired goal.

(b) Consider an automated machine vision based system for the sorting of the gender of juvenile guppy. The objective is to detect the presence and the size of a small black dot at a certain part of the body. The current set up of the system provides an image capturing window measuring 2 cm by 2 cm square. The CCD camera has a solid state sensor array 0.8 by 0.8 cm square, which can have a resolution of 512 by 512, 1024 by 1024, or 2048 by 2048 pixels. For the lenses, you are only allowed to use the available sizes, which are 25 mm, 35 mm or 50 mm. If the required tolerance of the measurement is 20 μm, and the object distance should be between 100 to 125 mm, design the system by choosing the appropriate lens and sensor array resolution. You are to note that the camera (with any of the stated array size) costs much more than the lenses. In addition, the higher the resolution of the sensor array, the more expensive is the camera. Discuss briefly your design.