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Calculators may be used in this examination but must not be used to store text. Calculators with the ability to store text should have their memories deleted prior to the start of the examination.

THE UNIVERSITY OF BIRMINGHAM

Degree of BSc with Honours
Artificial Intelligence and Computer Science. Second Examination
Computer Science/Software Engineering. Second Examination
Computer Science/Software Engineering with Business Studies. Second Examination

Degree of MSc in Computer Science

06 02504

(SEM 226)
Graphics 1

Friday 29th May 2000 0939 - 1100

[Answer TWO Questions]

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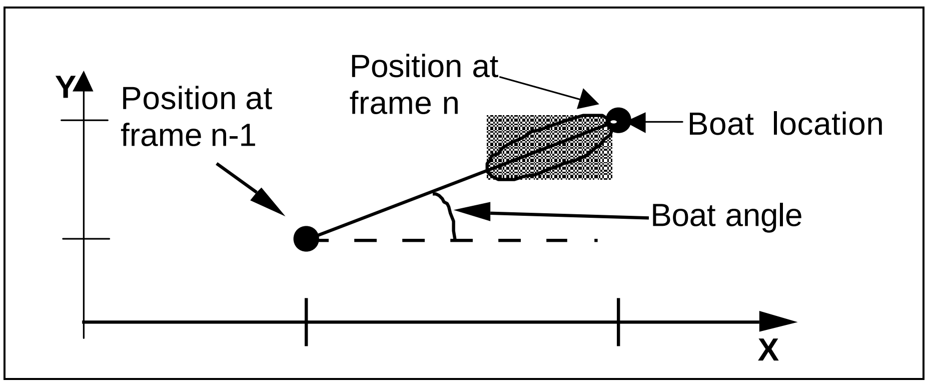
1. (a) Briefly explain the following terms:
   (i) double buffering
   (ii) an event record
   (iii) event driven program
   (iv) raster graphics
   (v) in-betweens

[10%]

You are to design an animation sequence in which a boat moves along a river.

The position of the boat is specified by a point representing its front (see the figure below). The boat's orientation is specified by the angle it makes with the x-axis of the image frame.



The shape of the river is depicted by a Bézier curve (see the Appendix) with the following control points:

$x_k = 0 \quad 10 \quad 80 \quad 100$
$y_k = 0 \quad 80 \quad 10 \quad 30$

The animation is to last 20 seconds and the key frames are to be computed in 1 second intervals.

(b) Calculate the blending functions for the given set of control points.

[10%]

(c) Calculate the position of the boat after 10 seconds of animation (in frame 10).

[10%]

Question 1 continued over the page

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(d) What is the orientation of the boat after 10 seconds of animation? Specify either the angle or its function (*tan*, *sin* or *cos*, see the Appendix). Assume that the boat is oriented along a line joining its position in frame 9 (boat position x=40, y=39) and the current frame 10 (see the figure above).

[10%]

(e) Assume the boat's position at an arbitrary frame n is (x_n,y_n) and its orientation is j_n, and that its position at frame $n+1$ is (x_{n+1},y_{n+1}) and its orientation is j_{n+1}.

Given this information, what 2-dimensional transformations need to be carried out to transform the boat from its current position and orientation at frame n to a correct position and orientation at frame $n+1$?

Specify the parameters of these transformations for the arbitrary frames n and $n+1$.

[10%]

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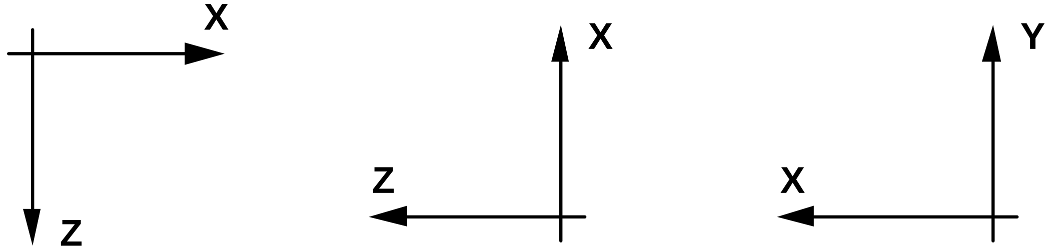
2. (a) Given below are sketches of 3-dimensional coordinate systems. State which of these sketches represent the left-handed coordinate system.



Y axis goes into the page — (A)

Y axis goes out of the page — (B)

Z axis goes into the page — (C)

[6%]

(b) Determine whether the following pair of 2-dimensional vectors is perpendicular:

$\bar{\mathbf{a}} = [\,-1 \quad 4\,]$ $\qquad \bar{\mathbf{b}} = [\,4 \quad 3\,]$

[2%]

(c) Calculate a vector normal (perpendicular) to the plane defined by the following two vectors:

$\bar{\mathbf{a}} = [\,1 \quad 0 \quad 0\,]$ $\qquad \bar{\mathbf{b}} = [\,1 \quad 1 \quad 1\,]$

[4%]

(d) Given the polygon tables shown below, sketch the 3-dimensional figure they represent. Ensure that the figure is shown in the RIGHT-handed coordinate system.

[10%]

Vertex table

	x	*y*	*z*
A	2	3	1
B	8	3	1
C	8	5	1
D	2	5	1
E	2	9	3
F	8	9	3

Edge table

	V1	*V2*
E1	A	B
E2	B	C
E3	C	D
E4	D	A
E5	A	E
E6	E	D
E7	B	F
E8	F	C
E9	E	F

Question 2 continued over the page
Question 2 continued

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(e) What transformation would you use to shift point C to the centre of the coordinate system? Define a suitable transformation matrix.

[3%]

(f) Your task is to rotate the figure defined by the polygon table in (d) by an arbitrary angle j about the axis defined by the edge AB. Using the notation of the basic transformation matrices (T, S, R_x, R_y, R_z), specify what transformations to use and in what order. State the purpose of each transformation you would use.

[10%]

(g) Define transformation matrices for rotating the figure defined by the polygon table in (d) by 45^o ($\pi/4$) about the axis defined by the edge AB. Your answer must include specific numerical parameters. See the Appendix for transformation matrix definitions.

[10%]

(h) The figure defined in (d) is to be rotated using the transformation matrices defined in (g). State precisely what *matrix* operations have to be carried out and in what order.

[5%]

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3. (a) Provide a brief description of the following terms associated with representations and data structures for digital images:
   (i) colour lookup table
   (ii) direct colour
   (iii) packed array
   (iv) alpha channel
   (v) grey level

[10%]

(b) Define the following colours using the RGB model. Assume that each colour channel has 8 bits and that the colours are fully saturated.
   (i) green
   (ii) yellow
   (iii) white

[6%]

(c) Explain briefly the key difference between the RGB and the XYZ colour models. Compute the XYZ representation of the colour defined in the RGB (normal) representation as:

$R = 1.0$
$G = 0.5$
$B = 0.0$

The transformation matrix from RGB to XYZ is

$$\begin{bmatrix} 0.41 & 0.21 & 0.02 \\ 0.36 & 0.71 & 0.12 \\ 0.18 & 0.07 & 0.95 \end{bmatrix}$$

[8%]

(d) Compute the CMY (normal) representation of the RGB colour given in (c) above.

[6%]

Question 3 continued over the page

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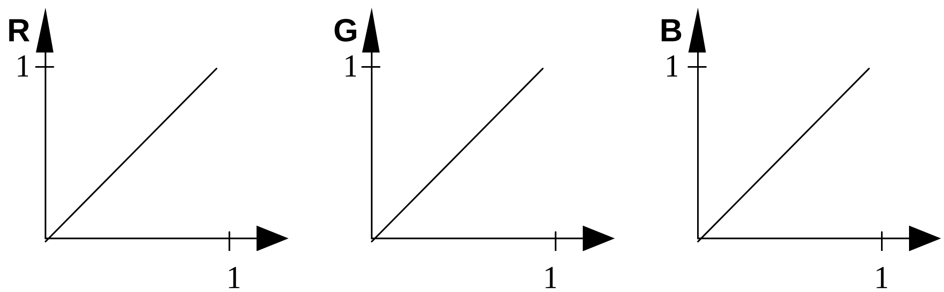
(e) The following three plots show colour mapping functions (or LUT definitions) for displaying 8-bit images in monochrome, i.e. using only shades of grey.



Define the approximate colour mapping functions for displaying images using a "rainbow" colour scheme, in which the image values are mapped into colours depicting colours of the rainbow (blue, cyan, green, yellow, red, magenta).

[10%]

(f) A digital image has been taken with an incorrect focus setting and therefore it appears blurred. How would you reduce the blur (without re-taking the picture)? Show with simple examples how the sharpening effect can be achieved.

[10%]

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THE APPENDIX - 3-dimensional transformations

Translation

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ T_x & T_y & T_z & 1 \end{bmatrix}$$

Scaling

$$S = \begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Rotation

about Z axis $$R_z = \begin{bmatrix} \cos\varphi & \sin\varphi & 0 & 0 \\ -\sin\varphi & \cos\varphi & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

about X axis $$R_x = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\varphi & \sin\varphi & 0 \\ 0 & -\sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

about Y axis $$R_y = \begin{bmatrix} \cos\varphi & 0 & -\sin\varphi & 0 \\ 0 & 1 & 0 & 0 \\ \sin\varphi & 0 & \cos\varphi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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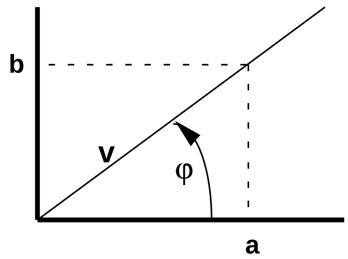
Basic trigonometric definitions



$\cos \varphi = \frac{a}{v}$

$\sin \varphi = \frac{b}{v}$

$v = \sqrt{a^2 + b^2}$

$\sin 45° = \cos 45° = \frac{1}{v2}$

Bézier curves

Bézier function *P(u)* in parametric form:

$$P(u) = \sum_{k=0}^{n} p_k \, B_{k\,n}(u)$$

Blending functions:

$$B_{k\,n}(u) = C(n, k)\, u^k (1 - u)^{n-k}$$

where

$$C(n, k) = \frac{n!}{k!\,(n - k)!}$$

$n! = n \times (n-1) \times \ldots \times 1, \qquad 0! = 1$

END OF APPENDIX