Royal Melbourne Institute of Technology

School of Computer Science and Information Technology

COSC1186/1187 Interactive 3D Graphics and Animation

Semester 1 2003

Date: Wednesday 18th June, 2003
Time: 9:15am to 12:30pm
Duration: 3 hours
Number of Pages: 5

Instructions to Candidates:

This examination accounts for 50% of the total marks for the course.
This examination totals 180 marks (or 1 mark per minute).
Answer all questions: 1 to 6.
Clearly state any assumptions made.
Write your answers in ink. Pencils may be used for diagrams.
Marks for each question are shown.
This examination is closed book.
Calculators are not permitted.

Question 1

Each of the following questions has a concise answer.

(a) What is 60° in radians?
(b) Normalise the vector: <1,1,1>
(c) When is the dot product of two vectors zero?
(d) When is the cross product of two vectors zero?
(e) What is the purpose of Bresenham’s algorithm?
(f) In what order is a BSP tree traversed for hidden surface removal?
(g) Is OpenGL a left-handed, or a right-handed co-ordinate system?
(h) In C, what is the result of (2<<3)&15?
(i) In OpenGL, which 4×4 matrix is used for hierarchically transforming objects?
(j) In GLUT, what is the function call for triggering a redraw?

\[(1+1+1+1+1+1+1+1 = 10 \text{ marks})\]
Question 2

(a) Given the following vectors:
\[
\vec{A} = 2i + 2j - k \\
\vec{B} = 4k
\]
Calculate each of the following, showing your working:

(i) \( \vec{A} \cdot \vec{B} \)
(ii) \( \vec{A} \times \vec{B} \)
(iii) \( |\vec{A}| \) and \( |\vec{B}| \)
(iv) The angle between \( \vec{A} \) and \( \vec{B} \)
(v) Normalised vectors for \( \vec{A} \) and \( \vec{B} \)

(b) Determine the equation of the plane of the following triangle:
\( \vec{d} = (3, -2, -2) \), \( \vec{b} = (6, 0, -3) \), \( \vec{c} = (3, 0, 0) \)

\[ ((3+4+4+4)+6 = 25 \text{ marks}) \]

Question 3

(a) 4 \times 4 \text{ matrices are used by OpenGL for 3D transformations, rather than } 3 \times 3 \text{ matrices. Explain why.}

(b) In the following illustration, a 4 \times 4 \text{ matrix is applied to transform the object on the left, into the object shown on the right.}

(i) What are the transformation steps?

(ii) What is the 4 \times 4 \text{ matrix for each transformation step?}

(iii) Showing your working, determine the CTM (combined transformation matrix).

(c) Write an OpenGL code fragment which includes the transformations needed to draw the object on the right. Assume the C function void displayObject(void) draws the object as shown on the left.

\[ (3+(8+8+12)+4 = 35 \text{ marks}) \]
Question 4

(a) The following `glutSolidSphere` has been rendered in four different ways.

![Images of four different renderings of a sphere]

(i) Give the OpenGL settings or modes which produce each of the renderings (a) to (d).

*Hint:* Refer to the following OpenGL calls, including values passed: `glColor`, `glColorMaterial`, `glColorMaterial`, `glColorMaterial`, `glEnable`, `glLightModeli`, `glMaterial`, `glPolygonMode` and `glShadeModel`.

*Hint:* The colour used here is 30% green and 30% blue.

(ii) In OpenGL how could the `glutSolidSphere` in the following image have a `glutWireSphere` overlaid/drawn over it?

![Image of a sphere with a wireframe sphere overlaid]

(iii) What type of shading could be used in the following image to achieve per-pixel specular highlights? How can this be achieved in real-time?

![Image of a sphere with specular highlights]

(b) OpenGL is a fixed pipeline model for processing geometric and pixel data. Lighting calculations form part of the graphics pipeline. Explain what you understand of the OpenGL lighting model.

Use the following notation and include diagrams, as appropriate.

\[ I_\alpha = I_{c\alpha} + I_{a\alpha}k_a + \sum_{n=0}^{t} f_{at}[I_{d\alpha}k_d(N \cdot L) + I_{s\alpha}k_s(R \cdot V)^n] \]

\[ ((12 + 4 + 4) + 10 = 30 \text{ marks}) \]
(a) An Imperial All-Terrain Armored Transport (ATAT) vehicle (as pictured above) is to be animated using linear interpolation of keyframed rotations forming a hierarchy. The ATAT can carry up to 40 troops and 400 kilograms of cargo and includes two fire-linked heavy laser cannons and two fire-linked medium blasters on its head-like cockpit. Each leg consists of three joints: at the hip, knee and ankle. Rotation at the hip, knee and ankle is constrained to the $z$ axis. The laser cannons and blasters have limited freedom to rotate in the $y$ and $z$ axes.

(i) Sketch the hierarchy of joints and segments for an ATAT, including the legs, head and weaponry.

(ii) Sketch a simple sequence of keyframe positions for an animated walk of a leg of the ATAT.

(iii) Sketch the parameter curves for the three leg joints with time on the horizontal axis and angle on the vertical axis. Use linear interpolation.

(iv) Assuming the following functions, write an OpenGL display function using modelview matrix stack manipulation functions to hierarchically draw an animated ATAT leg. State any assumptions you need to make.

```c
double hipAngle(double t);
double kneeAngle(double t);
double footAngle(double t);
void drawUpperLeg();
void drawLowerLeg();
void drawFoot();
```

(v) Give the C code for a linear interpolation function $\text{double interpolated(double t1, double v1, double t2, double v2, double t)}$ given the time $t_1$ and value $v_1$ of the previous keyframe, the time $t_2$ and value $v_2$ of the next keyframe, and the current time $t$ within the animation sequence.

\[(4 + 4 + 4 + 9 + 9 = 30 \text{ marks})\]
Question 6

(a) The graphics hardware pipeline applies several general stages of computation as information is passed from the application to the frame buffer. Sketch the overall structure of the pipeline including the important stages and the order in which these are arranged.

(b) Describe the concepts of preprocessing, coherence and incremental arithmetic in the context of the scan-line algorithm. Describe how they are used to achieve efficiency.

(c) Describe an algorithmic test for classifying 2D polygons as either convex or concave. Is this test is suitable for real-time computer graphics? Explain why, or why not.

(d) The Cohen-Sutherland Line-Clipping algorithm makes use of outcodes to improve efficiency. Describe how outcodes are calculated and how they are used to perform trivial acceptance and trivial rejection.

(e) Describe the graphics hardware approach to the Visible Surface Problem. What are the advantages and disadvantages of this approach?

(f) The Binary-Space Partition (BSP) Tree is an object-space approach to the Visible Surface Problem.

(i) Sketch the BSP Tree formed by choosing partition planes in the following order: A,B,C,D,E

(ii) In what order would the faces be drawn by traversing the BSP tree given the viewing position $p$?

(iii) Is a BSP tree suitable for dynamic scenes or shapes? Explain why, or why not.

$$(7+7+7+10+7+(5+4+3) = 50 \text{ marks})$$

THE END