Possible answers for COM3404 Modelling and Animation 2007

> These are **skeleton, possible** answers. Answers in an exam would in most cases need a bit of fleshing out and alternative answers might be acceptable.

1. (a) i. Vase: surface of revolution.

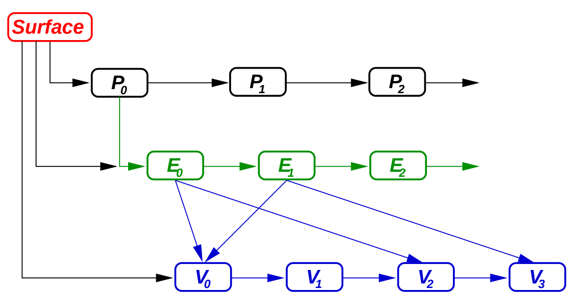
ii. Face: several possibilities: scanned, Bézier patches or single surface, metaballs.

iii. Wing of car: Lofting or Bézier patches.

(9 marks)

(b) Edges are advantageous because edges are not redrawn as they would be with a vertex-based representation. Principal advantage is that scan-line rendering is easy.

Hierarchical structure similar to following diagram with description of attributes of the components: surface, list of polygons, surface material properties; edges, references to vertices and polygons; polygons, normal, area, coefficients defining plane; vertex, location, normal, texture map coordinates.



(10 marks)

(c) Storyboards are a sequence of annotated pictures illustrating the key moments in a script. Divide the story into major scenes and action sequences. They show the framing of the scene by the camera and the duration of each scene. Marks for example storyboard. .

(8 marks)

(d) E_i emission from patch i

F_{ij} form factor between patches i and j , representing the geometrical fraction of energy leaving patch i that arrives at patch j

Form factor calculated by projecting patch j onto a hemicube of N pixels centred on patch i , then

$$F_{ij} = \frac{\cos\phi_i \cos\phi_j}{\pi r^2 N}\{\text{number of pixels to which patch } j \text{ projects}\}$$

Marks for the idea that F_{ij} is the fraction of pixels to which patch j projects and for details of equation. Gathering sums the contribution all other patches to patch i ; shooting updates the contribution of patch i to all other patches. Gathering and shooting repeated sequentially until convergence.

(13 marks)

(Total 40 marks)

2. (a) L, E, D, S mean light, eye, diffuse reflection and specular reflection respectively. Used to characterise paths emanating from light and arriving at the eye and therefore the types of path that can be rendered, e.g., $LDS * E$ describes a ray tracing algorithm.

Diagram. Classification of example paths in the scene might be:

LDE	Light, cylinder, eye
$LDSE$	Light, cylinder, cube, eye
$LSSE$	Light, cube, (transmission through cube,) refraction at cube, eye
$LSSSE$	Light, cube, internal reflection in cube, refraction at cube surface, eye.

(10 marks)

(b) Answers should describe the Whitted ray tracing algorithm, following rays from eye (pixel in image plane) to light, giving details of the recursion tree for the scene; and $L(D)S{*}E$ paths followed; the Phong model for specular reflection , the equation for propagation of light intensity,

$$I(\mathbf{x}) = I_{local}(\mathbf{x}) + k_{rg} I(\mathbf{x}_r) + k_{tg} I(\mathbf{x}_t)$$

with explanation of terms. Recursion stopping criteria (hitting diffuse surface, attenuation of traced ray, preset recursion depth) should be mentioned.

(12 marks)

(c) Principal factors affecting efficiency are recursion depth and ray-object intersection calculations.

Efficiency improved by

- Adaptive depth control: stop tracing when contribution of ray to pixel is small.
- Bound objects with simple shapes: only make detailed intersection calculations if ray is known to enter a simple bounding volume.
- Octrees or similar for rapid location of polygons close to ray.
- Eliminate first hit intersection calculations: for each pre-compute object that ray first intersects.

(8 marks)

(Total 30 marks)

3. (a) Diffuse reflection: light is reflected in all directions regardless of the direction of the incident ray. Phong models diffuse component as

$$I_d = I \cos\theta$$

where I is the incident component and θ is the angle between the incident direction and the surface normal. Diagram expected.

Specular reflection: light is reflected at the "mirror" angle or in a beam about the mirror angle for imperfect specular reflection. Modelled as

$$I_s = I(cos\Omega)^n$$

where I is the incident intensity, Ω is the angle between the mirror direction and the viewer and n describes the width of the scattering $n \to \infty$ for perfect specular reflection. Diagram expected.

(10 marks)

(b) Z-buffer has an entry for every pixel in the image plane and contains the minimum depth of all scene elements that project to that pixel. Z-buffer algorithm solves the hidden surface removal problem by using the Z-buffer to keep track of whether each polygon to that might be drawn is in front or behind others that project to the same pixel; an object is not drawn if it is behind others.

Z-buffer algorithm: Scan-line based algorithm to render polygons one at a time. Polygons are shaded using interpolative Phong shading , which requires interpolation of the surface normals together with scan-line segments ends from vertices. Outline pseudo-code is:

- for all x, y
-     $Z_{buf}(x, y) :=$ max-depth

- for each polygon
-     Convert to edge-based representation in screen coordinates

- for $y := y_{min}$ to y_{max}
-     for each segment in $EdgeList[y]$
-         Interpolate $X_{left}, X_{right}, Z_{left}, Z_{right}, \mathbf{n}_{left}, \mathbf{n}_{right}$ from segment ends
-         for $x := X_{left}$ to X_{right}
-             interpolate z and $\mathbf{n}$
-             if $z < Z_{buf}(x, y)$
-                 $Z_{buf}(x, y) := z$
-                 $F_{buf}(x, y) := shading(\mathbf{n})$

Scan-line formulation, taking advantage of edge coherence of polygons, makes the algorithm efficient

(14 marks)

(c) Vase: specular and diffuse reflections would be rendered

Mirror: Only specular reflection from the light would be visible; no reflection of vase in the mirror.

Texture or reflection mapping could be used to render the scene from a view point behind the mirror into an image; then the whole scene rendered a second time from the usual viewpoint with the image texture mapped onto the mirror.

(6 marks)

(Total 30 marks)

4. (a)

i. Propeller rotation expressed by a formula. Perhaps related to frame number.
ii. Retraction of wheel assembly by key-frame animation. Pivot point for each component would have to be carefully considered for a realistic animation .
iii. Plane itself animated with a motion path. Involves creation of route plane will take and specification of time to traverse path. Plane's direction along path and roll of plane as it corners must be specified.

Hierarchical animation to permit the three components to be animated separately but the propeller and undercarriage to move with the plane.

(10 marks)

i. Many models comprise several parts. Hierarchical structures permit control over the animations and transformations applied to individual components of a model. .
ii. Forward kinematics is an extension of hierarchical animation, but specifically when applied to character animation. Involves propagation of transformations down the hierarchy; e.g. animate shoulder, then elbow, then wrist in order to position the hand. Slow, but permits precise positioning of elements of a character. Appropriate for delicate character animation such as animation of fingers grasping an object.
iii. Inverse kinematics propagated transformations up the hierarchy, e.g., arm and shoulder motions derived from the specification of the hand animation. The ability to move ends of each limb permits much quicker character animation with (small) loss of precise control. Suitable for animating the overall movement of a character, such as walking.

(9 marks)

(b) Answer should describe use of motion dynamics for this problem. Good answers should describe principal elements of motion dynamics and the configuration of gravity, mass and friction parameters for a domino rally.

Collisions between dominos make it difficult to employ key frame animation. Manual simulation of a single domino might be possible, but very difficult and time consuming for many.

(11 marks)

(Total 30 marks)

5. (a) Solid modelling recognises the volumetric interior of objects as opposed to surface modelling which only models the surface.

Advantages of solid modelling:

- Many artifacts (particularly engineering artifacts) are naturally described by solid models.
- Alterations to dimensions of shapes are easily accommodated with constructive solid geometry but very difficult with polygonal meshes.
- Logic of the model (eg interconnections between components) is preserved in representation.

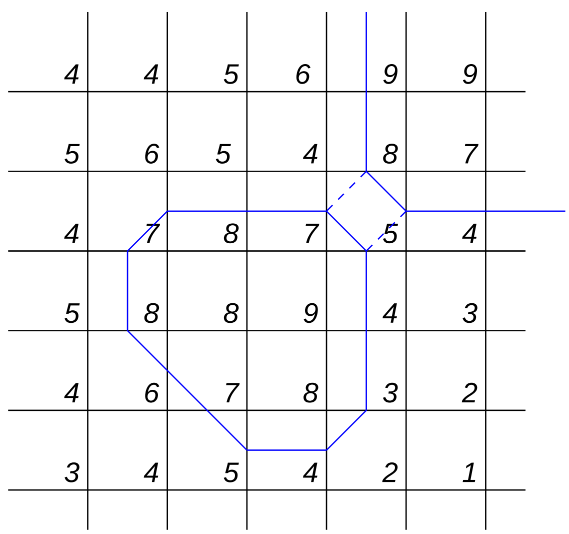
Disadvantages:

- Requires special rendering algorithms or conversion to polygonal form
- Detailed modification to local regions is difficult because Boolean operations are global
- Limited range of operations with which to construct models.

(6 marks)

(b) Marching squares scans each square in turn rather than by following contours. There are 16 prototypical configurations depending on whether each vertex is greater or less than the contour height z. Depending upon the configuration the appropriate line is drawn from edge to edge. Precise location of contour found by linear interpolation along entry and exit edges.

Contouring ambiguity arises when two diagonally opposite vertices are above z and two below z as shown in the diagram.



Ambiguity resolved by (arbitrarily) always choosing one configuration.

(12 marks)

(c) Marching squares algorithm extended to the marching cubes algorithm by considering voxels/cubes in place of squares and drawing planar iso-surfaces within each cube. There are now 15 prototypical configurations (after accounting for symmetries). Interpolation within each cell now consists of drawing between 1 and 4 facets connecting linear interpolation points on the edges.

Ambiguities cause holes in the iso-surface; resolved by higher order interpolation. Additional marks for more detail on ambiguity resolution from additional reading.

(7 marks)

(d) Metaballs are iso-surfaces of implicitly defined functions. Usually defined as point sources or potential functions whose location and strength can be manipulated interactively. Negatively weighted sources can be used to sculpt concavities. Rendered by conversion to polygonal mesh via marching cubes algorithm.

(5 marks)

(Total 30 marks)