CM30075 Advanced Computer Graphics

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Q1 (a) Halftones are binary patterns whose density approximates a continous tone, typically chosen to be non visually-intrusive.

They are appropriate when the output device can only mark at one density but the image to be represented has a range of densities. For example, a laser printer either lays down toner or it does not: it is not capable of shades. [2 marks]

In traditional printing (newspapers etc), the dots of ink vary in diameter. In computer display, the dots are the same size but are used to build up a variety of shapes. [2 marks]

(b) The spot function is a mathematical description of how the ink dots varies in shape with required density. It is usually expressed algebraically as a function which is continuous with density. In practice, this will be represented as an array called the threshold matrix. This matrix is the size of the printed cell representing one "dot" of ink. Each entry is the threshold level at which that pixel is first set to black. [2 marks]

Its resolution, perhaps 16 by 16, is what determines the tonal resolution achievable (in this example, 256 grey levels, plus white). Here is a simple example at 3 by 3:

$$\begin{pmatrix} 7 & 9 & 5 \\ 2 & 1 & 4 \\ 6 & 3 & 8 \end{pmatrix}$$

This says the central dot will be set for the palest grey tone, then the one to its left will additionally be set for the next darker tone etc. The top centre pixel will only be set for solid black tone. (An incorrect matrix will be acceptable if it is correctly used illustratively) [2 marks]

(This third part following was not explicit in the lectures, though all the elements were covered.) The relationship sought in the question can be identified by considering what area of the output device the input image must cover. This determines the number of device pixels available to each input pixel (the device is typically higher in spatial resolution than the image). If this is 16 by 16 or better, then all input pixels can be represented at adequate tonal resolution. If not, then the user must decide what trade-off to accept between input and output, balancing the needs of space and tone. Usign a smaller matrix will reduce the tonal resolution but retain more of the spatial resolution and vice versa. [2 marks]

(c) Cooks' method trades visible aliasing effects for less-visible noise. The lecture notes give a full account of the solution for both static and moving scenes and why it works. Full marks will be available for a fully-developed answer. [10 marks]

Q2 (a) Surface models represent an infinitely-thin shell, the outermost surface of a 3D object. Typically they are mesh representations, often based on triangles. Advantage: easy to render on modern PC graphics cards.

(any sensible alternatives accepted) Disadvantage: objects are solids, not surfaces. (any sensible alternatives accepted) [3 marks]

(b) Hidden surface removal. From a given viewpoint, some parts of a model may obscure other parts. HSR is removing those parts which cannot be seen in order to improve rendering efficiency. [2 marks]

The scanline method: fully described in lectures. Answers should refer to the use of bucket lists, vertical and horizontal extent of triangles, an active list, edge intersection calculation and maintenance, depth ordering and when needed etc [5 marks]

The z buffer method is used where there is fast support for it on the graphics card. It is appropriate for screen resolution pictures: its high memory costs make it generally better-suited to such low resolution pictures. [2 marks]

(c) CSG: primitives defined by suitable equations; boolean operators to combine them. Binary tree data structure to represent this. Raytrace the leaves, reduce the problem to one of ordering intercepts along the ray (1D instead of 3D). Choose nearest; calculate normal; apply lighting; colour the pixel. [4 marks]

Estimate volume [This part not covered in lectures]. Ray-trace the volume, noting how much of each ray is inside the solid. Use a reasonably dense set of rays parallel to a major axis (i.e. not in a perspective "fan"). Treat each ray as being the centre of a small square extending as a thin rectangular block. Add the results scaled by the area of the square. [4 marks]

Q3 (a) Radiosity achieves light interchange between objects in the scene, by modelling the steady state, thus giving a more physically accurate solution, including colour bleeding and soft shadows. [3 marks]

(b) A complete solution will describe the energy interchange, the solution of the equations, the hemisphere (or similar) method for integrating the energy. It will address the modelling, using surface patches, and the Gouraud rendering. Diagrams help with the interchange and integrating explanations in particular. [12 marks]

(c)[This part not covered in the lectures] Radiosity assumes an energy equilibrium, which is disturbed by moving light sources. The cost of computing the equilibrium is the high part, so it is not feasible to do this in real-time. An approximate solution would be to treat the torch's contribution as additional, using conventional shading techniques for this (and not including the consequent effects). In practice this would certainly require the use of blending (cannot recolour the patches because these will be too large). [5 marks]

Q4 (a) They are an n+1 dimensional representaton of n-dimensional space and transforms.

$$(x, y, z) <-> (wx, w, yw, zw)$$

Homogeneous coordinates permit independent control of the additive elements (translation) and the multiplicative (rotation/scaling) while also offering control of the projection (usually perspective) and overall scaling. This allows any sequence of operations to be represented by one matrix, produced by multiplying the individual matrices. [4 marks]

(b) m= multiplicative (rotation and scaling) t= additive (translation) p= plane of projection w= overall scaling of the projection. [4 marks]

(c) Direct from lectures. With the correct diagram, the vanishing point explanation is much simplified. [8 marks]

(d) [This part not covered in lectures] Certain ratios are preserved. This can be justified loosely. For example, the unit points on two arbitrary lines will not be spaced the same in perspective. However, because the "rate" of perspective is the same in both cases, then the rate at which they come closer together must be the same in both lines. This requires some careful thought so the marking will be generous. [4 marks]