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Suggested solutions to Examination, Computer Graphics MN1, 960113

1. Hardware

Refresh rate:	# of times per time unit the image is redrawn
Persistence:	in CRTs: time from removal of excitation to the moment when the phosphorence has decayed to 10 percent of the initial light output
Shadow mask:	in CRTs: a metal plate with a lot of holes mounted close to the viewing surface that makes sure that each of the 3 electron beams can hit only one type of phosphor spot (R, G, or B)
Mouse vs. digitizer:	a mouse is a relative device, a digitizer is an absolute device.

2. 2D Transformations

a) translation from (x,y) to (0,0) - assuming (x,y,) is the point
rotation 90 degrees counter-clockwise,
translation from (0,0) to (x,y)

b) translation T(-3,-3):

$$\begin{matrix} 1 & 0 & -3 \\ 0 & 1 & -3 \\ 0 & 0 & 1 \end{matrix}$$

rotation R(90):

$$\begin{matrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{matrix}$$

translation T(3,3):

$$\begin{matrix} 1 & 0 & 3 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{matrix}$$

These matrices work if we use postmultiplication of column vectors. The order then becomes:

T(3,3) R(90) T(-3,-3)

3. Polygon Filling

a) All edges are initially stored in the *ET* sorted according to their minimum y value. Within each y, edges are *bucket sorted* according to their minimum x value. The algorithm then loops over y, moving edges from ET to *AET*, and the bucket is updated (resorted) and the x coordinate for each edge is incrementally recalculated.
At each y: loop over edges, using the *odd-parity rule* (start with parity even, toggle parity when an edge is encountered)to determine whether we are inside (odd) or outside (even).
Horizontal edges are simply ignored.
Shared vertices are handled by counting the y_{min} vertex of an edge in the parity calculation but not the y_{max} vertex.

b) Seed fill which, starting at a seed pixel, recursively fills all pixels inside a polygon.

4. Line Clipping in 2D

The bits store information about the endpoints of a line. Each bit signals whether the pixel lies above the top edge of the window, below the bottom edge of the window, to the right of the right edge of the window, or to the left of the left edge of the window. The four-bits words of the two endpoints are used to trivially accept/reject lines.

5. 3D Viewing

The model describes the step in 3 viewing and each term is a transformation matrix (note that the transformations are done in the order T(PRP) to M_{VV3DV}.

Nper	the transformation for perspective projection of 3D scenes.
M_{VV3DV}	the window to viewport transformation.
M	transforms the perspective-projection canonical view volume into the parallel projection canonical view volume with parallel sides.
S_{per}	Scale the view volume into the canonical view volume
SH_{par}	shear so that the centre of the view volume becomes the z axis
T(-PRP)	Translate so that the perspective reference point is at the origin
R	Rotate the view reference coordinate system into the WC system
T(VRP)	Translate the view reference point to the origin

6. Perspective Transformation

Using similar triangles in the figure: xp/d = x/z.
Multiply by d: xp = (d*x)/z = x/(z/d).
Then we can use the matrix

$$\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1/d & 0 \end{matrix}$$

to transform (x y z 1)' to (x y z z/d)'
In order to obtain the 3D point it is necessary to divide by z/d: (x/(z/d) y/(z/d) d).
Thus, the perspective transformation is really only this division.

7. Rendering Pipelines

a - 1
b - 4
c - 3
d - 2

8. Hidden Surfaces

backface culling:	the elimination of back-facing (surface normal points away from the observer) polygons
bounding volume:	extents in z, y, and z used to trivially accept/reject polygons and/or determine whether two polygons overlap.

z-buffer: a buffer where the currently smallest z coordinate for each pixel is stored.

9. Shading

Constant shading applies an illumination model once for each polygon, i.e. a single intensity value is used for all pixels in the polygon. Interpolated shading linearly interpolates the shading over each polygon from values determined at the vertices.

Constant shading produces a correct image if:
1/ the light source is at infinity.
2/ the viewer is at infinity.
3/ the polygon representation is **not** an approximation of a curved surface.

10. Fractals

a) log(4) / log(3) ~1.2619
b) log(2) / log(3) ~0.6309
c) log(9) / log(3) 2

11. Graphics Systems

a) Immediate and retained mode are applied to graphics systems and refers to whether the system saves the primitives in a database for automatic regeneration (retained mode) or if the application programmer must redraw everything herself (immediate mode).

b) transformation, scan conversion, and display are good candidates for special-purpose processors while generation and database traversal should be done in the host processor for maximum flexibility. If interactive manipulations are rare traversal can be done in hardware as well.

12. Concepts in X and Motif

Xlib the library of functions in X
Xt toolkit a widget toolkit built on top of X
Motif a widget toolkit built on top of X that used Xt
widget in Xt and Motif: a interface component such as push button
callback an application function that is called as a result of a user interaction
resource file a file that defines resources (colours, fonts, placement, etc.) for widgets

13. The Significance of Bit Depth

In order to show full colour on an 8-bit workstation, colour tables are used. In this table there are 2^8 (256) entries, each of which defines a RGB value. This means that only 256 colours can be displayed simultaneously on a workstation of this type. On the other hand, it is possible to change colours dynamically simply by changing the values in the table. If no colour table is used (as is often the case on 24-bit workstations), the image must be redisplayed in order to change the colour.

14. Colour

a) RGB is an additive system, CMY a subtractive one. CMY defines a colour by subtracting from white while RGB defines a colour by adding to black. The relationship is:

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

b) Y in CIE and YIQ represents intensity.

15. Image Formats

GIF - 256 colours, JPEG - full colour.
JPEG uses a more efficient and thus slower compression scheme.