Exam – Computer Graphics

17 december 2008, 8-13

Answers may be given in either Swedish or English
Electronic calculator allowed

1 (a) Let $\boldsymbol{b}=(b_0,b_1,b_2)$ be the barycentric coordinates for a point with respect to the three points p_0, p_1 och p_2. What does always hold for $\boldsymbol{b}$? *(0.4)*
(b) What is also true in the points p_0, p_1 and p_2 respectively *(0.6)*

2 (a) What is special about the transformation of normal vectors? *(0.6)*
(b) For which transforms does this matter and for which transforms does it not? *(0.4*)

3 (a) How can you say that the *dot product* of two vectors is a measurement of the angle between them. *(0.4)*
(b) Describe how to construct a matrix which gives a *rotation* of angle *a* around an axis ***r***.*(0.6)*

4 (a) What is *bump mapping* and what is it used for? *(0.4)*
(b) Which data must the mesh provide in order to apply it? (*0.3*)
(c) Describe the algorithm for bump mapping. (*0.3*)

5 (a) What is drawn on the screen after a call to the function *draw()* below? *(0.8)*

```
def draw():
    glColor(1,0,0)
    glPushMatrix()
    glTranslate(1,2,0)
    glScale(2,1,1)
    glRotate(90, 0,0,1)
    glPushMatrix()
    glTranslate(3,0,0)
    drawSquare()

    glColor(0,1,0)
    glPopMatrix()
    glRotate(180, 0,0,-1)
    glPushMatrix()
    glTranslate(4,0,0)
    glPopMatrix()
    drawSquare()

def drawSquare():
    glBegin(GL_QUADS)
    glVertex(0,0,0)
    glVertex(0,1,0)
    glVertex(1,1,0)
    glVertex(1,0,0)
    glEnd()
```

(b) Describe two different matrices which are part of the OpenGL pipeline state? *(0.2)*

6. (a) The so called *rendering equation* can be written as:

$$I(\boldsymbol{p}_C, \boldsymbol{p}_S) = v(\boldsymbol{p}_C, \boldsymbol{p}_S)[e(\boldsymbol{p}_C, \boldsymbol{p}_S) + \int_{\boldsymbol{S}} r(\boldsymbol{p}_C, \boldsymbol{p}_S, \boldsymbol{p})\ I(\boldsymbol{p}_S, \boldsymbol{p})\ d\boldsymbol{p}]$$

Explain in words what it expresses. *(0.6)*

(b) Explain how raytracing is an approximation to the rendering equation? *(0.4)*

Give as detailed answers as you can to both questions.

THE END!

Short answers to the exam in Computer Graphics
17 december 2008

1 (a) The sum of the barycentric coordinates is always equal to zero.

(b) In each of these points one of the coordinates is equal to one and the others are equal to zero. $\boldsymbol{b}=(1,0,0)$ in p_0, $\boldsymbol{b}=(0,1,0)$ in p_1 and $\boldsymbol{b}=(0,0,1)$ in p_2.

2 (a) If $\boldsymbol{M}$ is the matrix used to transform vectors, normal vectors should be transformed by $(\boldsymbol{M}^{-1})^T$, the inverse transpose of $\boldsymbol{M}$.

(b) For similarity transforms this does not matter because $(\boldsymbol{M}^{-1})^T = \boldsymbol{M}$. But this is not the case when for example non-uniform scaling is involved.

3 (a) The dot product of two vectors divided by the product of the the lengths of the two vectors equals the cosine of the angle between them.

(b) The columns of this matrix are

$$rotation((1,0,0), a, \boldsymbol{r}),\ rotation((0,1,0), a, \boldsymbol{r}),\ rotation((0,0,1), a, \boldsymbol{r})$$

where the $rotationt(\boldsymbol{x}, a, \boldsymbol{r})$ is the rotation of a vector $\boldsymbol{x}$ by an angle a around the axis $\boldsymbol{r}$ given by:

$$rotationt(\boldsymbol{x}, a, \boldsymbol{r}) = cos(a)*rejection(\boldsymbol{x},\boldsymbol{r}) + sin(a)*cross(x, unit(r)) + projection(x,\boldsymbol{r})$$

and

$$projection(x,r) = dot(x, unit(r)) * unit(r)$$
$$rejection(x,r) = x - projection(x,r)$$
$$unit(x) = x/|x|$$

4 (a) With bump mapping the normal vector for each point is taken from a surface texture. This normal typically deviates from the true normal of the underlying geometry. This gives the surface a bumpy appearance.

(b) Bump mapping requires that each vertex, in addition to its position and normal, have tangent and binormal.

(c) Bump-mapping can be done as follows:
- For each vertex, transform tangent, binormal and normal to camera space.
- Interpolate the resulting vectors and normalize.
- Use texture coordinates to look up the perturbated normal from the bump map..
- Transform normal from tangent space to camera space (using the interpolated vectors to construct the transformation matrix).
- Use this transformed normal in the shading calculations.

5 (a) The following objects are drawn:

- A red rectangle with size (2,1) lower left corner in (-1,5)
- A green rectangle with size (2,1) lower left corner in (1,1)

(b) The projection matrix (GL_PROJECTION) and the model-view matrix (GL_MODELVIEW).

6 (a) See slide from lecture on shading.

(b) Raytracing attempts to be an globally accurate model only for specualar reflection and refraction. A local model like Phong is typically used for diffuse reflection.