Exam – Computer Graphics

11 december 2007, 8-13

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

1 (a) What is a rigid body transform. Give an as exact answer as you can . *(0.6)*
(b) Give one or more examples of transforms which are not rigid body transforms. *(0.4*)

2 Explain the following interpolation concepts:

- Binearest interpolation
- Perspective correct interpolation
- Hermite interpolation

3 (a) Give the formula for Phong shading and give definitions for all terms used. *(0.2)*
(b) In what respects is Phong shading an approximation to the rendering equation. *(0.4)*
(c) How is Gouraud shading different fron Phong shading? *(0.4)*

4 (a) In what respects are *ray tracing* and *radiosity* similar? How are they different? *(0.4)*
(b) What is *Perlin noise*? What can it be used for? (*0.3*)
(c) Explain the term *key frame animation*. (*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)
   glScale(1, 2, 1)
   glPushMatrix()
   glRotate(90, 0,0,-1)
   glTranslate(-1, 0, 0)
   drawSquare()

   glColor(0, 1, 0)
   glTranslate(2, 3, 0)
   glRotate(180, 0,0,1)
   glPopMatrix()
   glRotate(180, 0,0,1)
   glPushMatrix()
   glTranslate(-3, -1, 0)
   glScale(2, 2, 1)
   drawSquare()

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

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

(b) OpenGL has a concept called texture object. What is it and what is the benefit of using it? *(0.2)*

6 (a) A point has coordinates (4.0, -6.0, -16.0) in the coordinate system of the camera. What are the corresponding normalized device coordinates if the camera uses perspective projection and the distance to the image plane (the zoom factor) is 2.4? *(0.5)*

(b) Is this point visible on a screen with a size of (480,320) pixels? And if so, where? *(0.5)*

THE END!

Short answers to the exam in Computer Graphics
11 december 2007

1 (a) A rigid body transform is a transform which which preserves both distances and angles. It can always be expressed as a combination of translations and rotations.

(b) Scaling and skewing transforms are not rigid body transforms.

2 (a) Binearest interpolation is an method for interpolating between four points in two dimensions. The method calculates the interpolated value as the same as that of the closest point.

(b) Perspective correct interpolation refers to a correction process used in the rasterization and shading of triangles. Vertex attributes are correctly interpolated over the triangle before it is projected to 2D. To do this over the regular grid in 2D of pixel positions, requires back projection of the 2D positions. This in turns requires the correctly interpolated depths which can be calculated by linearly interpolating the reciprocal depths in 2D.

(c) Hermite interpolation is a cubic interpolation method, i.e. it fits a cubic polynomial through the two points which are to be interpreted between. Besides the position of the two points Hermite interpolation also require the specification of the tangents in these points.

3 (a) According to Phong's reflection model, the reflection consists of a global ambient term and, for each light source, one diffuse an one specular term:

$$I = k_a * I_a + \sum (k_d * (L_i \,.\, N) + k_s * (R_i \,.\, V)^{\alpha}) * I_l$$

I: The intensity of the reflected light

N: Surface normal
V: Unit vector directed towards the viewer
I_a: The intensity of the ambient light
I_l: The intensity of the incident light from light source i
L_l: A unit vector directed towards light source i
R_l: Reflection vector from light source i (= $unit(2*(L_i \,.\, N)*N - L_i)$)

k_a, k_d, k_s och α: Material parameters for the ambient, diffuse, and specular reflection as well as the shininess.

(b) Phong shading is an approximation to the rendering equation in two respects:

1. It is a local reflection model, which means that it takes only takes reflection of light which comes directly from light sources into account.
2. The model itself, with its separation into an ambient, diffuse and specular term, is a special case of the general BRDF in the rendering equation.

(c) Gouraud shading is a per-vertex method, which means that the color calculations are made for each vertex, and the resulting colors are interpolated over the pixels of each triangle. The color calculations are also done with a slightly different variant called Blinn-Phong shading

where the specular reflection factor uses the angle between the *halfway vector* (the vector halfway between the light vector and the view vector) and the surface normal instead of the angle between the view vector and the reflection vector.

4 (a) Ray tracing and radiosity are both methods which use global illumination lighting models. They are different in that ray tracing is a method which deals with (perfect) specular reflections whereas radiosity deals with diffuse reflections.

(b) Perlin noise is a continous random function in n-dimensional space. In points closer than a distance of 1, the function values are closely correlated, but for distances >1 they are uncorrelated. This means that distinguishable details are approximately of size one. This size can be changed by spatial scaling. By adding a number of differently scaled versions of Perlin noise it is possible to create results which have a fractal character known as turbulence.

Perlin noise is primarily used for procedural textures of natural phenomena, for example clouds, smoke, fire, wood, and marble.

(c) Quote from Wikipedia:

> A key frame (or keyframe) in animation and filmmaking is a drawing which defines the starting and ending points of any smooth transition. They are called "frames" because their position in time is measured in frames on a strip of film. A sequence of keyframes defines which movement the spectator will see, whereas the position of the keyframes on the film, video or animation defines the timing of the movement. Because only two or three keyframes over the span of a second does not create the illusion of movement, the remaining frames are filled with inbetweens.

5 (a) The following objects are drawn:

- A red rectangle with size (1,2) lower left corner in (0,0)
- A green rectangle with size (2,4) lower left corner in (1,-2)
- A blue rectangle with size (2,4) lower left corner in (3,-2)

(b) A texture object is texture data with associated parameters stored in graphics memory and can be referenced from the application program through a reference identifier. The benefit of texture objects is that bandwidth consuming transfers of texture data not has to be done for each image that is rendered.

6 (a) The normalized device coordinates are (0.6, -0.9).

(b) Yes, with the screen origin in the lower left corner it is visible at the screen position (336, 16).