Computer Graphics Comprehensive Exam

Computer Science Department
Stanford University
Fall 2002

MAGIC NUMBER: _____

Note: This exam is *closed-book*.

The exam consists of 5 questions. Each question is worth 20 points. Please answer all the questions in the space provided, overflowing on to the back of the page if necessary.

You have 60 minutes to complete the exam.

The following is a statement of the Stanford University Honor Code:

A. *The Honor Code is an undertaking of the students, individually and collectively:*
   1. *that they will not give or receive aid in examinations; that they will not give or receive unpermitted aid in class work, in the preparation of reports, or in any other work that is to be used by the instructor as the basis of grading;*
   2. *that they will do their share and take an active part in seeing to it that others as well as themselves uphold the spirit and the letter of the Honor Code.*

B. *The faculty on its part manifests its confidence in the honor of its students by refraining from proctoring examinations and from taking unusual and unreasonable precautions to prevent the forms of dishonesty mentioned above. The faculty will also avoid, as far as practicable, academic procedures that create temptations to violate the Honor Code.*

C. *While the faculty alone has the right and obligation to set academic requirements, the students and faculty will work together to establish optimal conditions for honorable academic work.*

By writing my "magic number" below, I certify that I acknowledge and accept the Honor Code.

_____
(Magic Number)

1. [Total: 20 points] Computer graphics definitions.

Define in a few sentences each of the following computer graphics terms. Some of these terms may be used in other fields, so be sure to give the computer graphics meaning.

1A [5 points]. Image composition.

1B [5 points]. Diffuse reflection.

1C [5 points]. Key-frame animation.

1D [5 points]. Hierarchical modeling.

2. [20 points] Transformations.

Computer graphics relies heavily on 3D transformations. Most common are the geometric transformations such as rotations, translations, scales, etc. In the following, T(dx,dy,dz) refers to a translation by (dx,dy,dz), Rx(a) refers to a rotation about the x-axis by a degrees, Ry(a) and Rz(a) refer to rotations about the y- and z-axis, respectively.

The order of transformations may matter. Also, sometimes the order may be rearranged, but the arguments will change. Describe whether the following statements are true or false.

T(1,0,0) Rx(45) = Rx(45) T(1,0,0)?

T(1,0,0) T(0,2,0) = T(0,2,0) T(1,0,0)?

Rx(45) Ry(30) = Ry(30) Rx(45)?

Rx(45) Rx(30) = Rx(30) Rx(45)?

T(1,0,0) Rz(180) = T(-1,0,0) Rz(0)

Transformations have inverses. State whether the following formulas for the inverse transformations are true or false.

$Rz(45)^{-1} = Rz(-45)$?

$Rz(180)^{-1} = Rz(180)$?

$T(1,1,1)^{-1} = T(1,1,1)$?

$[Rz(45)\ T(1,0,0)]^{-1} = T(1,0,0)\ Rz(45)$?

$[Rx(45)\ Ry(30)]^{-1} = Ry(-30)\ Rx(-45)$?

3. [20 points] Ray tracing.

One of the most general methods for rendering is ray tracing. At the core of a ray tracer is a procedure to find ray-surface intersections. The inputs to the procedure are a ray and a formula for a surface, the output is the point of intersection.

Assume is ray is given by the following parametric equations:

$$x = x0 + t * x1$$
$$y = y0 + t * y1$$
$$z = z0 + t * z1;$$

(x0,y0,z0) is the origin of the ray, and (x1,y1,z1) is the direction of the ray. As t increases, the points on the ray move from the origin along the direction.

Work out a procedure for computing the point of intersection of a ray with a cone. A cone is given by the following implicit function $x^2+y^2-z^2 = 0$. In general, a ray intersects a cone in two points. Return the closest point in the direction of the ray.

4. [20 points] Polygonal Meshes.

Polygonal meshes are widely used in computer graphics. A polygonal mesh consists of vertices that define the positions of 3D points, and topological information that organize the points into polygons. There are many different types of mesh data structures, depending on the operations that need to be performed.

1. Describe a simple data structure to store a triangular mesh so that vertices are not duplicated. In your description, define C structs for vertices and triangles.

2. Refine the data structure described above so that neighboring triangles may be found in constant time.

5. [20 points] Rasterization.

In your new job as chief graphics software architect, you receive a request to write a procedure to draw the following curve:

$$y^2 = x^3$$

To simplify the problem, consider only positive y values. This procedure should draw n pixels by stepping along the curve starting at the origin. Each pixel should be under the curve, or on the curve. No pixels should be above the curve. For example, (0,0) is on the curve, whereas (0,1) is above the curve; so we would choose (0,0) as the nearest pixel to the curve. The next few points would be (1,1), (2,2), (3,3), (3,4), (3,5), ... The procedure should ensure that each point is connected (that is, is adjacent) to the previous point. The procedure should also be written as efficiently as possible. That is, use no multiplications except by constants in the inner loop. To draw the curve, write down an implicit function that defines the set of points on the curve, and then incrementally trace out the curve. Work out the math, and then fill in the following template:

```
drawcurve(int n)
{
  int x = 0;
  int y = 0;




  for(i=0; i<n; i++) {
    drawpoint(x,y);









  }
}
```