CS354 Sample Midterm Exam (Spring, 2018

UTCS

1 Problem 1

This problem asks about ray tracing:

- What is ray tracing?
- Briefly describe Whitted ray tracing algorithm;
- When to terminate the recursive procedure in the Whitted ray tracing algorithm?

Solution.

- Say lecture notes.
- The answer has the include 1) it is a recursive procedure, and 2) it has Shadow rays, Reflection rays, and Refraction rays.
- The number of iterations, and/or the coefficients are below a threshold.

2 Problem 2

This problem asks about shading models:

- What are the different components of the phong shading model? Which are dependent on the viewing direction,and which are dependent on the lighting direction?
- What are the differences between normal mapping and bump mapping;

Solution.

- Ambient, diffusion and reflection. Diffusion and Reflection are dependent on the lighting. Reflection is dependent on the viewing direction.
- Normal mapping perturbs normal, while keep the original surface. Bump mapping modifies both the normal and the surface.

3 Problem 3

This problem asks about projection and transformations:

- Define parallel and perspective projections (e.g., using homogeneous coordinates).
- Do they preserve straight lines? How about parallel lines?

Solution.

- Your answer should include that a parallel projection is guided by a projection direction, while a perspective projection is guided by a focal point. Specifically, for a parallel projection along the z axis, a point (x, y, z) is projected to $(x, y, 0)$. For a perspective projection, (x, y, z) is projected to $(x/z, y/z, 1)$.
- Both projections preserve straight lines. Parallel projections preserve parallel lines. Perspective proejctiosn generally do not preserve parallel lines.

4 Problem 4

The problem asks about spatial data structures:

- Briefly describe the main idea of spatial data structures;
- List at two types of spatial data structures and compare their pros and cons;
- Use the circle $x^2 + y^2 = 1$ as the example to describe the memory complexity of both data structures;

Solution.

- Your answer should include the following keypoints: 1) A spatial data structure is organized using a tree, and 2) each node should be assocated with a bounding volume.
- Kdtree and Octree (Quadtree). The answers should highlight the main idea, namely, Each node of a Kdtree has two children and each node of a Octree has eight children.
- The idea is that both data structures should have linear number of leaf-nodes, meaning linear number of nodes in total.

5 Problem 5

Suppose I have a triangle $P_0P_1P_2$ in 3D, whose vertex positions are given by

$$P_0 = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \qquad P_1 = \begin{pmatrix} 1 \\ 0 \\ \frac{1}{2} \end{pmatrix}, \qquad P_2 = \begin{pmatrix} 0 \\ 1 \\ \frac{1}{2} \end{pmatrix}.$$

Please answer the following question:

1. Calculate its face normal;
2. Show that point $P = (\frac{1}{3}, \frac{1}{3}, \frac{1}{3})^T$ is on this triangle;
3. Suppose P_0, P_1 and P_2 are associated with color $(1, 0, 0)^T$ (Red), $(0, 1, 0)^T$ (Green) and $(0, 0, 1)^T$ (Blue), respectively. Use Barycentric coordinates to obtain the interpolated color associated with P.

Solution.

- The normal is given by
$$\boldsymbol{n} = \left(-\frac{1}{\sqrt{6}}, -\frac{1}{\sqrt{6}}, \frac{2}{\sqrt{6}}\right)^T.$$
-
$$P = \frac{P_1 + P_2 + P_3}{3}.$$
-
$$\boldsymbol{c} = (\frac{1}{3}, \frac{1}{3}, \frac{1}{3}).$$

6 Problem 6

Consider a Berizer curve

$$P(t) = P_0(1-t)^3 + P_1(3(1-t)^2 t) + P_2(3(1-t)t^2) + P_3 t^3,$$

where

$$P_0 = \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \quad P_1 = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \quad P_2 = \begin{pmatrix} 1 \\ 1 \end{pmatrix}, \quad P_3 = \begin{pmatrix} 0 \\ 1 \end{pmatrix}.$$

- Calculate $P(0), P(0.5), P(1), P'(0), P''(1)$;
- Convert the curve into the corresponding Hermite representation.

Solution.

- $P(0) = (0,0)^T$; $P(0.5) = (\frac{3}{4}, \frac{1}{2})^T$; $P(1) = (0,1)^T$; $P'(0) = 3(1,0)^T$; $P''(1) = -(6,6)^T$;
- $P(t) = (0,0)^T(2s^3 - 3s^2 + 1) + (0,1)^T(-2s^3 + 3s^2) + (\frac{1}{3}, 0)(s^3 - 2s^2 + s) + (-\frac{1}{3}, 0)^T(s^3 - s^2)$.

7 Problem 7

- Describe the matching square algorithm for converting the implicit representation of a circle $x^2+y^2=1$ into a polygonal curve;
- In the class we described the procedure for describing 1/4 of a circle using a NURBS curve. Can we extend the representation to describe a full circle.

Solution.

- The answer should contain the following keypoints: 1) Create a grid; 2) Determine the values of the implicit function at the grid vertices; 3) Determine the grid edges that are intersecting the zero levelset; 4) For each cell, determine the intersection segment; 5) Connect the intersection segments into a polygon.
- Check[1].

[1] https://www.geometrictools.com/Documentation/NURBSCircleSphere.pdf