CSC 3260 Midterm Exam, 1st term 2018-2019

Date: 26th October 2018 (Friday)

Time: 6:30 pm – 8:30 pm

Venue: LSB LT1

Answer Any 5 out of 6 questions (total = 100%)

If all the questions are answered, the top 5 scores will be added as the final total.

Remarks:

- When you receive the exam paper, **do not turn over** until you are told to do so. Otherwise, marks will be deducted.
- You may first write down your name and student ID on your answer book.
- **Write all your answers on the answer book ONLY**.
- Take **alternative seats**, make sure there is at least one empty seat between you and the students sit next to you.
- Submit both the exam paper and answer book when the exam is over.

1. Normal Vector and Plane Equation (20 %)

Given a 3D plane that passes through the following three points –
$P_1 = (1,0,0)$, $P_2 = (0,1,0)$ and $P_3=(0,0,1)$

(a) Compute the normal vector to this plane? (4%)

(b) What is the implicit equation of this plane? (4%) **Implicit plane equation: Ax+By+Cz+D = 0**

(c) Given another point $P_4 = (1,2,3)$, what is the shortest distance between this point and the above plane? (4%)

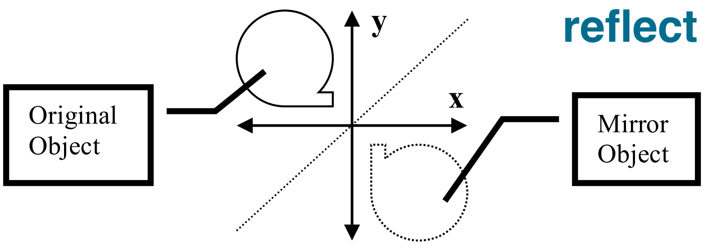
(d) Given a line that pass through the origin and P_4, what is the intersection point of this line and the above plane? (4%)

(e) Is the point of intersection also a point within the triangle formed by P_1, P_2 and P_3? If yes, what is its barycentric coordinate? (4%)

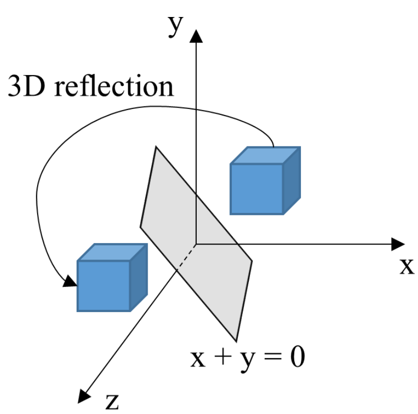
2. 2D and 3D Transformations (20%)

(a) Show how 2D reflection about the line y = x can be performed by using scaling, rotation, or translation operations. Write down the matrix multiplication in post-multiplication order. (10%)

rotate anticlockwise 90
reflect



b) Write down the 3D transformation matrix multiplication (in post-multiplication order) that perform a 3D-reflection on the plane x + y = 0 (10 %)



3. Clipping and Projection (20 %)

Given the following Perspective Projection Matrix:

$$\begin{bmatrix} x_c \\ y_c \\ z_c \\ w_c \end{bmatrix} = \begin{bmatrix} \frac{2n}{r-l} & 0 & \frac{r+l}{r-l} & 0 \\ 0 & \frac{2n}{t-b} & \frac{t+b}{t-b} & 0 \\ 0 & 0 & -\frac{f+n}{f-n} & -\frac{2fn}{f-n} \\ 0 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

(a) Draw a picture of a viewing frustum to clearly illustrate what are the parameters: **n, f, r, l, t, b** (4%)

(b) Draw a picture of the viewing frustum after performing the above perspective transformation. (4%)

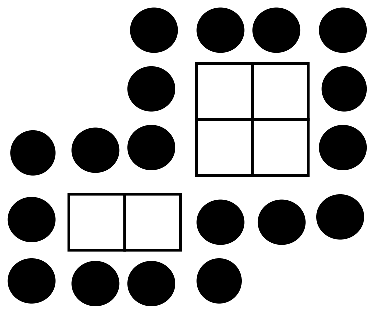
(c) How to obtain the Normalized Device Coordinates (NDC) and what are the ranges of the NDC coordinates of the transformed viewing frustum? (4%)

(d) We can perform clipping either before or after converting to NDC, what are the tests to perform for clipping before such NDC conversion. Are there any benefits to perform clipping before NDC conversion? (4%)

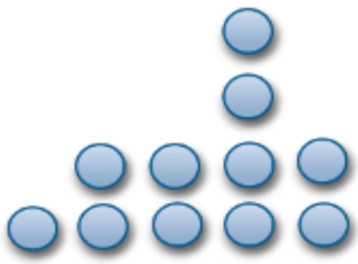
(e) What are vanishing points in perspective projection? You can explain with a simple figure. (4%)

4. Rasterization (20 %)

(a) Provide the pseudo code of a region-filling algorithm that could be used to fill all the square pixels with a specific color F in the following figure. State clearly the required inputs for your given algorithm. (5%)



(b) Provide the pseudo code of a region-filling algorithm that could be used to fill all the pixels with a specific fill color F in the following figure. State clearly the required inputs for your given algorithm. (5%)



(c) Explain how to determine whether a given 2D point is inside or outside of an arbitrary 2D polygon. (5%)

(d) Explain how to determine whether a given 3D point is inside or outside of a view frustum bounded by six planes. (5%)

5. Hidden Surface Removal (20 %)

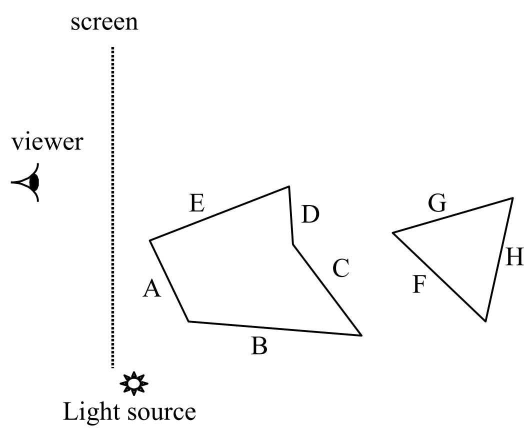
a) Provide the pseudo code of z-buffer algorithm for hidden surface removal. (5 %)

b) The figure below is a 2D version of hidden surface removal problem. Suppose all the lines segments are projected onto the screen in a perspective way.

Let N_x be the outward normal of a line segment x,

L_x be a light vector pointing from the line segment x to the light source

V_x be a viewer vector pointing from the line segment x to the viewer.



i) Which line segment(s) will be removed by back face culling? (4 %)

ii) How to test whether a line segment x should be removed before rendering? (4 %)

iii) Should we modify the testing method if the objects project on the screen in a parallel manner? If yes, How? Which line segment(s) will be removed by back face culling now? (5%)

iv) Under what kind of situation, we can use back face culling alone to completely solve the hidden surface removal problem for rendering a scene? (2%)

6. Illumination Model & Shading (20 %)

(a) Given the following equation for Phong illumination model:

$$I = k_e + k_a I_a + \sum_i f(d_i) I_{li} \left[k_d (\mathbf{N} \cdot \mathbf{L}_i)_+ + k_s (\mathbf{V} \cdot \mathbf{R})_+^{ns} \right]$$

i) Explain what is *$f(d_i)$? (3%)*

ii) To render a red metallic surface with small and focused specular highlight, which of the above parameter(s) used in the Phong illumination model should be adjusted and to what value(s)? (3%)

iii) To render a green plastic surface with widespread and soft white specular highlight, which of the above parameter(s) used should be adjusted and to what value(s)? (3%)

(b) Given a four-sided polygon that covers exactly 64 pixels after projected to the raster space. You are further given the following information:

- The unit normal vector of the polygon
- The unit normal vector at each of the four vertices
- The required operation cost for setting a pixel to a certain color is **C,** where a color is expressed in term of R, G, and B components
- The required operation cost for evaluating the **PHONG shading equation** at a given point is **S**
- The required operation cost for a **Linear scalar interpolation** at a given point is **L**

Express in term of **C, S**, & **L**, the required total operation cost to perform the following tasks:

i) To apply Flat shading on the above polygon (3%)

ii) To apply Gouraud shading on the above polygon (3%)

iii) To apply Phong shading on the above polygon (3%)

iv) Explain what are the highlight anomalies that may appear in Gouraud shading? (2%)

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