HÁSKÓLINN Í REYKJAVÍK
REYKJAVIK UNIVERSITY

Computer Graphics
T- 511 – TGRA

Final Exam

Teacher: Kári Halldórsson

Date: 23. November, 2018

Time: 14:00 - 17:00

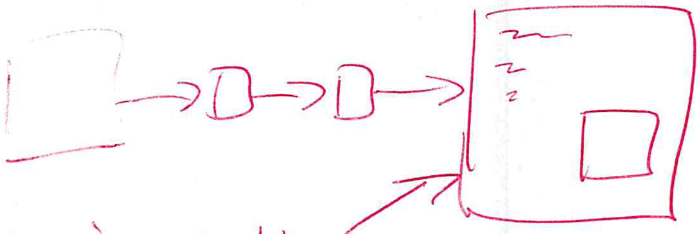
Helping materials: non-programmable calculator

Name: LAUSNIR

Kt.: ____________________

Answers can be given in English and/or Icelandic.

1. **(10%) Rasterization**
Describe the process of rasterization in OpenGL, considering the following questions:
- Where in the OpenGL pipeline does it occur, and what is its purpose?
- How does the algorithm work and what are its inputs?
- What values does it affect and which processes does it run?



1 Last in pipeline

1 Make pixels in framebuffer from vertex coordinates

2 Inputs: vertices of a polygon and linked data like varying

3 Loops from min y to max y and do each scan line from min x to max x

1 Linearly interpolates data like varying

1 runs fragment shader with those values

1 uses output to set pixel values in frame buffer

2. **(10%) Depth testing**
Describe the process of depth testing in OpenGL.
What is the purpose of it?
What values are used and how, and where/when are they calculated?
How is the data processed between different parts of the calculations?

2 To display what is closer, regardless of drawing order

1 pseudo depth calculated for vertex
1 in projection

1 interpolated for each pixel
1 in rasterization

1 check if lower than z-buffer
1 then set color in frame buffer
1 and z in z-buffer
else
1 discard both.

3. **(10%) Shaders**
Describe the input and output of the OpenGL pipeline's two main shaders, considering the following questions:
What types of "global" variables can be defined in each shader?
How are the values of each type of variable affected?
What main output variable is set in each shader?

1 attribute variables

1 in vertex shader

1 when pipeline run, these are set from vertex lists and run automatically

1 uniform variables

in both vertex and fragment shaders

1 set at any time by program.

1 varying variables

1 set in main() code of vertex shader

1 interpolated and set by rasterization before running fragment shader

1 gl_Position in vertex shader

1 gl_FragColor in fragment shader

4. (10%) Cohen-Sutherland Clipping

A clipping window has the following geometry:

Window(left, right, bottom, top) = (-16, 16, -9, 9)

A line with the following end points is drawn in the world:

P1: (22, 11)

P2: (10, 5)

Show how the Cohen-Sutherland clipping algorithm will clip these lines and what their final endpoints, if any, are. Show the coordinate values of P1 and P2 after each pass of the algorithm.

1 del x = 22 - 10 = 12

1 del y = 11 - 5 = 6

1 Pass 1:   code 1 : 1010 (or 0110 or etc.)

1 code 2 : 00 00

P1 to right :

3 $P1.y = P1.y + (W.r - P1.x) \cdot \frac{dely}{delx}$

$= 11 + (16 - 22) \cdot \frac{6}{12}$

$= 11 - 6 \cdot \frac{1}{2} = 11 - 3 = \underline{8}$

1 $P1.x = W.r = 16$

P1 = (16, 8)   P2 = (10, 5)

Pass 2:   code 1 : 0000

2 code 2 : 0000

TRIVIAL ACCEPT !!

5. (10%) Window-2-Viewport mapping

A second line is drawn into the same window as in the previous example (4. Cohen-Sutherland clipping). This line has the endpoints:

P1 = (-5, 7) & P2 = (12, -2)

In which pixels on a 1920x1080 viewport (bottom left corner (0,0)) will the line's endpoints be rendered?

$$A = \frac{1920}{16-(-16)} = 60 \qquad B = \frac{1080}{9-(-9)} = 60$$

$$C = 0 - 60 \cdot (-16) = 960 \qquad D = 0 - 60 \cdot (-9) = 540$$

P1:

$$sx = 60 \cdot (-5) + 960 = 660$$
$$sy = 60 \cdot 7 + 540 = 960$$

P1: $\underline{(660, 960)}$

P2:

$$sx = 60 \cdot 12 + 960 = 1680$$
$$sy = 60 \cdot (-2) + 540 = 420$$

P2: $\underline{(1680, 420)}$

6. (40%) Matrices and transformations

a) (10%)
A camera is set up to be positioned in (-2, 3, 1) looking at the point (1, -1, -1).
It has an up vector (0,1,0).
Find the values for the camera's coordinate frame, clearly showing each of the four parts of the coordinate frame and what they are.

n = eye − center = $(-2,3,1)-(1,-1,-1)=(-3,4,2)$ | $|n|=\sqrt{29}$

u = up × n = $(2,0,3)$ | $|u|=\sqrt{13}$

v = n × u = $(12,13,-8)$ | $|v|=\sqrt{377}$

Coordinate frame:

$$\boxed{\begin{aligned} eye &= (-2,3,1) \\ u &= \frac{1}{\sqrt{13}}\cdot(2,0,3) \\ v &= \frac{1}{\sqrt{377}}\cdot(12,13,-8) \\ n &= \frac{1}{\sqrt{29}}\cdot(-3,4,2) \end{aligned}}$$

MUST NORMALIZE!

b) (5%)
Show how this coordinate frame would commonly be represented in a matrix. What matrix is this and what are its values in this particular case?

$$-eye \circ u = \frac{2\cdot 2 + 0 - 1\cdot 3}{\sqrt{13}} = \frac{1}{\sqrt{13}}$$

$$-eye \circ v = \frac{2\cdot 12 - 3\cdot 13 - 1\cdot(-8)}{\sqrt{377}} = \frac{-7}{\sqrt{377}}$$

$$-eye \circ n = \frac{2\cdot(-3) - 3\cdot 4 - 1\cdot 2}{\sqrt{29}} = \frac{-20}{\sqrt{29}}$$

VIEW MATRIX:

$$\begin{bmatrix} 2/\sqrt{13}^{\;0,55} & 0^{\;0} & 3/\sqrt{13}^{\;0,83} & 1/\sqrt{13}^{\;0,28} \\ 12/\sqrt{377}^{\;0,62} & 13/\sqrt{377}^{\;0,67} & -8/\sqrt{377}^{\;-0,41} & -7/\sqrt{377}^{\;-0,36} \\ -3/\sqrt{29}^{\;-0,56} & 4/\sqrt{29}^{\;0,74} & 2/\sqrt{29}^{\;0,37} & -20/\sqrt{29}^{\;-3,7} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

c) (10%)
The camera should have a field of view of 120°, an aspect ratio of 16:9, a near plane at 1 and a far plane at 10. Find the exact values for a matrix that calculates this camera.
Which matrix in your shader should be set to these values?

$$top = N \cdot \tan\left(\frac{fovy}{2}\right) = 1 \cdot \tan(60^\circ) = 1{,}732$$

$$bottom = -top = -1{,}732$$

$$right = top \cdot ratio = 1{,}732 \cdot \frac{16}{9} = 3{,}079$$

$$left = -right = -3{,}079$$

Projection:

$$\begin{bmatrix} \frac{2\cdot 1}{3{,}079-3{,}079}\ \ 0{,}32 & 0\ \ 0 & 0\ \ 0 & 0\ \ 0 \\ 0\ \ 0 & \frac{2\cdot 1}{1{,}732-1{,}732}\ \ 0{,}58 & 0\ \ 0 & 0\ \ 0 \\ 0\ \ 0 & 0\ \ 0 & \frac{-(10+1)}{10-1}\ \ -1{,}22 & \frac{-2\cdot 10\cdot 1}{10-1}\ \ -2{,}22 \\ 0\ \ 0 & 0\ \ 0 & -1\ \ -1 & 0\ \ 0 \end{bmatrix}$$

d) (10%)
Vertex data should be drawn into a coordinate frame that has been first scaled double in all dimensions, then rotated by 30° about the z-axis and finally translated by (2, 4, 7).
Represent this coordinate frame in a matrix. Which matrix would this commonly be?

1 2 1

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 0{,}866 & -0{,}5 & 0 & 0 \\ 0{,}5 & 0{,}866 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 1 & 7 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

2

$$= \begin{bmatrix} 1{,}732 & -1{,}0 & 0 & -0{,}536 \\ 1{,}0 & 1{,}732 & 0 & 8{,}928 \\ 0 & 0 & 2 & 14 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad 2$$

MODEL MATRIX 2