CPSC 314
Assignment 2

Due Monday November 3, 2014

Answer the questions in the spaces provided on the question sheets. If you run out of space for an answer, use separate pages and staple them to your assignment.

Name: ____________________________

Student Number: __________________

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1. (5 points) Scan Conversion

Give the pseudocode for scan converting the ellipse shown below. It is centred at $x_c, y_c$, has a major axis length of $2a$, a minor axis length of $2b$, and contains a circular hole of radius $r$. Use implicit equations to develop your solution.

```
for (x = x_c - a; x <= x_c + a; x++) {
    for (y = y_c - b; y <= y_c + b; y++) {
        if ($F_1(x,y) > 0$ and $F_2(x,y) > 0$)
            SetPixel(x,y)
    }
}
```

$F_1(x,y) = (x-x_c)^2 + (y-y_c)^2 - r^2$

- $= 0$ on circle
- $> 0$ outside
- $< 0$ inside

$F_2(x,y) = 1 - \frac{(x-x_c)^2}{a^2} - \frac{(y-y_c)^2}{b^2}$

- $= 0$ on circle
- $> 0$ inside
- $< 0$ outside
2. Scan Conversion and Interpolation

A triangle has device coordinates $P_1(10, 10)$, $P_2(80, 20)$, and $P_3(40, 90)$. You wish to interpolate a value $v$ for point $P(60, 30)$, given the value of $v$ at the vertices: $v_1 = 40$, $v_2 = 20$, $v_3 = 30$.

(a) (1 point) Sketch the triangle and the point $P$.

(b) (4 points) Develop a plane equation for $v$ as a function of $x$ and $y$. You can use Matlab or an online linear equation calculator (Google this) to solve a set of linear equations for your plane parameters. Compute $v$ for point $P$ using the plane equation.

Plane equation: $Ax + By + C = v$

For point $P$:

\[ A = -0.2852, \quad B = -0.0487, \quad C = 25.5 \]

(c) (4 points) Compute the barycentric coordinates for point $P$. Compute $v$ for point $P$ using the Barycentric coordinates.

\[ \alpha = \frac{F_{12}(60, 30) - (70)(60) + (70)(30) - 6400}{5300} = 0.1887 \]
\[ \beta = \frac{F_{17}(60, 30) = (10)(60) - (70)(30) + 6400}{5300} = 0.1698 \]
\[ \gamma = 1 - \alpha - \beta = 0.6415 \]
3. (6 points) Culling

For the following scene, shown as a side-view of VCS, list which polygons would be culled by (a) view frustrum culling, and (b) back-face culling. Assume that each segment with a letter represents a face. Consider both types of culling independently of each other.

(a) View frustrum culling: culled if both vertices of a given face are "outside" with respect to one of the frustrum planes.

\[
\text{cull: } [a, b, c, q, u]
\]

(b) Back face culling: culled if the eye is below the plane that embeds the given polygon.

\[
\text{cull: } [a, b, d, g, h, j, k, n, p, q, t]
\]
4. Clipping

Suppose that a perspective view-volume is defined by near=1, far=4, bot=-1, top=1, left=-1, far=1. Consider the line defined by the VCS coordinates $P_1(2, 0, 5)P_2(-1, 2, 2)$.

(a) (3 points) Sketch a side-view and top-view of the view-volume and the line.

(b) (3 points) Determine if view-frustum culling can be applied to the line, i.e., if both vertices are “outside” with respect to any one of the six view frustum planes. Use the implicit plane equations:

- Left: $x + \frac{\text{left}}{\text{near}} z = x - z$  \hspace{1cm} $P_1: 2 - (-5) = 7$\hspace{1cm} $P_2: -1 - (-2) = 1$
- Right: $-x - \frac{\text{right}}{\text{near}} z = -x - z$  \hspace{1cm} $P_1: -2 - (-5) = 3$\hspace{1cm} $P_2: -(-1) - (-2) = 3$
- Top: $-y - \frac{\text{top}}{\text{near}} z = -y - z$  \hspace{1cm} $P_1: -0 - (-5) = 5$\hspace{1cm} $P_2: -(-1) - (-2) = 3$
- Bottom: $y + \frac{\text{bottom}}{\text{near}} z = y - z$  \hspace{1cm} $P_1: 0 - (-5) = 5$\hspace{1cm} $P_2: 2 - (-2) = 4$

(c) (1 point) Based on your work for the question above, determine the view-frustum planes that the line intersects.

We need to clip with respect to the back plane: $P_1$ is inside\hspace{1cm} $P_2$ is outside

(d) (3 points) Compute the final clipped version of line $P_1P_2$ in VCS. Show your work.

$$p(t) = P_i + t(P_2 - P_i)$$

for intersection: \hspace{1cm} $t = \frac{-\mathbf{F}(P_i)}{\mathbf{F}(P_2) - \mathbf{F}(P_1)} = \frac{-(-1)}{2 - (-1)} = \frac{1}{3}$

$$P_i' = \begin{bmatrix} 2 \\ 0 \\ -5 \end{bmatrix} + \frac{1}{3} \begin{bmatrix} -3 \\ 2 \\ 3 \end{bmatrix} = \begin{bmatrix} 1 \\ 2/3 \\ -4 \end{bmatrix} = P_i'$$

Final clipped segment is $P_i'P_2$
5. Coding: Texture mapping, vertex shaders, and fragment shaders

The objective of this coding question is to gain some hands-on experience with using texture mapping, vertex shaders, and fragment shaders. You will be starting with template code (see the lectures web page for the link) and making a number of changes to it. A screen shot of what the final solution might look like is shown below.

Complete the following modifications to the template code. You need not exactly follow the given order, as most of the modifications are independent of each other.

(a) (5 points) Examine the vertex shader (`mesh_vs.glsl`) and the fragment shader (`mesh_fs.glsl`) for the available input variables, which are listed at the beginning of the shader. In the space below, sketch a diagram with illustrated blocks for the javascript application code, the GPU memory, the vertex shader, the fragment shader, and the final image buffer. On this diagram, list the attribute, uniform, and varying variables and illustrate between which blocks they are communicated. Also illustrate the default output variables for the vertex shader and fragment shader. Include your diagram below as part of your paper assignment handin.
(b) (2 points) The ground texture is modeled using a textured plane, constructed with four vertices, which is defined in a2.js. Change the texture coordinates assigned to the four vertices such that the texture becomes much finer than it currently is, i.e., so that it repeats many more times.

(c) (2 points) Change the texture map that is used for the bunny from the UBC logo to something more appropriate. See the loadTextures() function for where the texture map file names are specified. Note that the dimensions of images used for texture mapping must by powers of 2, i.e., 256x256, 512x512, etc. If you like, use psychedelic.png. Or, better yet, take any image you like, and resize it using your favorite image resizing application. This is optional, but it can count as one of the “extras” you do for the last step.

(d) (4 points) Now you will be changing the texture mapping for the faces of the cube. First, view the image ubcTexture.png, which is currently used to texture map the cube. You should change the texture coordinates for each of the cube faces (see a2.js) in order to map the four individual sub-images in that texture map to individual faces, in a way that makes sense, i.e., upright and legible. See the solution image at the start of this question for an example.

(e) (3 points) Now take a look inside the fragment shader, (mesh_fs.glsl). The ultimate output of the fragment shader is gl_FragColor. Comment out the last line and add a new line that assigns gl_FragColor = u_FragColor; . Observe what this does, i.e., produce a simple flat-shaded rendering without textures. Now the goal for this step is to give your bunny a ‘colour tinted’ texture. Look for the code in drawScene() where u_FragColor is used before drawing. Change the colour assignments to something distinct and observe the resulting change in your ‘flat shaded’ rendered version. Now compute the product of the default colour with the texture-map colour and use that as the colour for the fragment. Note that the shading language allows for component-wise multiplication using a statement such as: vec4 c = a*b; , where a and b are also of type vec4. You should now be able to produce a texture mapped bunny with a desired color tint.

(f) (3 points) We’ll now use the fragment shader to produce an elliptical viewing window. In the supplied fragment shader, you are already given the NDCS coordinates of the fragment being rendered. Use this to evaluate an implicit function, f, for a circle, which will appear as an ellipse on screen because of the aspect ratio. Replacing the default f=1.0; line with your function should result in the fragment being assigned the colour black when it is outside the elliptical border.

(g) (3 points) We’ll now be making changes to the vertex shader. The goal in this step is to distort the geometry in the vertex shader. First, you could simply move the geometry as a function of time, given by u_DistortionTime. Thus adding an offset to one of the x,y,z components, in model space, according to DistortionAmp*sin(c2*DistortionTime) will result in the vertex shader adding a sinusoidal translation to the entire model over time. While all the objects are drawn using the same vertex shader, only the bunny should move because DistortionAmp
is set to zero before the cube and ground plane are drawn. Now, further change the
distortion so that the offset also varies as a function of space,
i.e., $\text{DistortionAmp} \cdot \sin(c2 \cdot \text{DistortionTime} + c3 \cdot x)$, where $x$ could be any of
the point’s $x, y, z$ model coordinates. Hitting the spacebar will start and stop the
advancement of $\text{DistortionTime}$.

(h) (3 points) We’ll now introduce a simple model of colored fog using the fragment
shader. You will see some template code in the fragment shader that blends the fog
colour, white by default, with the computed fragment colour in order to compute a
final pixel colour. First, understand the visual effect by setting $\text{fogAmount}=0.5$ and
also experimenting with fog colours other than white. Now compute $\text{fogAmount}$
as a linear function of the viewing distance, which you have access to because
$v_{\text{ViewPosition}}$ is provided as a varying variable, and this represents the VCS
coordinates for the current fragment. You will need to further clamp $\text{fogAmount}$ to
within the range $[0, 1]$. This will mean that beyond some distance, the fragment
will be completely fog coloured, while closer than some distance, the fragment will
have no fog colour at all.

(i) (5 points) Develop your ideas of your own for augmenting the scene. You could
add more bunnies, make the fog color vary with time and space, add some motion,
etc.

Submit your code using handin cs314 a2.
Include a README.txt file that contains: (a) your name; (b) your student number; (c)
any comments and explanations that you wish to include.