CS559 Computer Graphics – Spring 2018

Practice Final Exam

1. [$6 \times 4\% = 24\%$] MULTIPLE CHOICE SECTION. Write the letter of the correct answer (or answers) in the space provided. You do not need to give a justification for your answer(s).

   (1) Sometimes when using texture mapping we will have a situation where the size of a display pixel (fragment) where a textured object is drawn will be much **smaller** than the size of the pixels of the texture image that has been mapped to that same object location.
   Which of the following statements is correct about this scenario?

   Write the letter the ONE most correct answer: ☐

   (a) If the texture image contained black and white stripes that alternated at a certain frequency, the rendered image could make those stripes appear as if they were alternating at a lower frequency, due to aliasing.
   (b) This is exactly the scenario for which mip-mapping can be most successful in eliminating aliasing artifacts.
   (c) In this scenario, if texture look-ups select only the closest pixel in the texture image, we risk jagged edges appearing on our display. Interpolating between nearby texture pixels (usually via bilinear interpolation) is the typical remedy.

   (2) Sometimes when using texture mapping we will have a situation where the size of a display pixel (fragment) where a textured object is drawn will be much **larger** than the size of the pixels of the texture image that has been mapped to that same object location.
   Which of the following statements is correct about this scenario?

   Write the letter the ONE most correct answer: ☐

   (a) This scenario occurs when we have zoomed our camera too close to a textured object.
   (b) This is exactly the scenario for which mip-mapping can be most successful in eliminating aliasing artifacts.
   (c) This is exactly the scenario for which bi-linear interpolation between nearby texture image pixels will be the best way to avoid artifacts.

(3) Which of the following statements are true about bump mapping?

Write the letter of ALL correct answers here:

(a) It can create surface roughness in the interior of individual triangles by displacing points interior to each triangle outside of the triangle plane.

(b) Its effect on a flat plane goes away if we tilt the bump-mapped plane to the point where it becomes parallel with the viewing direction.

(c) It requires using a texture mapping unit, regardless of whether we use texture mapping for color purposes.

(4) In polynomial curves, each component $x(t), y(t), z(t)$ of the curve formula $\mathcal{C}(t) = [x(t), y(t), z(t)]$ is a polynomial expression. Which of the following are legitimate reasons explaining why polynomial curves are very popular, and often advantageous compared to alternatives?

Write the letter of ALL correct answers here:

(a) The derivatives of polynomial curves are, conveniently, polynomials themselves.

(b) Polynomial curves are arc-length parameterized by construction.

(c) It is relatively easy to solve for the coefficients of such polynomials, given intuitive constraints such as what the value of the curve or its derivative is desired to be at various parts of the curve.

(5) We want to construct a polynomial parametric curve $\mathcal{C}(t)$, defined over the interval $[0, 1]$, such that it satisfies the constraints:

$$\mathcal{C}(0) = P_0, \quad \mathcal{C}(1) = P_1, \quad \mathcal{C}'(0.5) = G$$

where P_0, P_1 are given control points, and G is also a vector given as input. What is the **lowest** degree of the polynomial we need to use, to allow our curve to satisfy such constraints for any input value of P_0, P_1, and G?

Write the letter of the ONE most correct answer here:

(a) We need a polynomial of degree 2, regardless of whether the curve is in 2D or 3D.

(b) We need a polynomial of degree 3, regardless of whether the curve is in 2D or 3D.

(c) The answer will be different depending on whether the curve in question (and the input points) are in 2D or 3D.

(6) Which of the following appearance effects would be extremely hard (or impossible) to do without the render-to-texture functionality of modern graphics cards?

Write the letter of ALL correct answers here: $\boxed{}$

(a) Bump mapping.

(b) Shadow mapping.

(c) Reflection mapping (also called environment mapping) for a scene containing a single metallic-looking cube, in a skybox.

2. [30%] SHORT ANSWER SECTION. Answer the following questions in no more than 1-3 sentences (when required) or by filling in the answer boxes.

   (a) [8%] Polynomial curves, where each component $x(u), y(u), z(u)$ of the curve formula $\mathcal{C}(u) = (x(u), y(u), z(u))$ is a polynomial expression, are the most important and popular class of parametric curves. Explain one reason why using polynomial expressions can be very advantageous, when designing parametric curves.
   Hint: Alternatives to polynomials would be expressions that include trigonometric, exponential or logarithmic functions, square roots, ratios of expressions, etc. What disadvantages would those have?

   (b) [8%] When we were discussing diffuse and specular lighting, we saw that performing the lighting calculations in the *vertex shader* (instead of the fragment shader) would probably be suboptimal, but maybe acceptable in some cases. Explain why, in the case of texture mapping, it would make almost no sense to attempt to do texture look-ups in the vertex shader, and why such texture calculations should be done in the fragment shader instead.

(c) [14%] There are certain appearance effects that rely on the graphics card's ability to support multiple textures (i.e. having multiple texture mapping units), while other effects are only made possible due to the render-to-texture ability of the modern graphics pipeline. Finally, some effects would be too complex to reproduce using the standard pipeline and shaders, and would be best suited to global illumination techniques. For the scenarios below, mark one of the following options in the boxes provided, to indicate which of these features will be necessary to reproduce them.

MULTI-TEXTURE: Give this answer if the ability to have multiple textures is crucial in order to support this effect. Another way to think about this – select this option if this effect would have been very difficult to achieve using only a single texture mapping unit.

RENDER-TO-TEXTURE: Give this answer if the ability to support rendering-to-texture is crucial in order to achieve this effect.

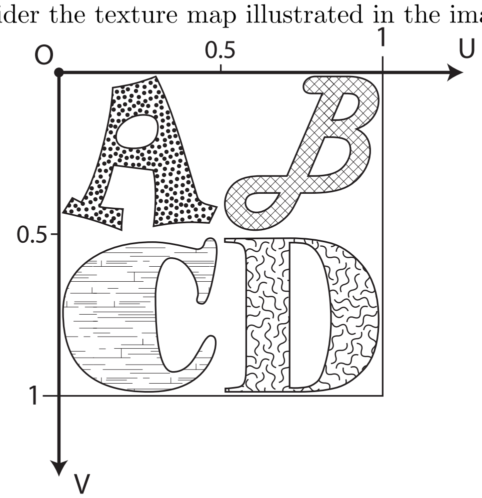
MR: *Both* multi-texture *and* render-to-texture are needed.

NONE: This effect can be achieved with the standard graphics pipeline, even without using multi-texture or render-to-texture capabilities.

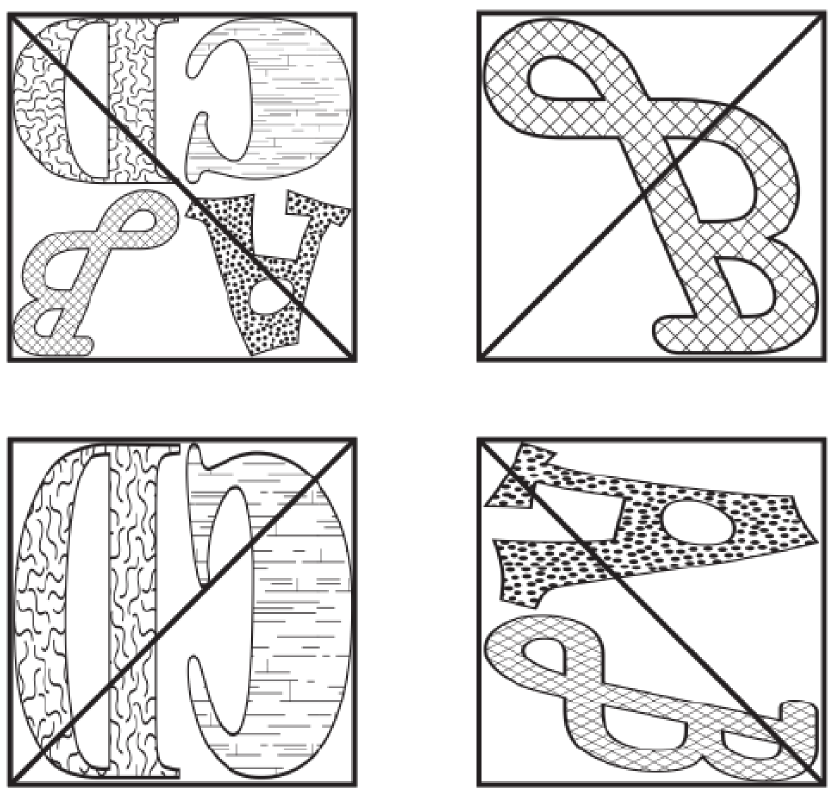
(Write "M","R", "MR", "G", or "N" next to each question below. You don't need to provide an explanation, unless you really feel that your answer comes with significant caveats.)

- ☐ A scene with a skybox.
- ☐ A textured object that also exhibits specular reflection.
- ☐ Object shadows generated via shadow mapping.
- ☐ Applying decal textures to objects.
- ☐ Using dynamic environment maps to allow object surfaces to reflect the image of other objects within the scene.
- ☐ A scene containing a moving, hierarchically modeled object with many solid-colored, diffuse-shaded, parts.
- ☐ An object with a simple texture (for color), and a bump map for faking surface roughness.

3. [16%] Consider the texture map illustrated in the image below:

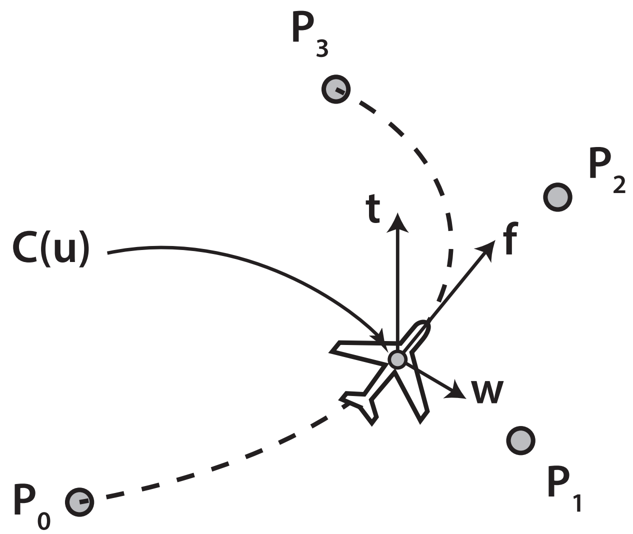


We want to apply this texture to the four square surface patches shown below, each of which has been split into two triangles:



For each vertex of each of the four squares, write the texture coordinates that we need to associate with this vertex in order to produce the desired apperance. Write the coordinates in the form (u, v) next to each vertex. *Note: Don't be confused by the fact that each square is "split" into two triangles. You can simply answer this question on a vertex-by-vertex basis. At the end, you will write 16 (u, v) pairs of numbers, one next to each vertex of the squares above.*

4. [15%] A plane is flying (in 3D) along a cubic Bézier curve $\mathcal{C}(u)$ as shown in the illustration below.



Remember that the Bézier curve is described by the expression

$$\mathcal{C}(u) = \begin{bmatrix} 1 & u & u^2 & u^3 \end{bmatrix} \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ -3 & 3 & 0 & 0 \\ 3 & -6 & 3 & 0 \\ -1 & 3 & -3 & 1 \end{bmatrix}}_{\mathbf{B}} \underbrace{\begin{bmatrix} P_0 \\ P_1 \\ P_2 \\ P_3 \end{bmatrix}}_{\mathbf{P}}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ -3 & 3 & 0 & 0 \\ 3 & -6 & 3 & 0 \\ -1 & 3 & -3 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 8 & 0 & 0 \\ 8 & 8 & 8 \\ 0 & 8 & 8 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 24 & 0 & 0 \\ -24 & 24 & 24 \\ 0 & -16 & -16 \end{bmatrix}$$

where $\mathbf{B}$ is the Bézier basis matrix, and $\mathbf{P}$ is the 4×3 matrix with the coordinates of the control points P_0, P_1, P_2, P_3 as its rows.

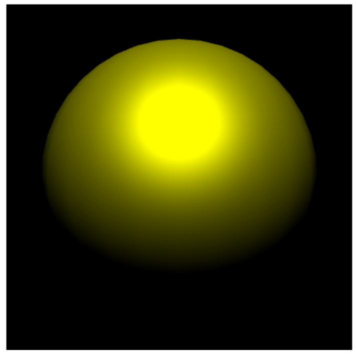
In the picture above, the control points have the coordinates $P_0 = [0, 0, 0]$, $P_1 = [8, 0, 0], P_2 = [8, 8, 8], P_3 = [0, 8, 8]$.

(a) Compute the position of the plane $\mathcal{C}(u)$ for parameter value $u = 0.5$.

(b) Compute a vector $\mathbf{f}$ that is *tangential* to the trajectory at $u = 0.5$, as shown in the illustration. The magnitude of the vector is not important, as long as the direction you compute is correct.

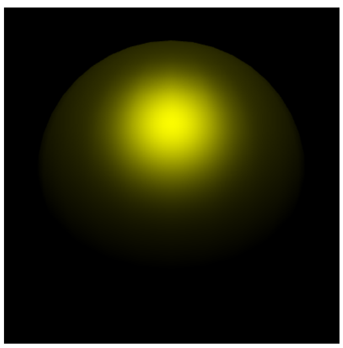
(c) For the same parameter value $u = 0.5$, compute a vector $\mathbf{w}$ ("wing" vector) such that (a) it is perpendicular to the direction of motion, and (b) it is perpendicular to the vector $\mathbf{t} = [0, 1, 0]$ (the "up" vector). *Note: It is acceptable to express* $\mathbf{w}$ *using a mathematical expression (e.g. a cross product). It is not essential to carry out the operations to compute the individual coordinates of* $\mathbf{w}$.

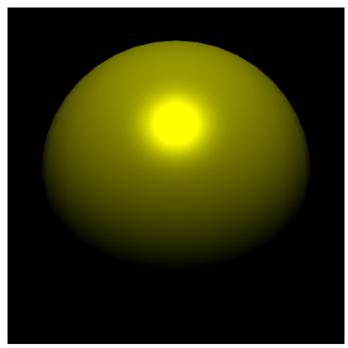
5. [15%] The image below has been produced by a certain set of parameters for ambient, diffuse and specular lighting.

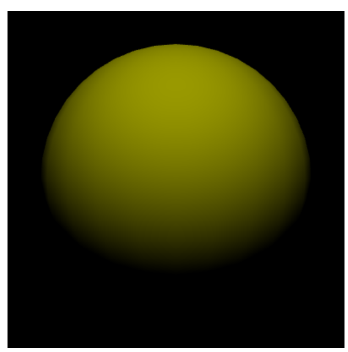


Each one of the following images was created by either increasing or decreasing just *one* of the following parameters, relative to the image above.

- The **A**mbient lighting coefficient.
- The **D**iffuse reflection coefficient.
- The **S**pecular reflection coefficient.
- The Specular **E**xponent.







In each of the boxes provided, write "A","D","S" or "E" to indicate the parameter that changed, with an up- or down-arrow to indicate if the parameter was increased or decreased.