SCHOOL of ELECTRICAL ENGINEERING & COMPUTING
FACULTY of ENGINEERING & BUILT ENVIRONMENT
The UNIVERSITY of NEWCASTLE

Comp3320/6370 Computer Graphics

Semester 2, 2018

Exercises: Midterm feedback

Question 1: **Basic CG** (2 marks)

a) (1 mark) What is the difference between Phong shading and Gouraud shading?

Solution:

Gouraud shading:

- Calculate lighting at each vertex and interpolate over the triangles surface.
- Smooth and still fast
- Dependent on the level of detail of the object
- Problems: Missing highlights, failure to capture spotlight effects. (Textures can help)
- If triangles smaller than pixels, then Gouraud is as good as Phong.

Phong shading:

- Uses shading normals stored at the vertices to interpolate the shading normal at each pixel.
- Use sthis normal to calculate the colour for that pixel. Costly.

b) (1 Mark) Describe in detail Phong and Blinn Lighting and the difference between them.

Solution:

Let $\mathbf{l}$ be the dirrection of light vector and $\mathbf{v}$ the view direction. Then the reflection vector is $\mathbf{r} = 2(\mathbf{n} \cdot \mathbf{l})\mathbf{n} - \mathbf{l}$

Phong lighting equation: The specular contribution gets stronger the more closely aligned the reflection vector r is with the view vector v.

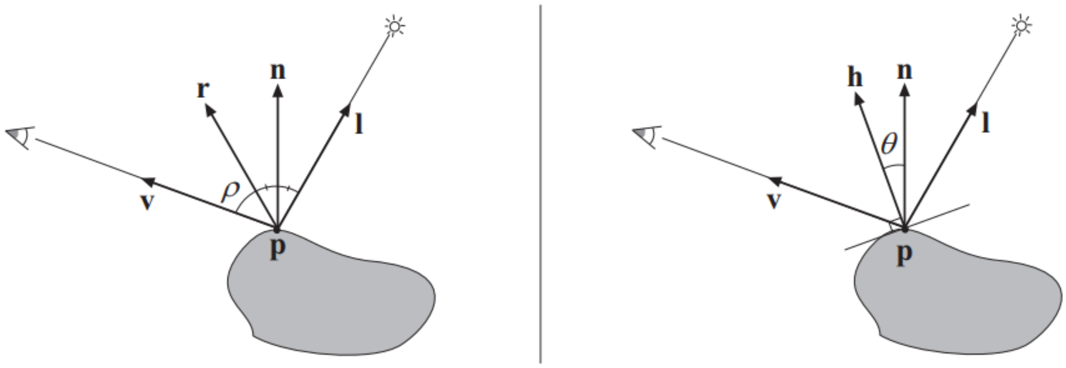
$$\mathbf{i}_{spec} = (\mathbf{r} \cdot \mathbf{v})^{m_{shi}} = (\cos \rho)^{m_{shi}}$$

Blinn lighting equation: Let h be the normalised half vector between l and v, i.e. $\mathbf{h} = \frac{\mathbf{l}+\mathbf{v}}{\|\mathbf{l}+\mathbf{v}\|}$. Then

$$\mathbf{i}_{spec} = (\mathbf{n} \cdot \mathbf{h})^{m_{shi}} = (\cos \theta)^{m_{shi}}$$

Blinn lighting is faster to calculate than Phong lighting.

Phong Lighting and Blinn Lighting



Question 2: **Dot Product and Collisions** (2 marks)

Consider homogeneous coordinates in 3-dimensional space.

a) (1 mark) Let $\mathbf{u} = (1, 5, 2, 0)$ and $\mathbf{v} = (4, 0, 3, 0)$ be two vectors. Calculate the length of the projection of $\mathbf{u}$ onto the line through the origin in direction of $\mathbf{v}$.

Solution:
We can use the dot product and then obtain: $\|\text{proj}_{\vec{v}}(\vec{u})\| = \vec{u} \cdot \frac{\vec{v}}{\|\vec{v}\|}$
$\vec{u} \cdot \vec{v} = 10$
$\|\vec{v}\| = 5$

Answer is: **2**

b) (1 mark) Let $\mathbf{A} = (4, 2, 1, 1)$ be a point and let p be the line that contains the origin and $\mathbf{A}$. Calculate the "hitpoint" where line p intersects with the plane that is determined by the normal vector $\mathbf{n} = (1, 5, 2, 0)$ and the anchor point $\mathbf{B} = (1, 3, 4, 1)$ on the plane.

We want to find the **hit point** P_{hit}.

Suppose the line hits at $t = t_{hit}$, with the equation of line as $\vec{A}t = P$.
At $t = t_{hit}$, the line $\vec{A}t = P$ and the plane $\vec{n} \cdot (P - B) = \vec{0}$ must have same coordinates.
We exploit this fact and substitute the point P in the equation of the plane to calculate the hit point:

$$\begin{aligned} \vec{n} \cdot \left(\vec{A}t_{hit} - B\right) &= 0 \\ \Rightarrow t_{hit} &= \frac{\vec{n} \cdot B}{\vec{n} \cdot \vec{A}} = 1.5 \end{aligned}$$

Using t_{hit} the hit point can now be calculated as:

$$P_{hit} = \vec{A}t_{hit} = (6, 3, 1.5)$$

Question 3: **Transforms in 3D** (2 marks)

a) (0.5 marks) What is the rotation matrix (in homogeneous coordinates) that rotates some entity by angle $\alpha = \pi$ about the x-axis?
Solution:

$$R_x(\pi) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\pi & -\sin\pi & 0 \\ 0 & \sin\pi & \cos\pi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

b) (0.5 marks) What is the inverse of the following transform in homogeneous coordinates.

$$\mathbf{F} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Solution:
As $\mathbf{F} \in M(4 \times 4, \mathbf{R})$ have the general form of a 3D transform in homogeneous coordinates. then $\mathbf{F}$ can be written as:

$$\mathbf{F} = \left[\begin{array}{c|c} \mathbf{M} & \mathbf{T} \\ \hline \mathbf{0} & 1 \end{array}\right] = \left[\begin{array}{ccc|c} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

Let $\mathbf{N} = \mathbf{M}^{-1}$ be the inverse of $\mathbf{M}$. The inverse of $\mathbf{F}$ is given by:

$$\mathbf{F}^{-1} = \left[\begin{array}{c|c} \mathbf{N} & -\mathbf{NT} \\ \hline \mathbf{0} & 1 \end{array}\right] = \left[\begin{array}{ccc|c} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 1 & 0 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

Alternatively you could explain that the original matrix is a translation by $+1$ and therefore the inverse must be a translation by -1.

c) (1 mark) Scale a model by a factor of 2 in direction of $\mathbf{w} = (1, 3, 1, 0)$. What is the transform in mathematical notation?
Solution: See exercise 21.

Question 4: **Buffers and Effects** (2 marks)

a) (1 mark) What is an accummulation buffer and what is it usually used for?
Solution:
The accumulation buffer is an extended-range color buffer. Images are not rendered into it. Rather, images rendered into one of the color buffers are added to the contents of the accumulation buffer after rendering. Effects such as antialiasing (of points, lines, and polygons), motion blur, and depth of field can be created by accumulating images generated with different transformation matrices.

b) (1 mark) Billboard: The polygon's original surface normal $\mathbf{n}$ should be aligned with the negation of the view direction $-\mathbf{v}_{dir}$, and the polygon's original up–direction $\mathbf{u}$ should be aligned with the up–direction for the viewer $\mathbf{v}_{up}$. Assume that all mentioned vectors have unit length. How can we obtain a fast transform to screen-align the billboard?
Solution:
Let $\mathbf{M} = \left[\begin{array}{ccc} \mathbf{n} & \mathbf{u} & \mathbf{n} \times \mathbf{u} \end{array}\right]$ be the matrix with **n**, **u** and **n** x **u** as column vectors and similarly define $\mathbf{N} = [-\mathbf{v}_{dir}\mathbf{v}_{up} - \mathbf{v}_{dir} \times \mathbf{v}_{up}]$.
The billboard matrix is then $\mathbf{N}\mathbf{M}^{\mathrm{T}}$ if we assume that all vectors have unit length.

Question 5: **VR** (2 marks)

Humans use a variety of cues to determine the distance to visible objects, including cues present in static images, cues which require one eye and cues which require two eyes. Describe

a) (1 mark) two image-based depth cues
Solution:
Image based depth cues: fog, screen position, shadows, texture, blur, size, occlusion, interposition (T shapes)

b) (0.5 marks) a monocular depth cue
Solution:
In monocular depth cues, the lens of the eye is strained to focus on near objects and distant objects appear to move slower than the close objects: Accomodation (amount eye lenses must strain to view focussed image) and parallax (relative speeds of near and far objects)

c) (0.5 marks) a stereoscopic depth cue
Solution:
A depth cue is stereoscopic if two eyes are required to perceive it. In stereoscopic view, the eyes must rotate an amount dependent on the distance to object. Each eye views a slightly different angle of an object seen by the left and right eyes. If an object is far away, the disparity of that image falling on both retinas will be small. If the object is close or near, the disparity will be large. These cues are commonly used in 3D movies and are called Vergence (amount eyes must rotate to unite images on both foveas) and Binocular Disparity (difference in images between the two eyes)

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