

CT4510: Computer Graphics

Culling

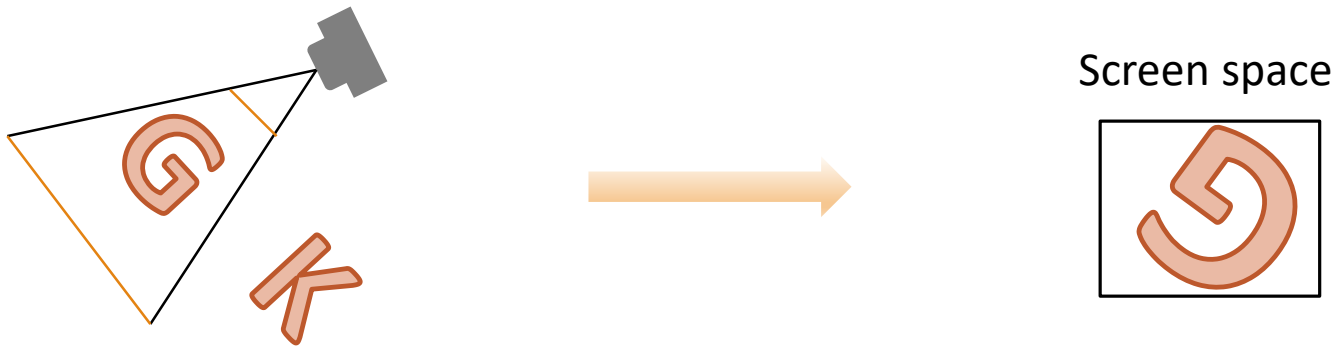
BOCHANG MOON

Culling

- An optimization process that removes invisible geometry to speed up rendering
- Three types of culling
 - View volume culling
 - Occlusion culling
 - Back-face culling

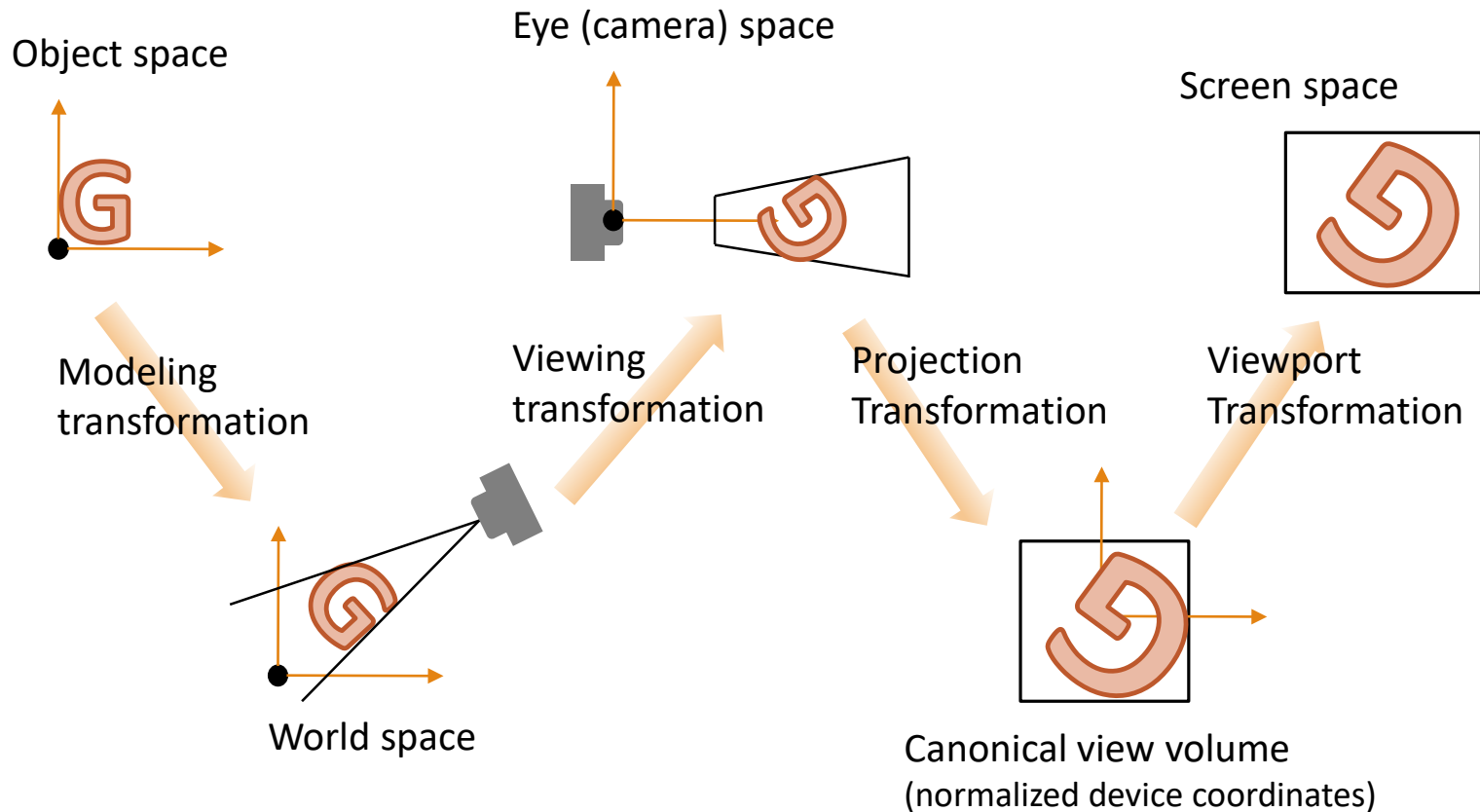
View Volume Culling

- A process to remove geometry that is outside the view volume
- Q. why do we need to do this culling?
- Q. how do we efficiently identify the object that is totally outside of the volume?



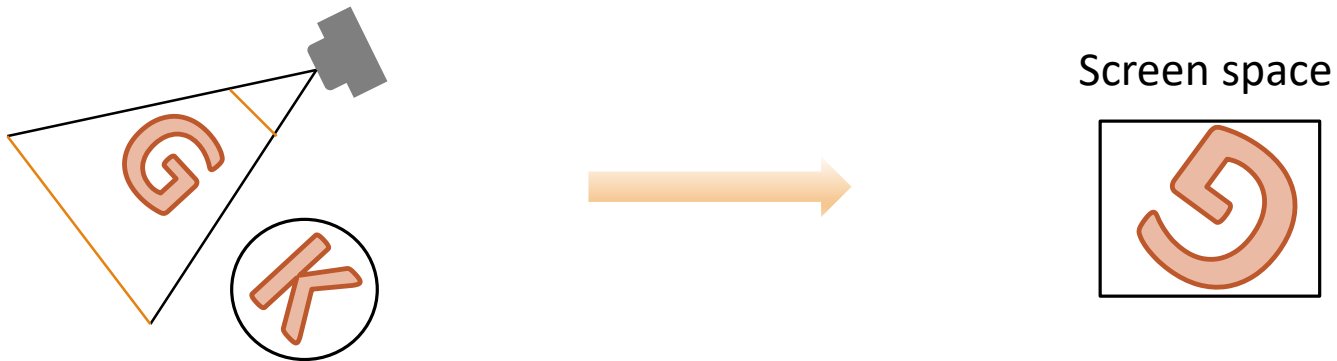
View Volume Culling

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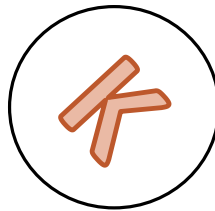
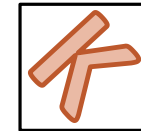
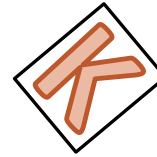
View Volume Culling

- A process to remove geometry that is outside the view volume
- Q. how do we efficiently identify the object that is totally outside of the volume?
 - A bounding volume can be utilized. Why?



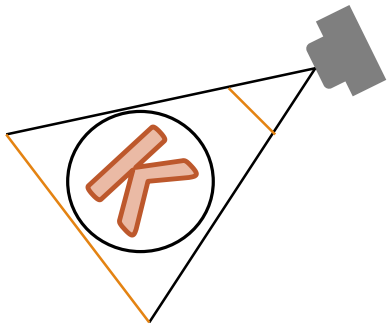
View Volume Culling

- Simple bounding volumes
 - Bounding box
 - e.g., axis-aligned bounding box (AABB)
 - Bounding sphere

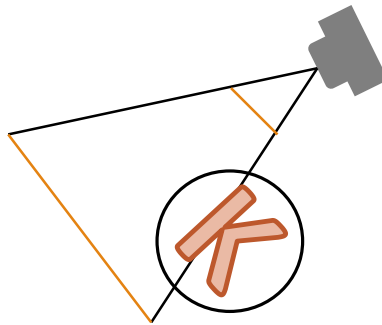


View Volume Culling

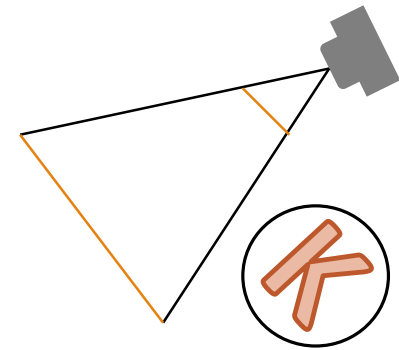
- Need identify the three cases



inside



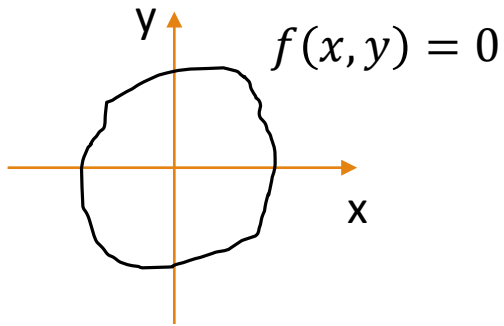
intermediate



outside

Background: Implicit Functions

- 2D implicit curves



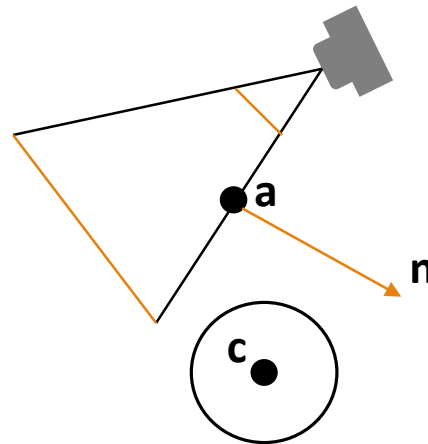
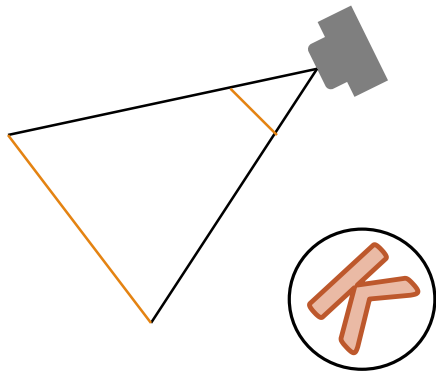
- 3D implicit surfaces
 - $f(x, y, z) = 0$

Background: Implicit Functions

- Infinite plane through point \mathbf{a} with surface normal \mathbf{n}
 - $(\mathbf{p} - \mathbf{a}) \cdot \mathbf{n} = 0$
 - The surface normal \mathbf{n} is a vector perpendicular to the plane.
 - When a point \mathbf{p} is on the plane, $(\mathbf{p} - \mathbf{a}) \cdot \mathbf{n}$ will be zero.
 - Recall the definition of a dot product
 - $\mathbf{a} \cdot \mathbf{b} = \|\mathbf{a}\| \|\mathbf{b}\| \cos\theta$

View Volume Culling

- We can check the following:
 - $\frac{(c-a) \cdot n}{\|n\|} > r$
 - **c**: center of the bounding sphere
 - r: radius of the sphere
 - Q. what's the geometric meaning of $\frac{(c-a) \cdot n}{\|n\|}$?



Background: Dot Product

- Vector multiplications

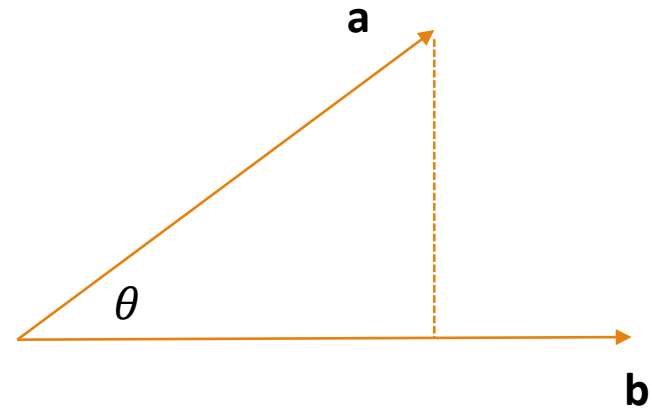
- Dot product (scalar product)

- $\mathbf{a} \cdot \mathbf{b} = \|\mathbf{a}\| \|\mathbf{b}\| \cos\theta$

- Usage: ($\mathbf{a} \rightarrow \mathbf{b}$) projection of a vector to another one

- $a \rightarrow b = \|\mathbf{a}\| \cos\theta = \frac{\mathbf{a} \cdot \mathbf{b}}{\|\mathbf{b}\|}$

- Note: this is the length of the projected vector onto \mathbf{b}



- Dot product in Cartesian coordinates

- Properties: $\mathbf{x} \cdot \mathbf{x} = \mathbf{y} \cdot \mathbf{y} = 1$ and $\mathbf{x} \cdot \mathbf{y} = 0$

- $\mathbf{a} \cdot \mathbf{b} = (x_a \mathbf{x} + y_a \mathbf{y}) \cdot (x_b \mathbf{x} + y_b \mathbf{y})$

- $= x_a x_b (\mathbf{x} \cdot \mathbf{x}) + x_a y_b (\mathbf{x} \cdot \mathbf{y}) + x_b y_a (\mathbf{y} \cdot \mathbf{x}) + y_a y_b (\mathbf{y} \cdot \mathbf{y})$

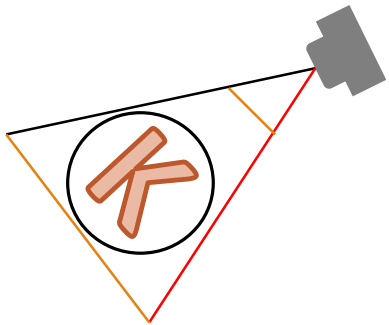
- $= x_a x_b + y_a y_b$

- In 3D,

- $\mathbf{a} \cdot \mathbf{b} = x_a x_b + y_a y_b + z_a z_b$

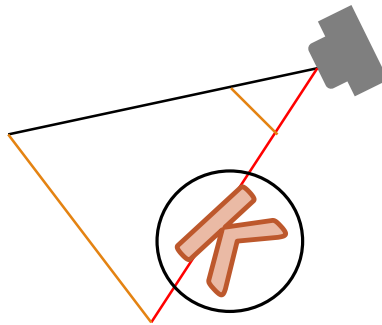
View Volume Culling

- Need identify the three cases



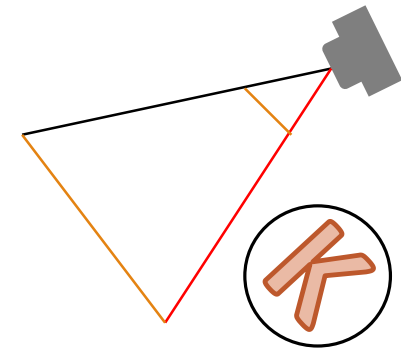
inside

$$\frac{(\mathbf{c} - \mathbf{a}) \cdot \mathbf{n}}{\|\mathbf{n}\|} < -r$$



intermediate

$$-r < \frac{(\mathbf{c} - \mathbf{a}) \cdot \mathbf{n}}{\|\mathbf{n}\|} < r$$

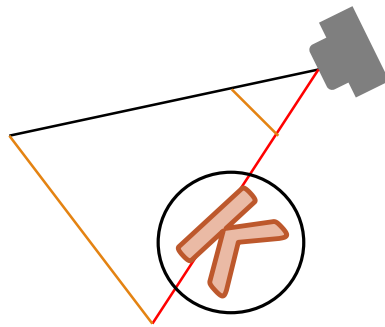


outside

$$\frac{(\mathbf{c} - \mathbf{a}) \cdot \mathbf{n}}{\|\mathbf{n}\|} > r$$

View Volume Culling

- Q. can we optimize our pipeline further?

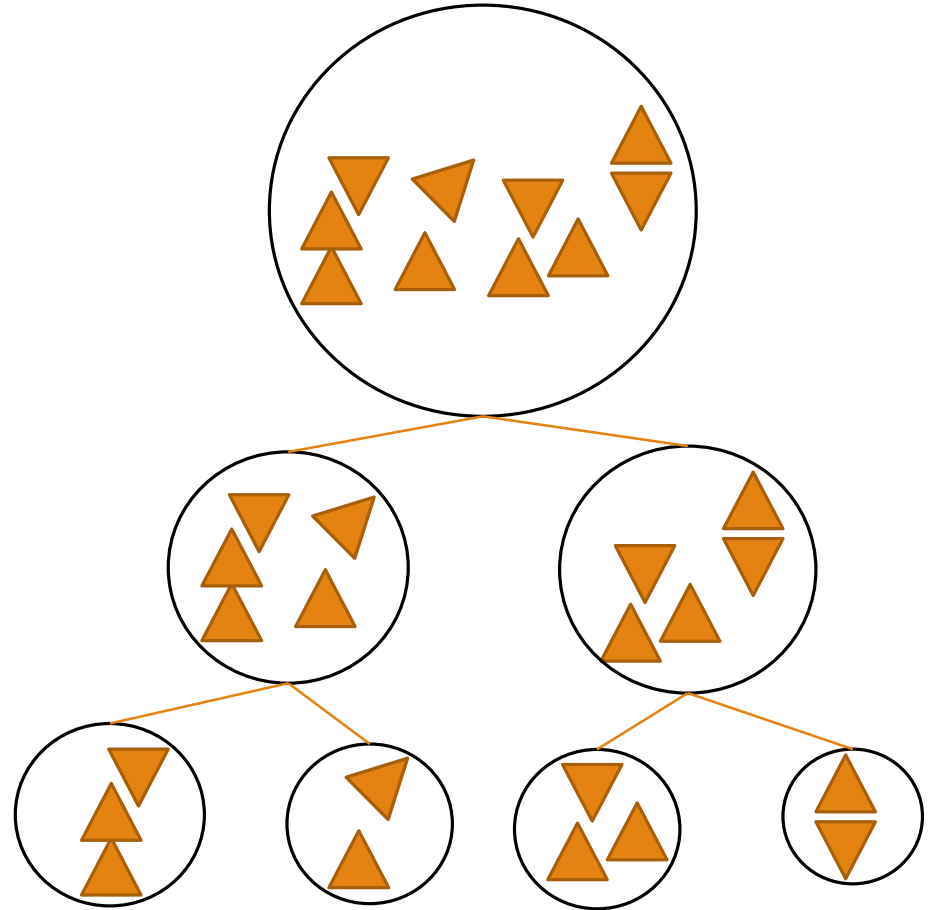
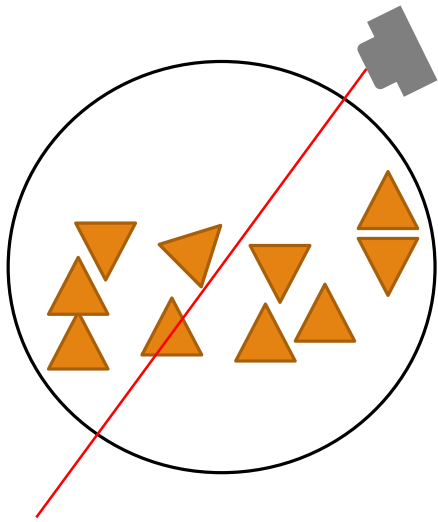


intermediate

$$-r < \frac{(\mathbf{c} - \mathbf{a}) \cdot \mathbf{n}}{\|\mathbf{n}\|} < r$$

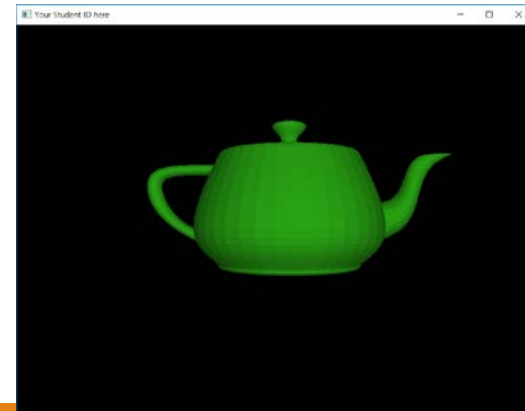
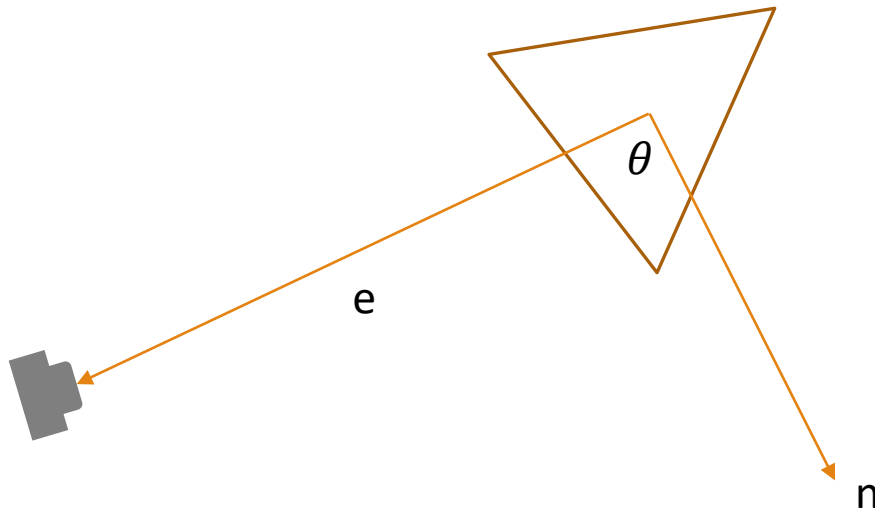
Hierarchical Culling

- If a bounding volume is intermediate,
 - Check its left and right children



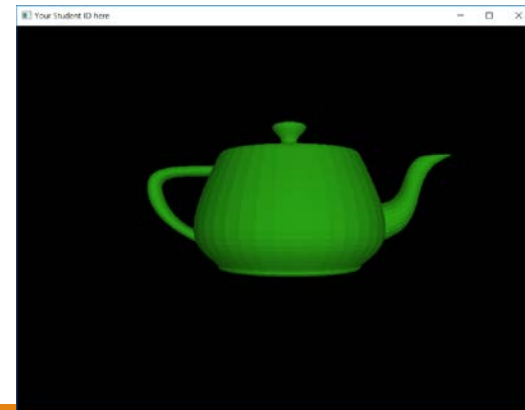
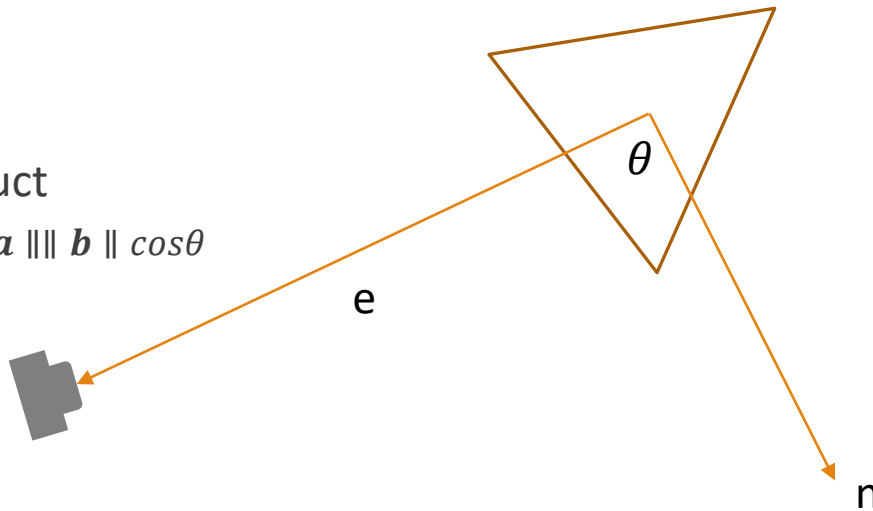
Back-Face Culling

- If the angle between the view and normal is within a range (-90 to 90 degrees), the triangle is visible.
 - $\cos\theta \geq 0$



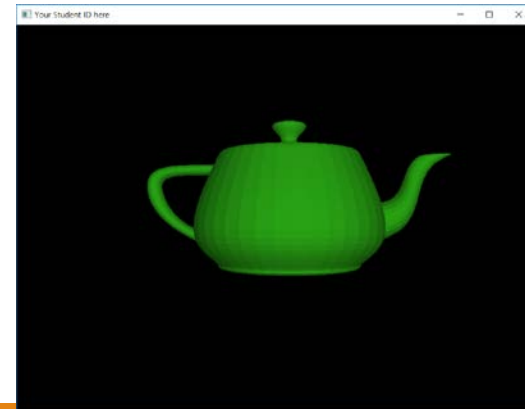
Back-Face Culling

- If the angle between the view and normal is within a range (-90 to 90 degrees), the triangle is visible.
 - $\cos\theta \geq 0$
 - $e \cdot n \geq 0$
- Dot product
 - $a \cdot b = \|a\| \|b\| \cos\theta$



Back-Face Culling

- Assumption for the back-face culling:
 - Models are closed (i.e., no holes).



Further Readings

- Chapter 2.5
- Chapter 8.4 and 12