CT4201/EC4215: Computer Graphics

Culling

BOCHANG MOON

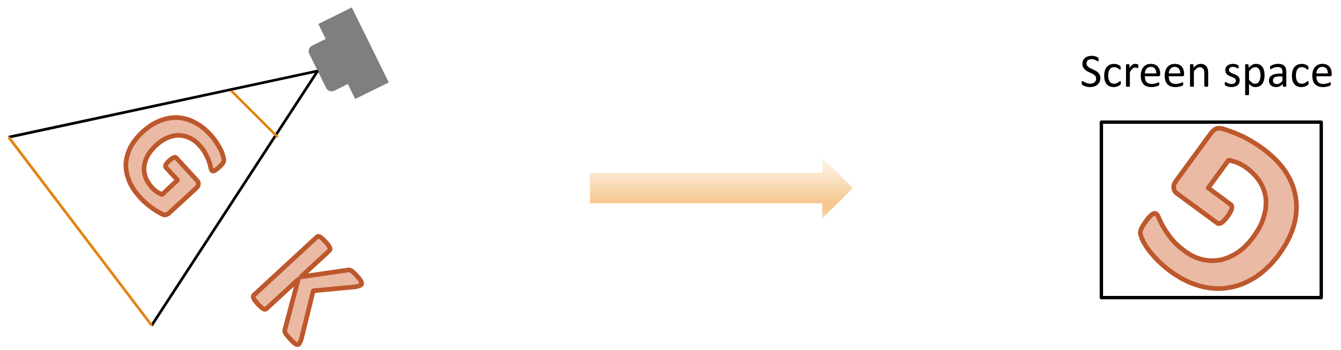
Culling

- 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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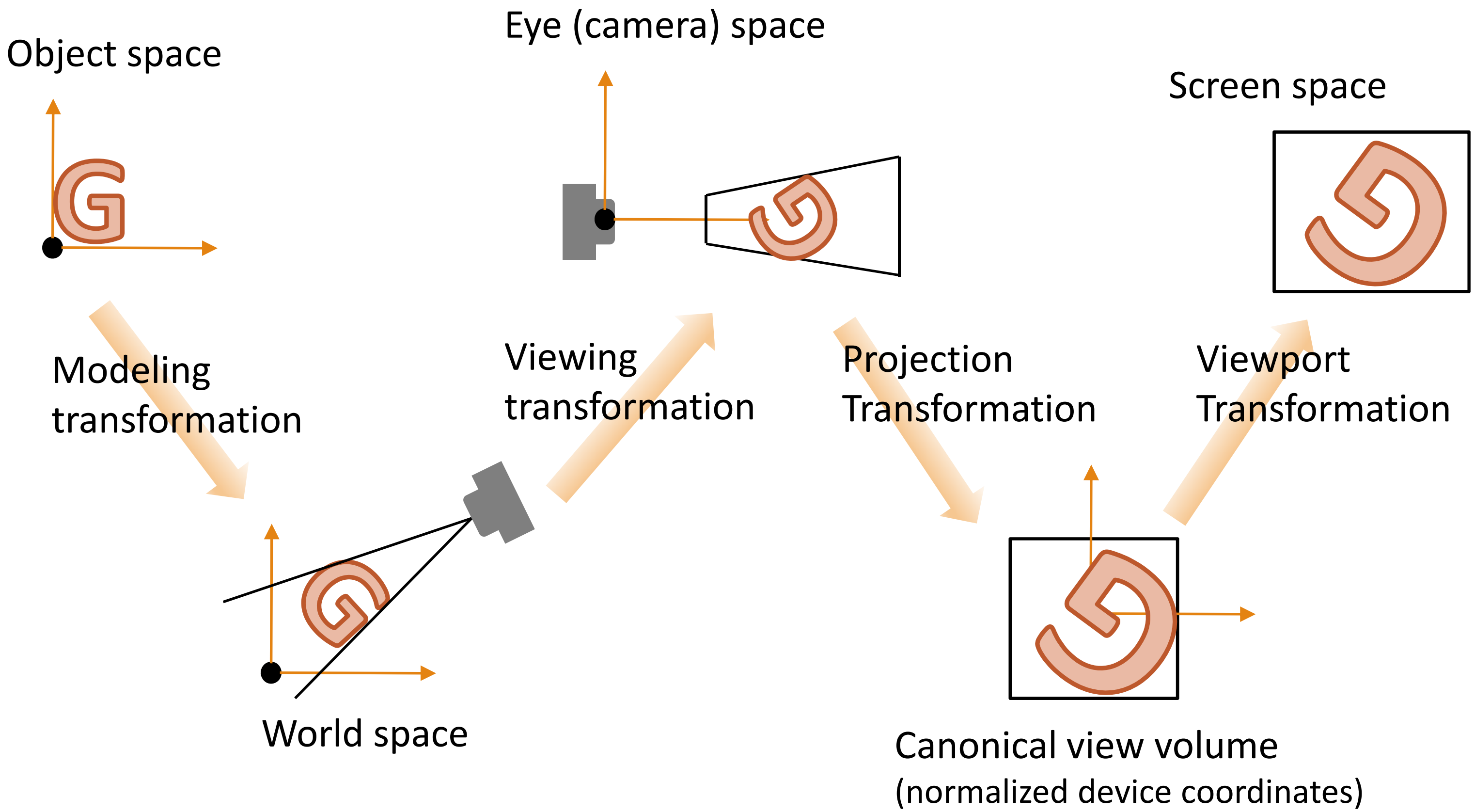
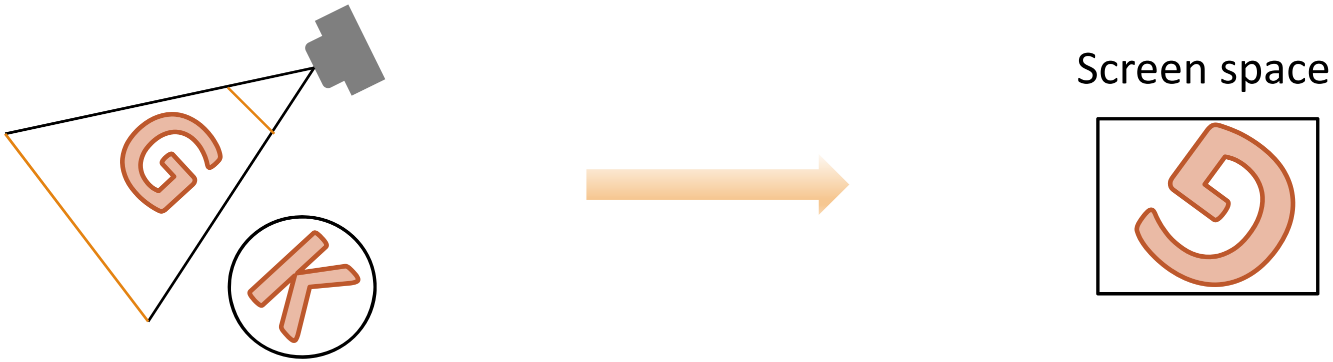


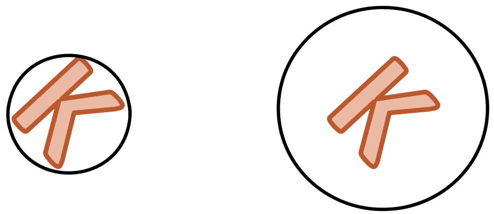
View Volume Culling

- 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?



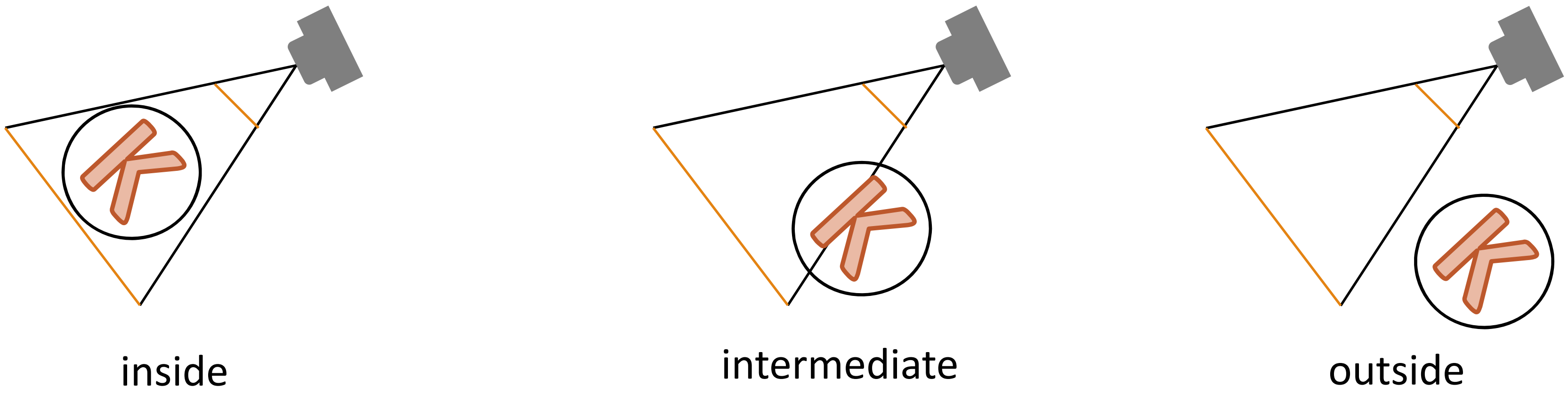
View Volume Culling

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



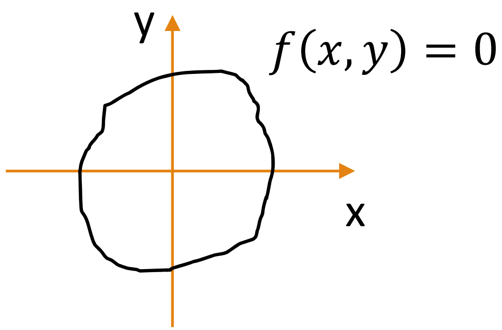
View Volume Culling

- Need identify the three cases



Background: Implicit Functions

- 2D implicit curves



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

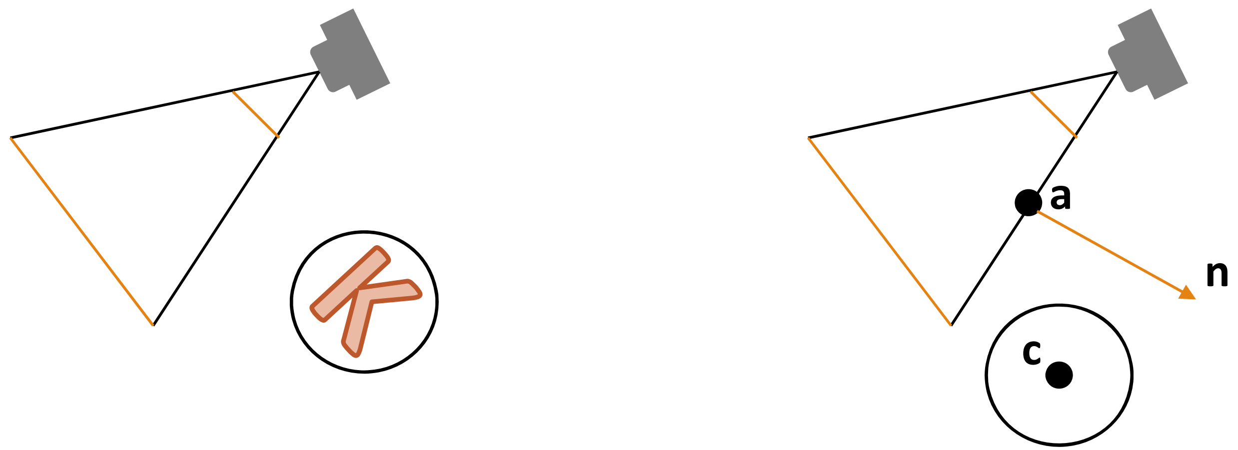
Background: Implicit Functions

- Infinite plane through point **a** with surface normal **n**
  - $(\boldsymbol{p} - \boldsymbol{a}) \cdot \boldsymbol{n} = 0$

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

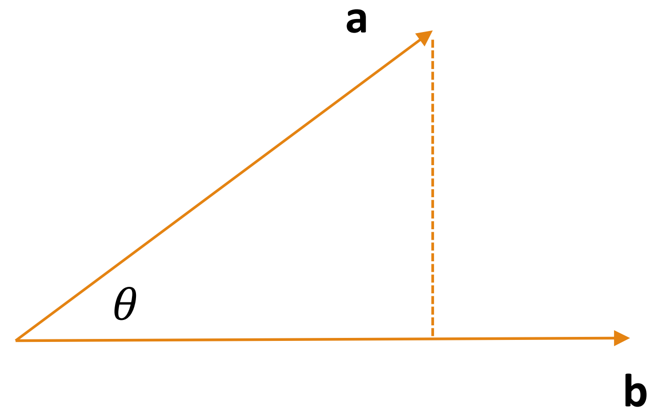
View Volume Culling

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



Background: Dot Product

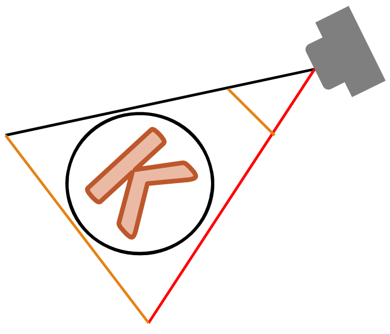
- Vector multiplications
  - Dot product (scalar product)
    - $\boldsymbol{a} \cdot \boldsymbol{b} = \| \boldsymbol{a} \| \| \boldsymbol{b} \| \, cos\theta$
    - Usage: $(\boldsymbol{a} \rightarrow \boldsymbol{b})$ projection of a vector to another one
    - $a \rightarrow b = \| \boldsymbol{a} \| \cos\theta = \frac{\boldsymbol{a} \cdot \boldsymbol{b}}{\| \boldsymbol{b} \|}$
    - Note: this is the length of the projected vector onto **b**



  - Dot product in Cartesian coordinates
    - Properties: $\boldsymbol{x} \cdot \boldsymbol{x} = \boldsymbol{y} \cdot \boldsymbol{y} = 1$ and $\boldsymbol{x} \cdot \boldsymbol{y} = 0$
    - $\boldsymbol{a} \cdot \boldsymbol{b} = (x_a \boldsymbol{x} + y_a \boldsymbol{y}) \cdot (x_b \boldsymbol{x} + y_b \boldsymbol{y})$
    - $\quad = x_a x_b (\boldsymbol{x} \cdot \boldsymbol{x}) + x_a y_b (\boldsymbol{x} \cdot \boldsymbol{y}) + x_b y_a (\boldsymbol{y} \cdot \boldsymbol{x}) + y_a y_b (\boldsymbol{y} \cdot \boldsymbol{y})$
    - $\quad = x_a x_b + y_a y_b$
    - In 3D,
      - $\boldsymbol{a} \cdot \boldsymbol{b} = x_a x_b + y_a y_b + z_a z_b$

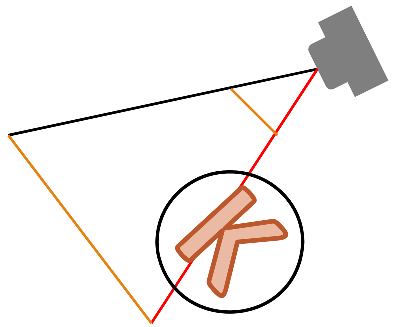
View Volume Culling

- Need identify the three cases



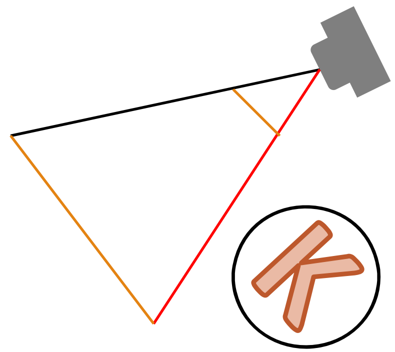
inside

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



intermediate

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

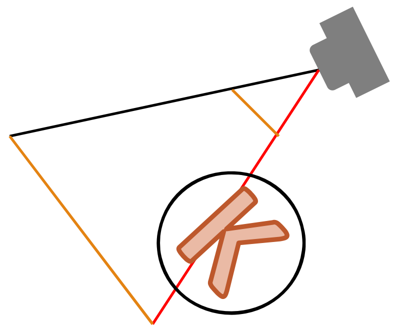


outside

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

View Volume Culling

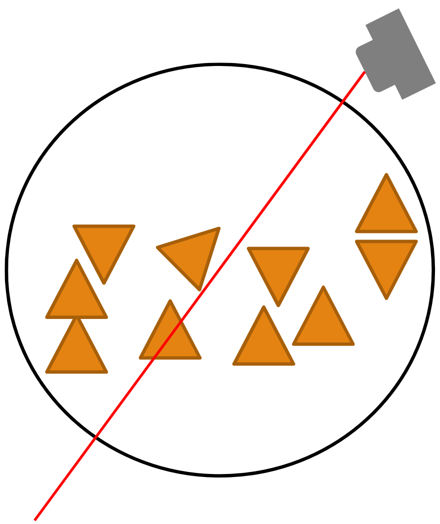
- Q. can we optimize our pipeline further?

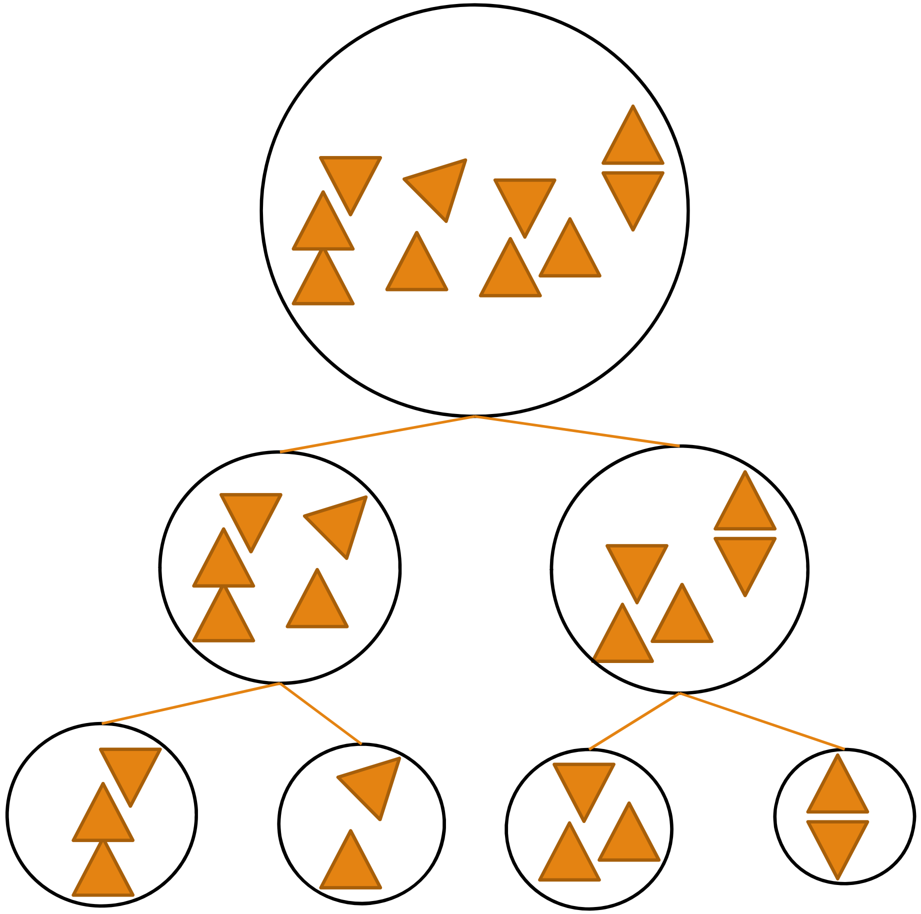


$$-r < \frac{(\boldsymbol{c} - \boldsymbol{a}) \cdot \boldsymbol{n}}{\| \boldsymbol{n} \|} < r$$

Hierarchical Culling

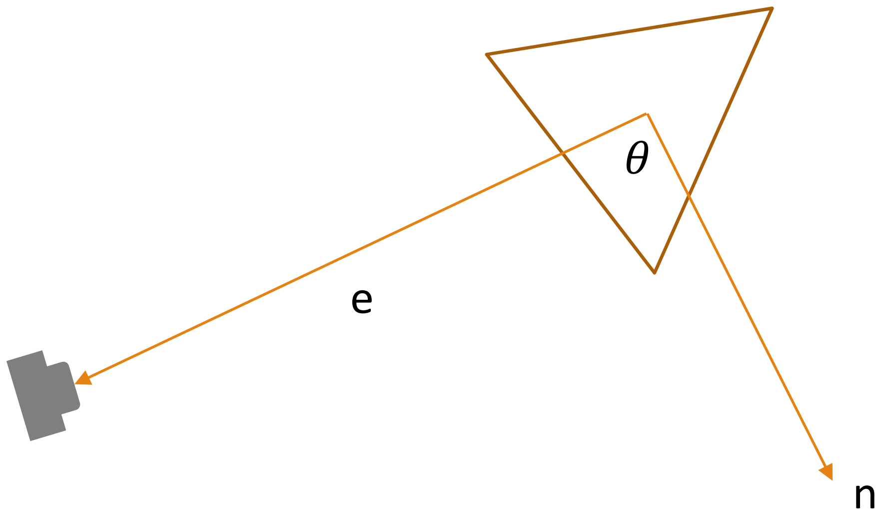
- If a bounding volume is intermediate,
  - Check its left and right children

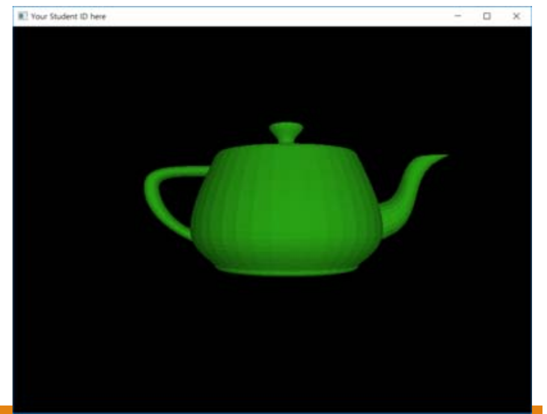




Back-Face Culling

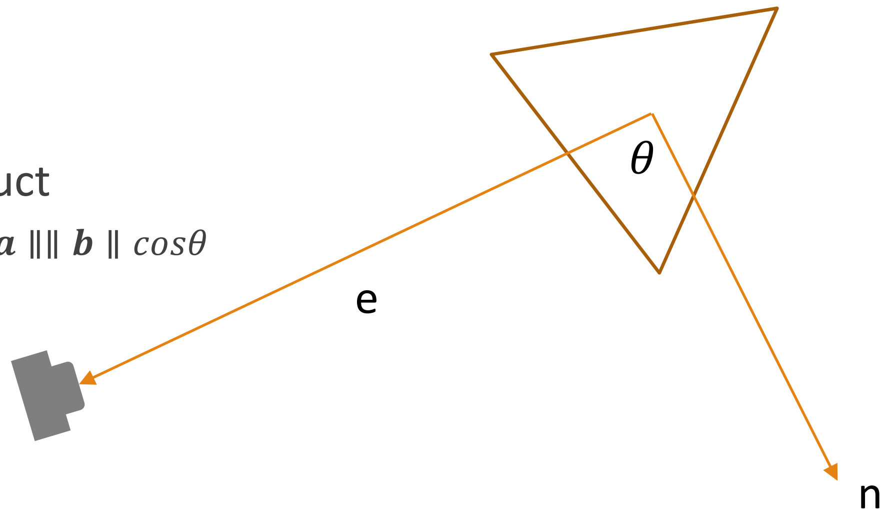
- If the angle between the view and normal is within a range (-90 to 90 degrees), the triangle is visible.
  - $\cos\theta \geq 0$

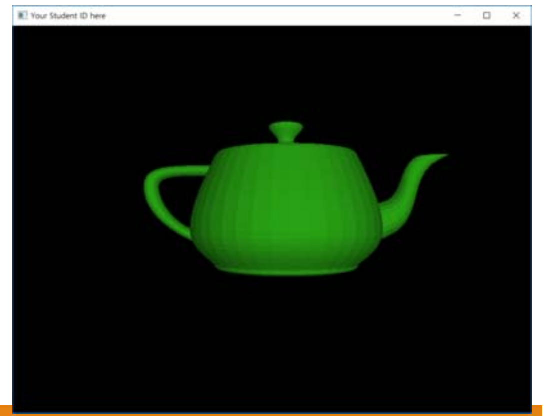




Back-Face Culling

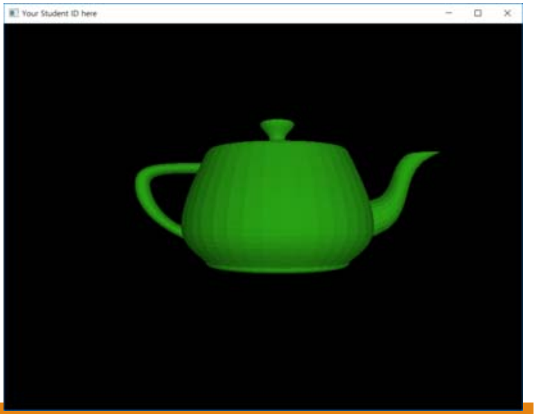
- If the angle between the view and normal is within a range (-90 to 90 degrees), the triangle is visible.
  - $\cos\theta \geq 0$
  - $\boldsymbol{e} \cdot \boldsymbol{n} \geq 0$
  - Dot product
    - $\boldsymbol{a} \cdot \boldsymbol{b} = \| \boldsymbol{a} \| \| \boldsymbol{b} \| \cos\theta$





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