A4: FACE TO FACE

- Starting today
- Sign up if you haven’t
- No-show: -20%, marked after
- You have to understand each line of your code

LITTLE FAVOR

- Please answer a couple of questions here:
  - https://survey.ubc.ca/s/cpsc-314/

- It's not a course evaluation, it's just for us to know how to make the course more popular.

- Thank you!

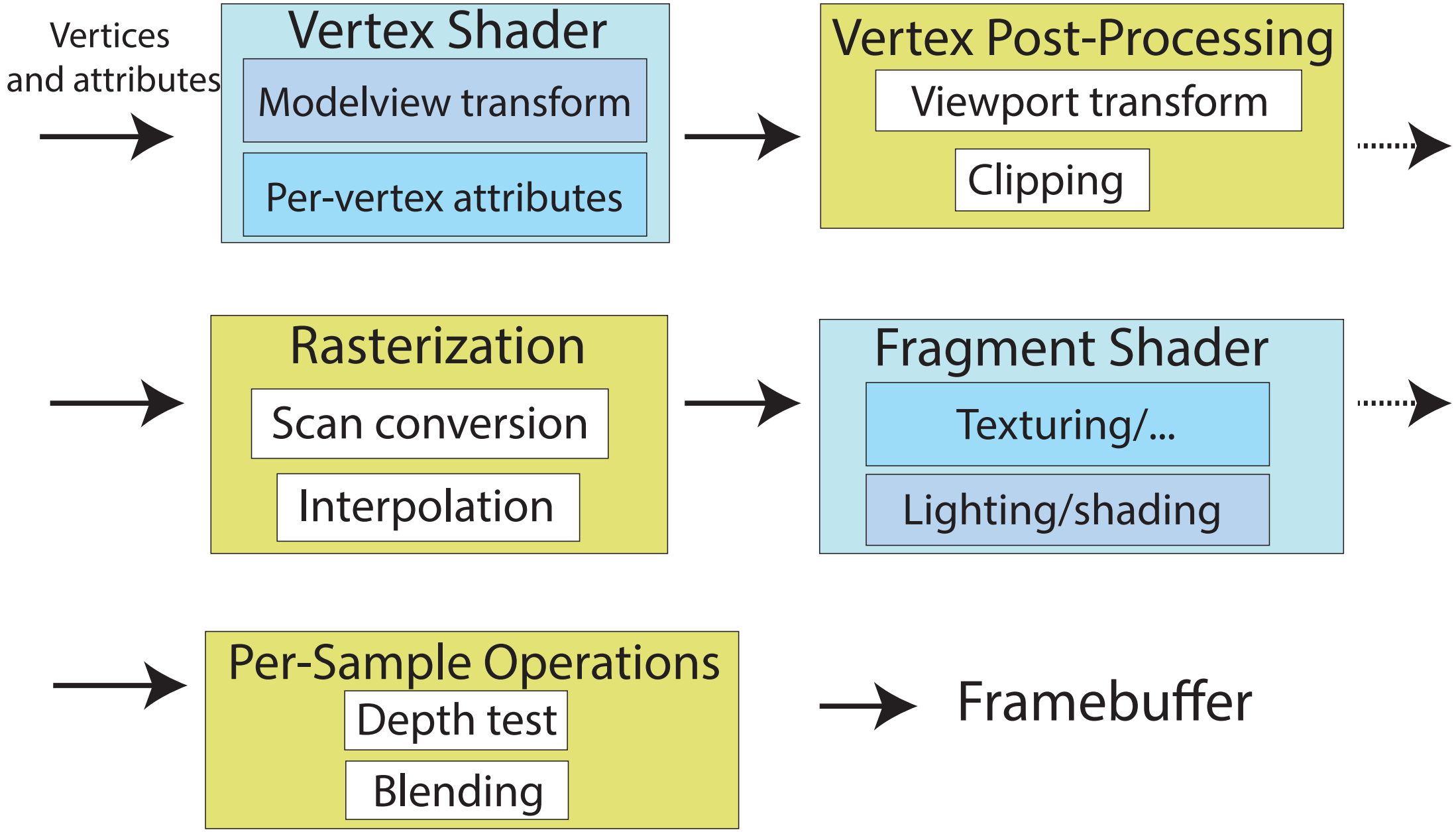
33 – BIG REVIEW I

- This review is NOT everything you need to know
- This is just a list of questions you might want to answer in order to start preparation
- Now is a good time to start preparing!

RENDERING

- What is rendering?
- What is the input for the rendering process? Output?
- What are the stages of rendering?
  - Describe each one
- How do we make rendering real-time?
- How do we make rendering realistic?

THE RENDERING PIPELINE



HOMOGENEOUS COORDINATES

- Why do we use homogeneous coordinates?
- How to convert them from/to Euclidean coordinates?
  - Is such conversion 1-1?
- Where in the pipeline do we operate with HC/EC?
- How to tell a vector from a point in HC?

TRANSFORMATION MATRICES

- What's an affine transformation? Linear?
- Can all of them be represented as matrix operations?
- What's a structure of a transformation matrix?

AUGMENTED MATRIX

Translation

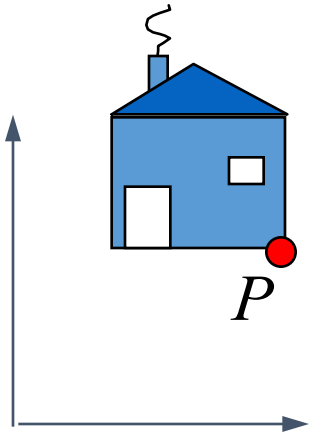
Linear Transformation

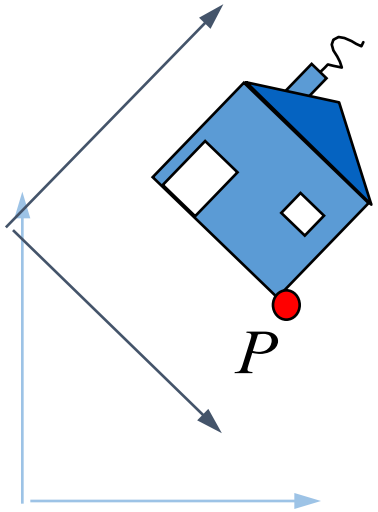
$$\begin{bmatrix} m_{11} & m_{12} & m_{13} & b_x \\ m_{21} & m_{22} & m_{23} & b_y \\ m_{31} & m_{32} & m_{33} & b_z \\ 0 & 0 & 0 & w \end{bmatrix}$$

TRANSFORMING COORDINATE FRAME

Columns are new basis vectors (and new origin)!

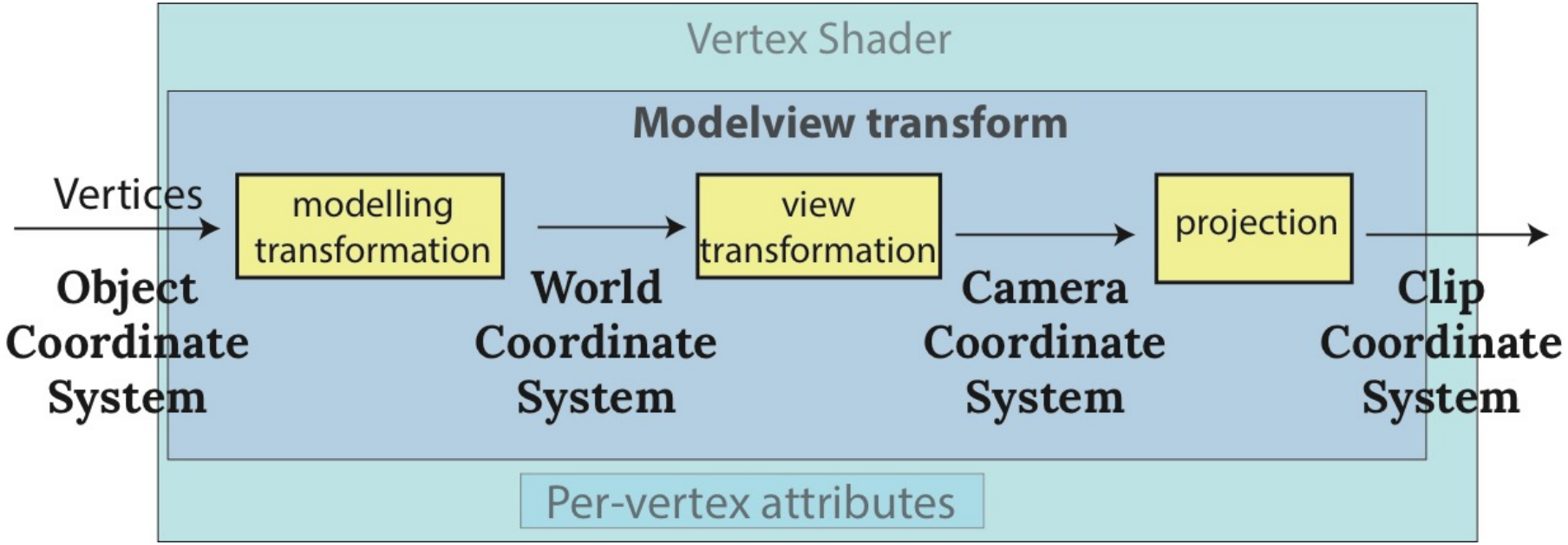
$$\begin{pmatrix} \cos\theta & -\sin\theta & p_x \cdot (1-\cos\theta) + p_y \cdot \sin\theta \\ \sin\theta & \cos\theta & p_y \cdot (1-\cos\theta) + p_x \cdot \sin\theta \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} v_x \\ v_y \\ 1 \end{pmatrix}$$

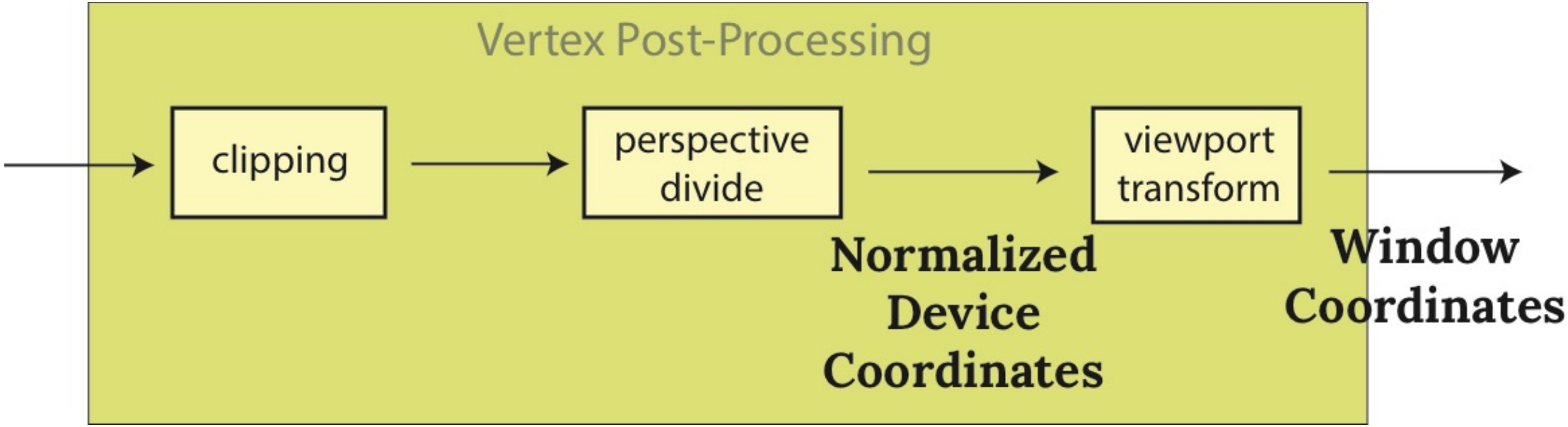




PIPELINE

- What are the transformations involved in the pipeline?
- What are the coordinate systems involved?
- Why do we do perspective divide?
- Why do we do clipping before perspective divide?
- Why do we need viewport transform?


Vertex Shader
Modelview transform
Vertices
modelling transformation
view transformation
projection
Object Coordinate System
World Coordinate System
Camera Coordinate System
Clip Coordinate System
Per-vertex attributes


Vertex Post-Processing
clipping
perspective divide
viewport transform
Normalized Device Coordinates
Window Coordinates

MATH

- What are implicit, explicit, and parametric ways to define geometry?
  - What are their limitations?

- How to intersect two objects if they are
  - Both implicitly defined
  - Both explicitly defined

- How many parameters do we need to represent objects parametrically?

MATH

- How to calculate a normal to an implicit surface/curve?
- How to calculate a tangent plane?
- How to approximate surface area of some 2D shape?
- How to intersect a ray with a planar polygon in 2D? In 3D?

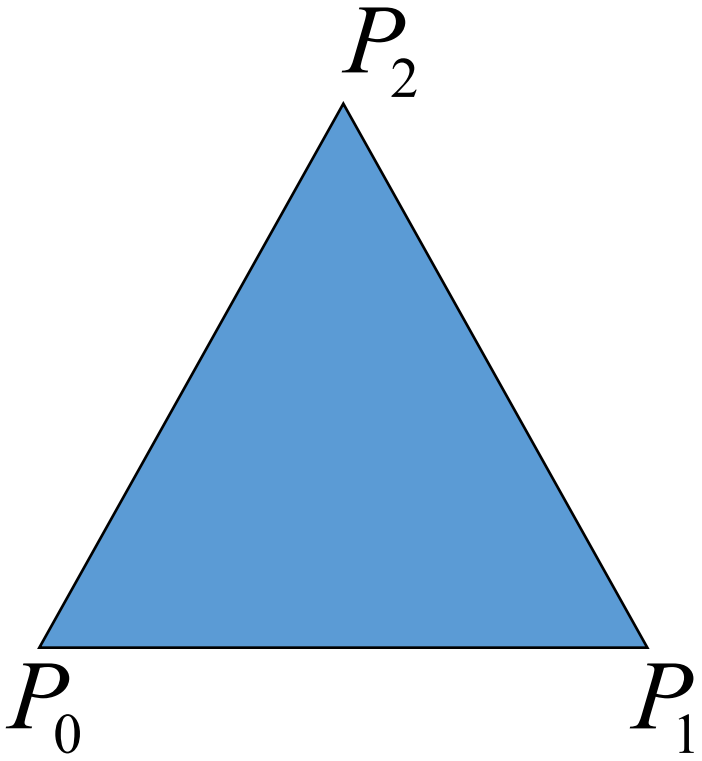
TRIANGLE

- Normal

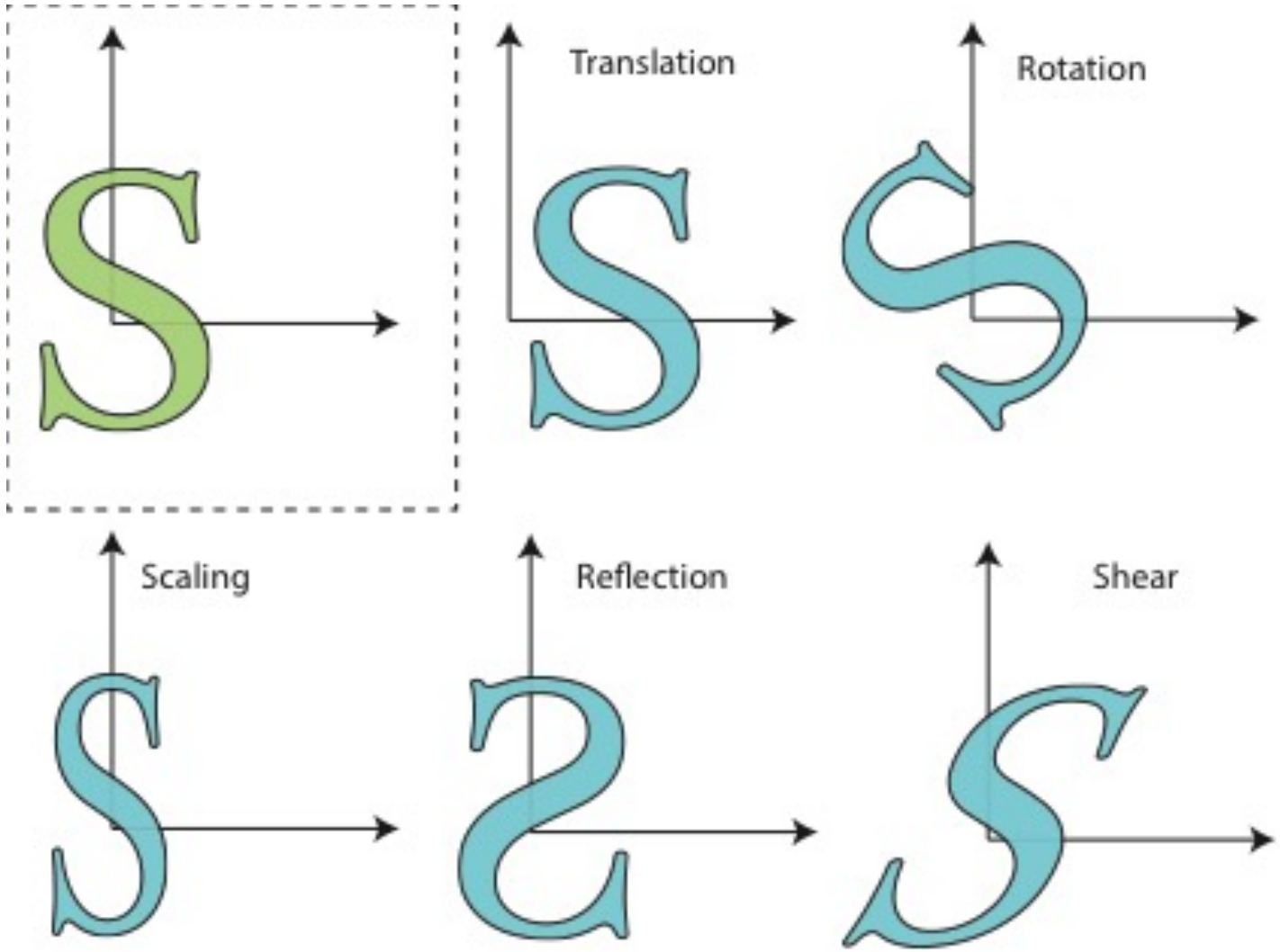
$$n = \frac{(P_1 - P_0) \times (P_2 - P_0)}{\left\| (P_1 - P_0) \times (P_2 - P_0) \right\|}$$

- Area

$$A = \frac{1}{2} \left\| \overrightarrow{P_0 P_1} \times \overrightarrow{P_0 P_2} \right\|$$

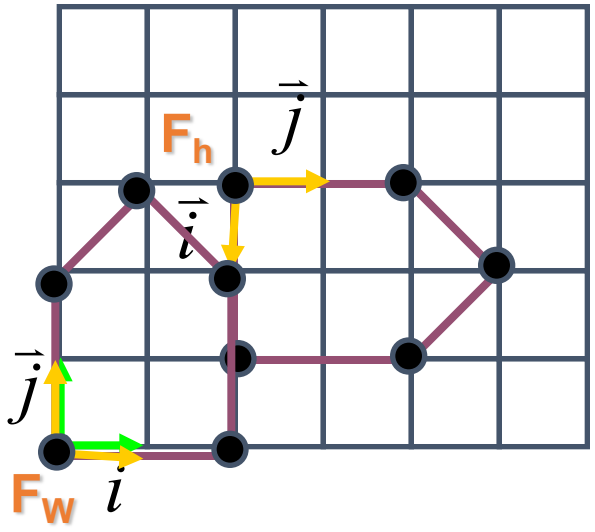


AFFINE TRANSFORMATIONS

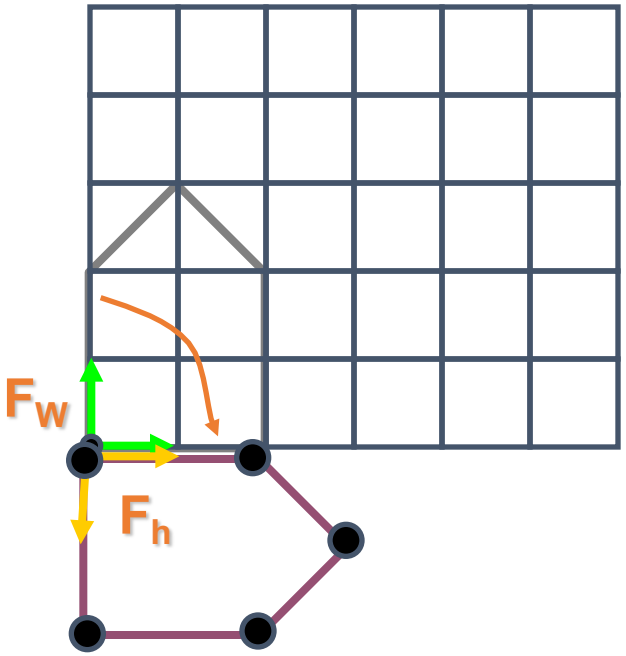


COMPOSING TRANSFORMATIONS

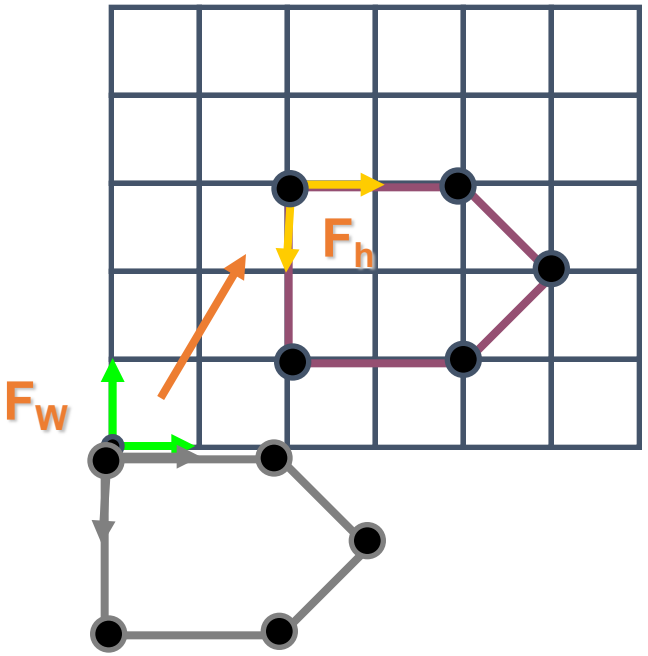
suppose we want



Rotate(z,-90)



Translate(2,3,0)



$$P_A = Rot(z,-90)\,P_h$$

$$P_W = Trans(2,3,0)\,P_A$$

F_h

$$P_W = Trans(2,3,0)Rot(z,-90)\,P_h$$

COMPOSING TRANSFORMATIONS

$$P_W = Trans(2,3,0)Rot(z,-90)\,P_h$$

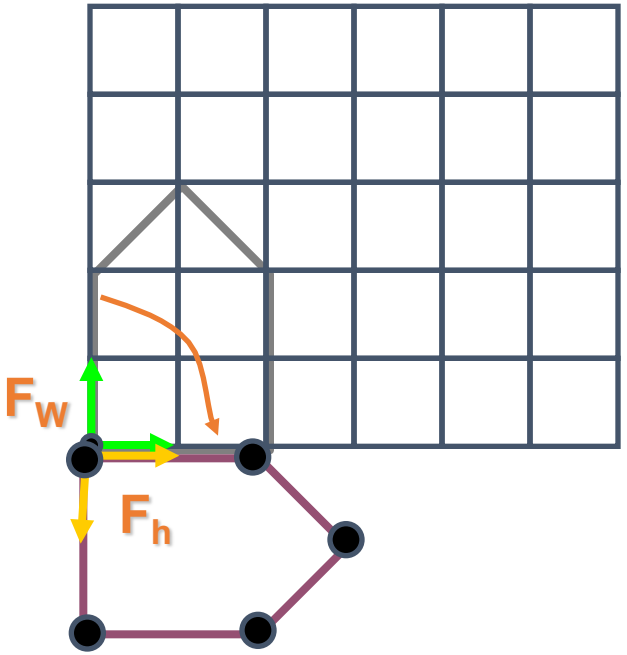
- R-to-L: interpret operations wrt fixed coords
  - moving object
- L-to-R: interpret operations wrt local coords
  - changing coordinate system

$$M_{MV} = Trans(2,3,0)\cdot M_{MV}$$

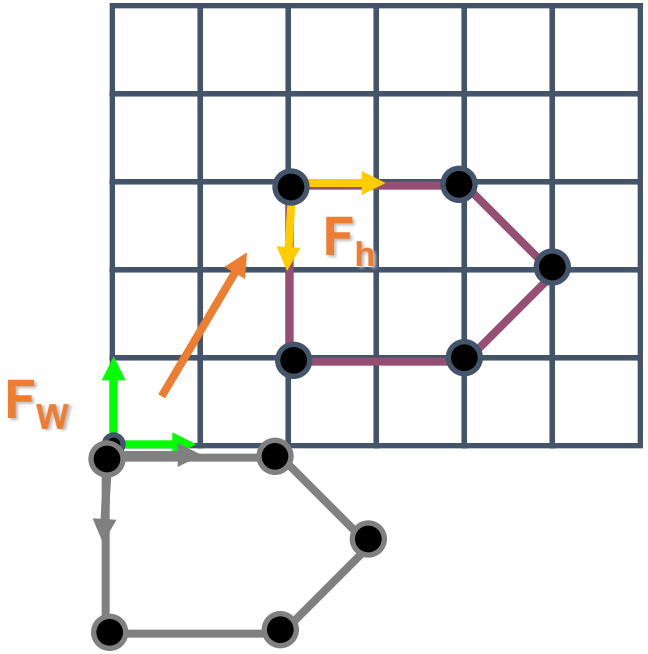
$$M_{MV} = Rot(z,-90)M_{MV}$$

COMPOSING TRANSFORMATIONS

Rotate(z,-90)

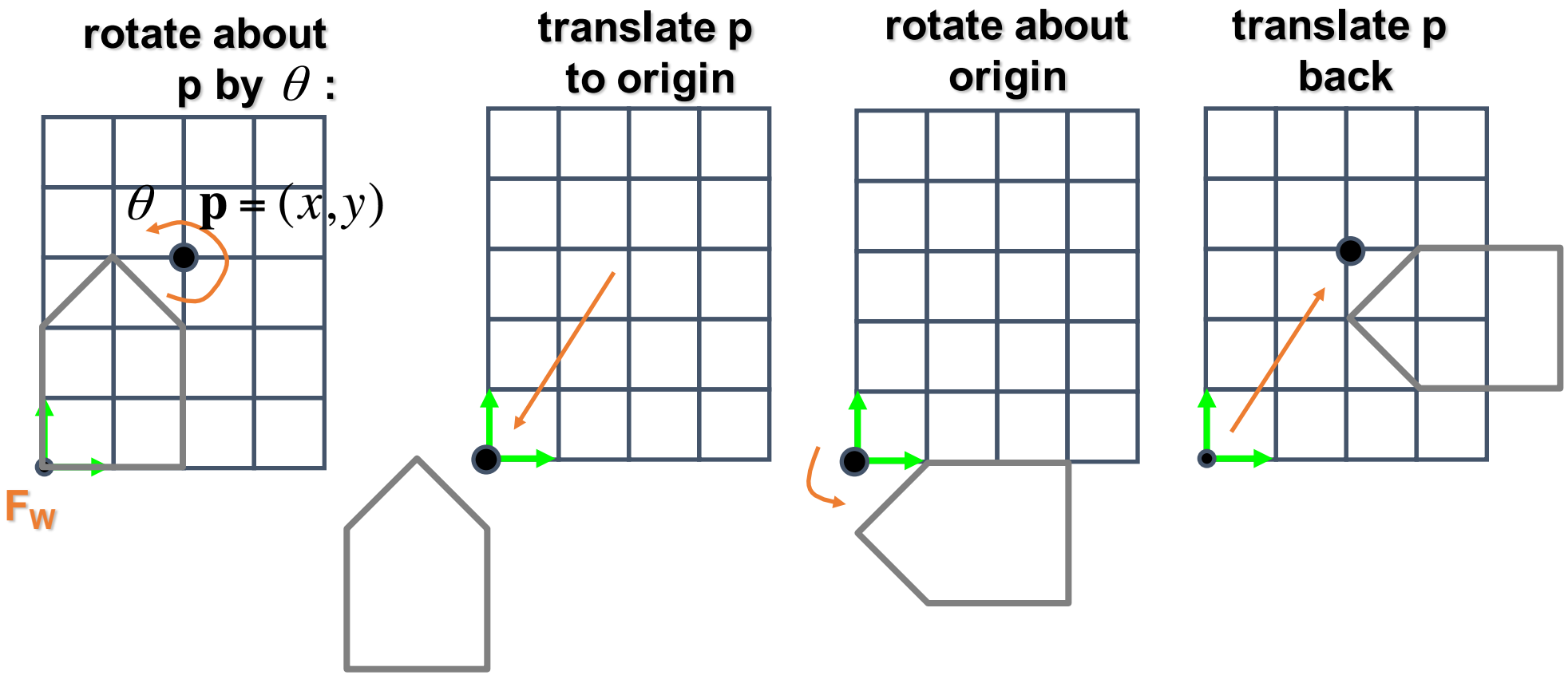


Translate(-3,2,0) in local coords



$$P_W = Rot(z,-90)Trans(-3,2,0)\,P_h$$

ROTATION ABOUT A POINT: MOVING OBJECT



$$\mathbf{T}(x,y,z)\mathbf{R}(z,\theta)\mathbf{T}(-x,-y,-z)$$

SIMPLE COMPOSITIONS

$$Tr(x_1, y_1, z_1) \cdot Tr(x_2, y_2, z_2) = Tr(x_1 + x_2, y_1 + y_2, z_1 + z_2)$$
$$Tr(x_2, y_2, z_2) \cdot Tr(x_1, y_1, z_1) = Tr(x_2, y_2, z_2) \cdot Tr(x_1, y_1, z_1)$$

$$Scale(a, b, c) \cdot Scale(d, e, f) = Scale(ad, be, cf)$$
$$Scale(a, b, c) \cdot Scale(d, e, f) = Scale(d, e, f) \cdot Scale(a, b, c)$$

$$Rot(\alpha, 0,0,1) \cdot Rot(\beta, 0,0,1) = Rot(\alpha + \beta, 0,0,1)$$
$$Rot(\alpha, 0,0,1) \cdot Rot(\beta, 0,0,1) = Rot(\beta, 0,0,1) \cdot Rot(\alpha, 0,0,1)$$

MORE COMPLICATED COMPOSITIONS

$$Tr(x,y,z) \cdot Scale(a,b,c) \neq Scale(a,b,c) \cdot Tr(x,y,z)$$

$$Tr(x,y,z) \cdot Scale(a,b,c) = Scale(a,b,c) \cdot Tr\left(\frac{x}{a},\frac{y}{b},\frac{z}{c}\right)$$

$$Tr(x,y,z) \cdot Rot(\alpha,0,0,1) \neq Rot(\alpha,0,0,1) \cdot Tr(x,y,z)$$

$$Rot(\alpha,0,0,1) \cdot Rot(\beta,0,1,0) \neq Rot(\beta,0,1,0) \cdot Rot(\alpha,0,0,1)$$

$$Scale(a,a,a) \cdot Rot(\beta,0,0,1) = Rot(\beta,0,0,1) \cdot Scale(a,a,a)$$

$$Scale(a,b,c) \cdot Rot(\beta,0,0,1) \neq Rot(\beta,0,0,1) \cdot Scale(a,b,c)$$

INVERSE TRANSFORMS

$$Tr(x, y, z)^{-1} = Tr(-x, -y, -z)$$

$$Rot(\alpha, 0,0,1)^{-1} = Rot(-\alpha, 0,0,1) = Rot(\alpha, 0,0,1)^T$$ (orthogonal!)

$$Scale(a, b, c)^{-1} = Scale\left(\frac{1}{a}, \frac{1}{b}, \frac{1}{c}\right)$$

ROTATION AFTER NON-UNIFORM SCALE

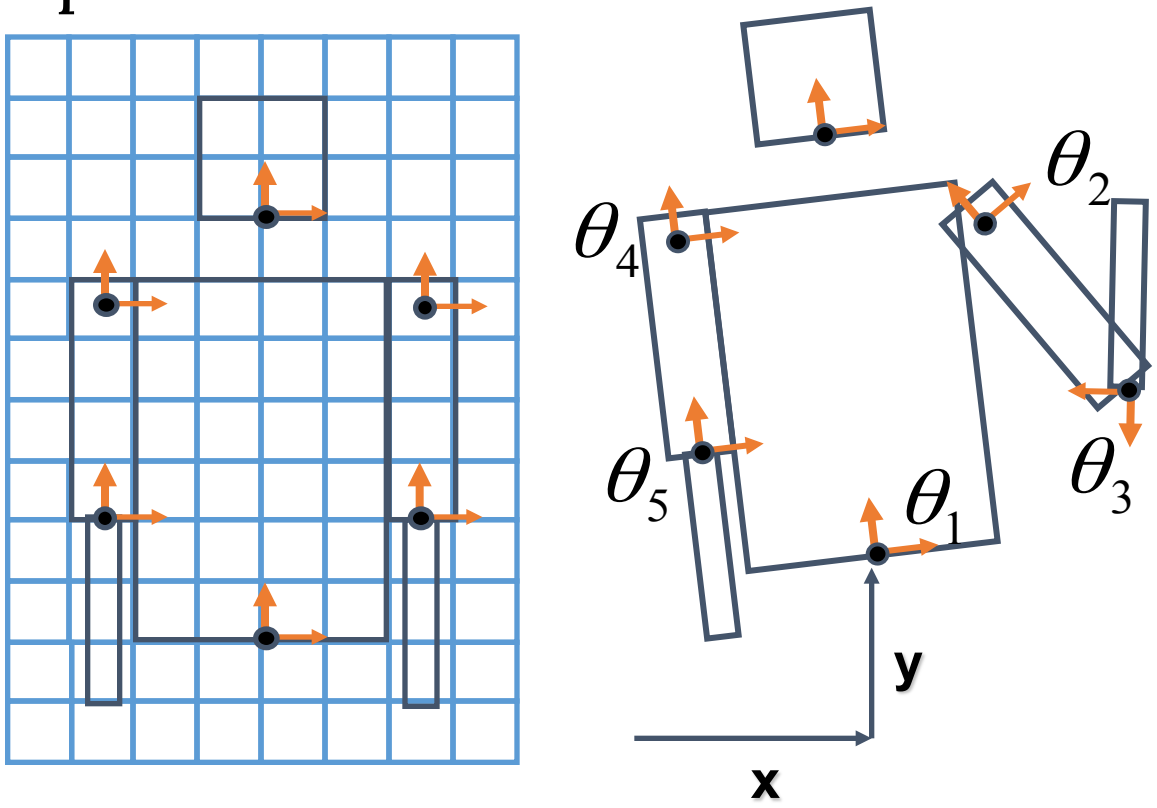
- Not what you'd expect!
- $M = Rot(\beta, 0,0,1) \cdot Scale(a, b, c) =$

$$\begin{pmatrix} \mathrm{a} \cdot \cos(\beta) & -a \cdot \sin(\beta) & 0 & 0 \\ \mathrm{b} \cdot \sin(\beta) & b \cdot \cos(\beta) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

- Basis vector not orthogonal!
- (demo)

TRANSFORMATION HIERARCHIES

- Example



$$M_1 = Tr_{(x,y)} \cdot Rot\theta_1$$

$$M_2 = M_1 \cdot Tr_{(2.5,5.5)} \cdot Rot\ \theta_2$$

$$M_3 = M_2 \cdot Tr_{(0,-3.5)} \cdot Rot\ \theta_3$$

PROJECTIONS

- What is the purpose of projections?
- What's the difference between ortho- and perspective projections?
- Who chooses which projection to use?
- Can we get a nearly orthographic projection while using a perspective projection matrix?
- What happens to z in perspective projection?
- What happens to the view volumes?

CLIPPING

- What happens to points during clipping? Triangles?
- What are the equations of the frustum planes?
- How can we test if a triangle should be clipped?

RASTERIZATION

- What's rasterization?
- How do we rasterize a polygon?
- Why do we interpolate?
- What are the values we typically interpolate?
- How?
- How is it done in ray/path tracing?

LIGHTING & SHADING

- What's a Gouraud shading?
- What are Lambert/Phong materals?
- If the scene is lit with only ambient light, what will we see?
  - Only diffuse/specular?
- How can we control size of the specular highlight?
- How do we shade in ray tracing? in path tracing?
- In path tracing, how can we simulate more complex materials?

TEXTURING

- How can we tile a wall with bricks?
  - If a texture contains a single brick, what should be texture coordinates for wall's corners?
- Why do we use mipmaps?
- How much storage do we need for them?
- How do we generate mipmaps?
- Where do we get texture coordinates?
- How do we interpolate them?

BUMP AND NORMAL MAPPING

- Why?
- Which mapping would you use to add scales to a fish?
- Bullets on the walls?
- Fur on an animal?
- How do we apply bump mapping?

ENVIRONMENT MAPS

- Why do we need them?
- What are the types?
- How do we generate them?
- How do we apply them?
- When do we re-generate them?

SHADOW MAPS

- Why do we need them?
- How does it fit into pipeline?
- What's the algorithm?