(sorry for my writing quality)

If my laptop disconnects, DON'T leave. I will switch to sharing directly from the ipad.
(should be fine, just tested for 1 hour before class :))

- "get big picture"

basic R_x, R_y, R_z

could break down in R_x, R_y, R_z

→ "gimble lock"

Unit Vector $= |V|$ length 1

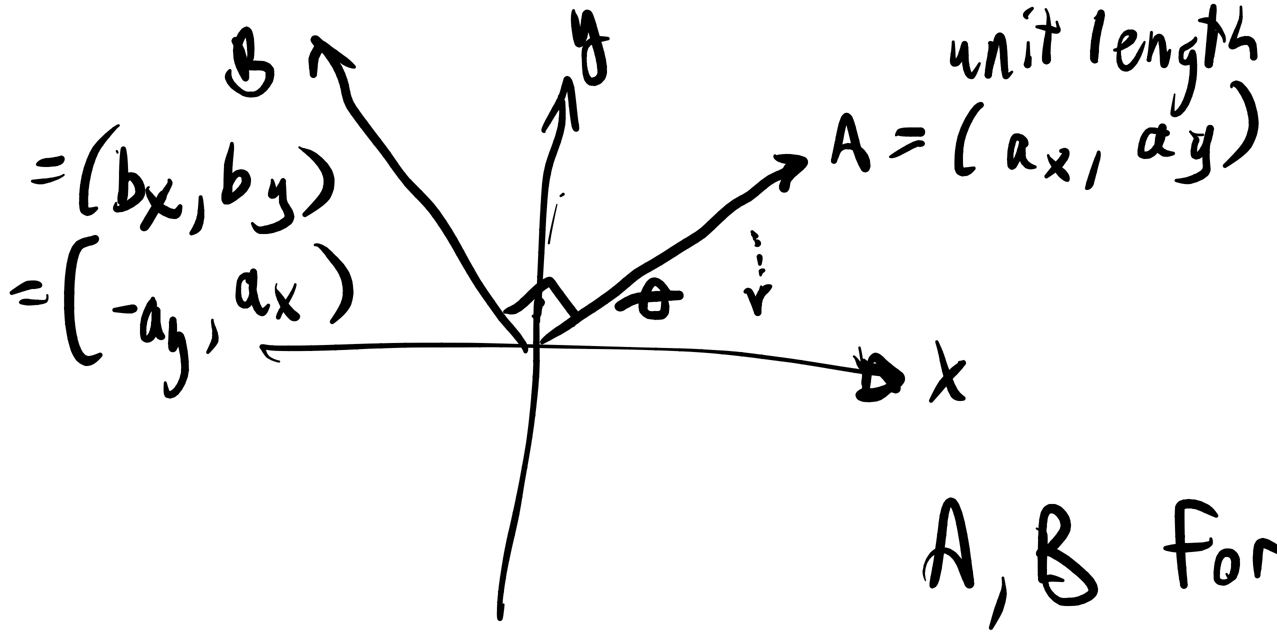
$$\hat{V} = \frac{V}{|V|} = \left(\frac{x}{L}, \frac{y}{L}, \frac{z}{L}\right) \qquad L = \sqrt{x^2+y^2+z^2}$$

$$\hat{V} \cdot \hat{V} = 1$$

If A & B are orthoganal (perpendicular)

$$A \cdot B = 0$$

$$V_1 \times V_2 \Rightarrow V_3$$



want to rotate θ to have A lie on x-axis

A, B form orthonormal basis

$$R = \begin{bmatrix} a_x & a_y & 0 \\ b_x & b_y & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} a_x & a_y & 0 \\ -a_y & a_x & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R \cdot A = \begin{bmatrix} a_x \\ a_y \\ 1 \end{bmatrix}$$

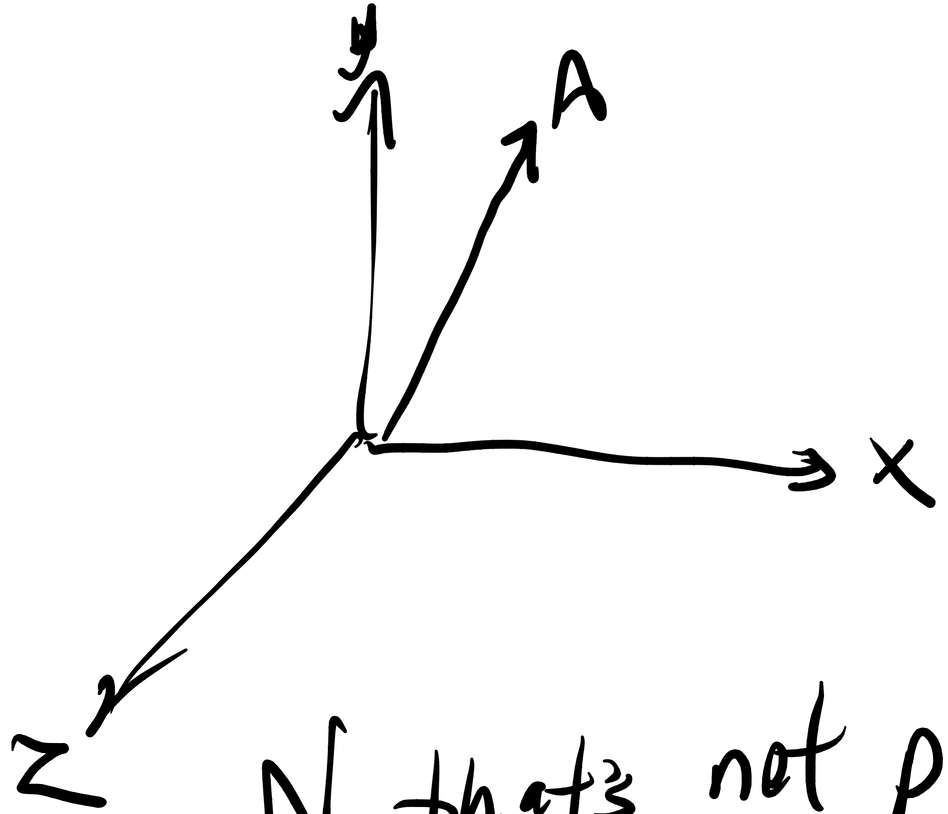
$$R^T \cdot [1, 0, 1]$$

$$R \begin{bmatrix} a_x & a_y & 0 \\ -a_y & a_x & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} a_x^2 + a_y^2 + 0 \\ -a_x a_y + a_x a_y + 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} \quad \begin{bmatrix} a_x \\ a_y \\ 1 \end{bmatrix}$$

$$R \cdot A \rightarrow [1, 0, 1]$$

$$R \cdot B \rightarrow [0, 1, 1]$$

$$R^{-1} = R^T = \begin{bmatrix} a_x & -a_y & 0 \\ a_y & a_x & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



$A = (a_x, a_y, a_z)$

Goal: rotate(theta, a_x, a_y, a_z)

$$R = R_3 R_2 R_1$$
$$= R_1^{-1} R_2 R_1$$

$$R_1 = \begin{bmatrix} a_x & a_y & a_z & 0 \\ b_x & b_y & b_z & 0 \\ c_x & c_y & c_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

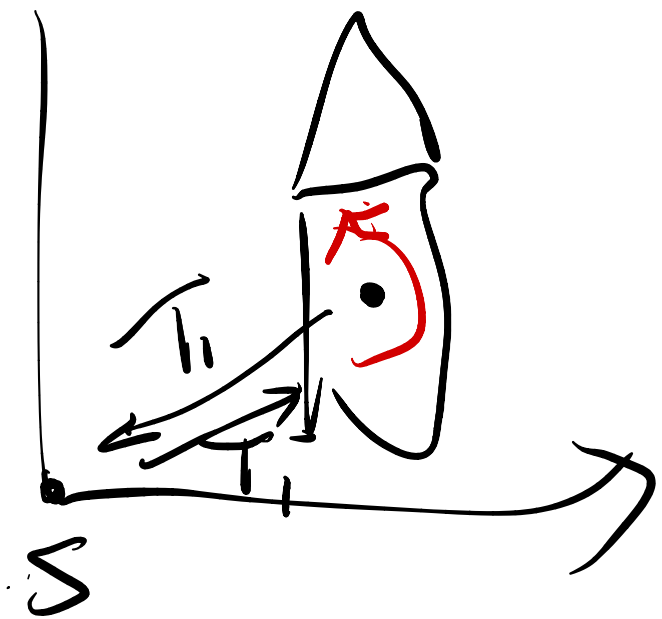
N that's not parallel to A

$$B = \frac{A \times N}{|A \times N|}$$

$B \perp A$, unit length

$$C = A \times B$$

A, B, C form an orthonormal basis in 3D



$$S_{orig} = T_1^{-1} S T_1$$

form N

if (dx is very small)

$N = (1, 0, 0)$

else

$N = (0, 1, 0)$

$R_2 = $ rotateX(theta)

$R_3 = R_1^{-1}$ ← matrix inversion

For Rotation Matrices $R_1^{-1} = R_1^T$

$R = R_3 R_2 R_1$

rotate(theta, A)

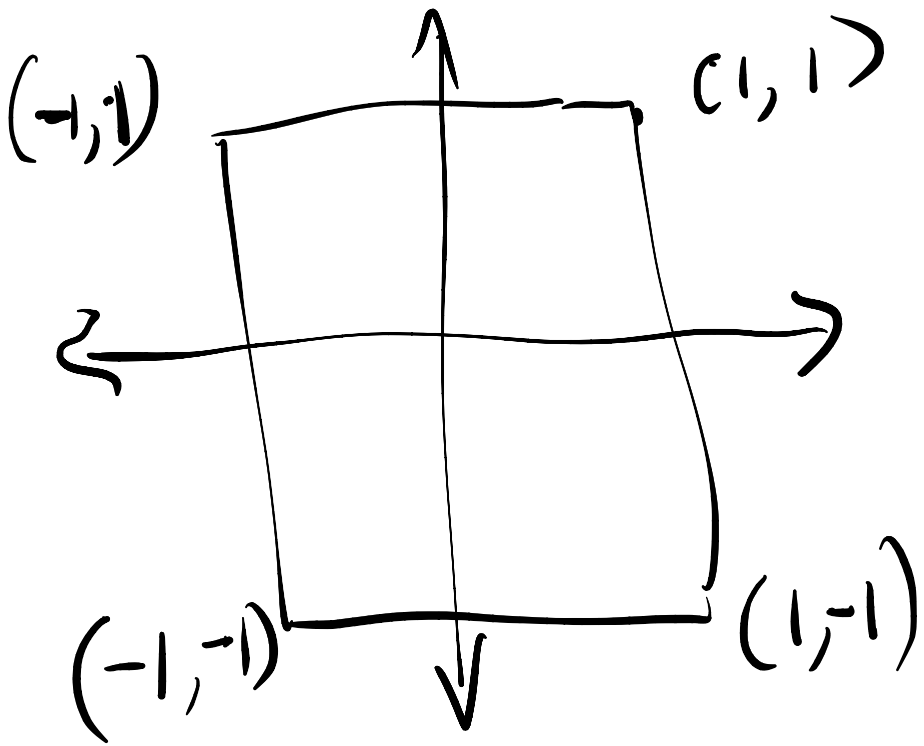
$$Q = (s, x, y, z)$$

interpolation problem as well

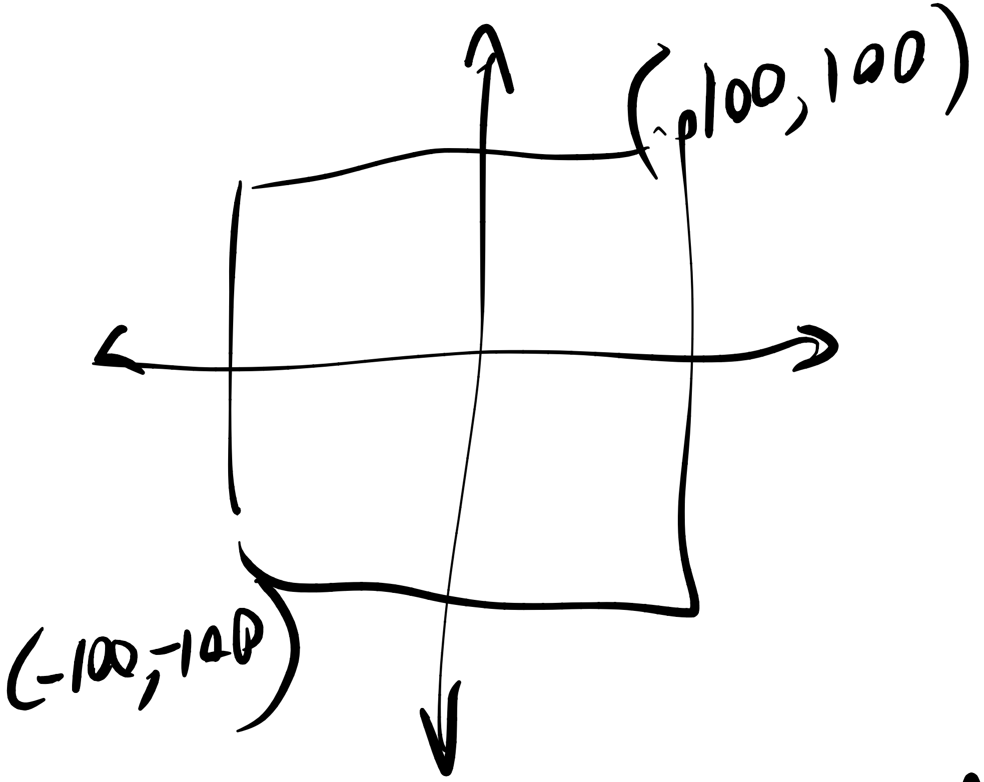
matrices $\Rightarrow$ difficult because we can't interpolate

$$\begin{bmatrix} 0 & 1 \\ 0 & 1 \end{bmatrix} \Rightarrow \begin{bmatrix} 0 & -1 \\ 0 & 1 \end{bmatrix} \quad \cdots \quad \text{at } 0.5 \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$$

if I do pointwise interp.




```
function Square() {
  beginShape();
  startpoint(1, 1)
  lineto (-1, 1)
  lineto (-1, -1)
  lineto (1, -1)
  endShape()
}
```



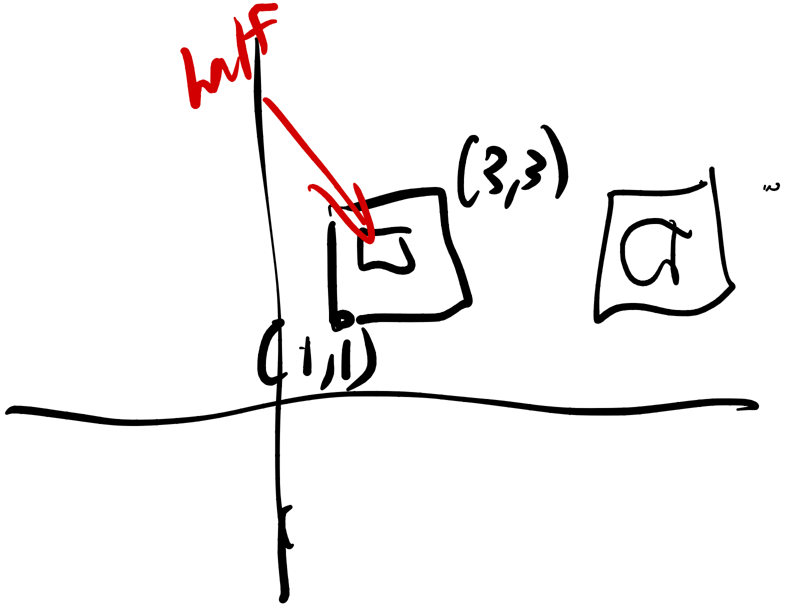
`init()` // $C = I$

`scale(100,100)` // $C = I \cdot S$

`Square()`

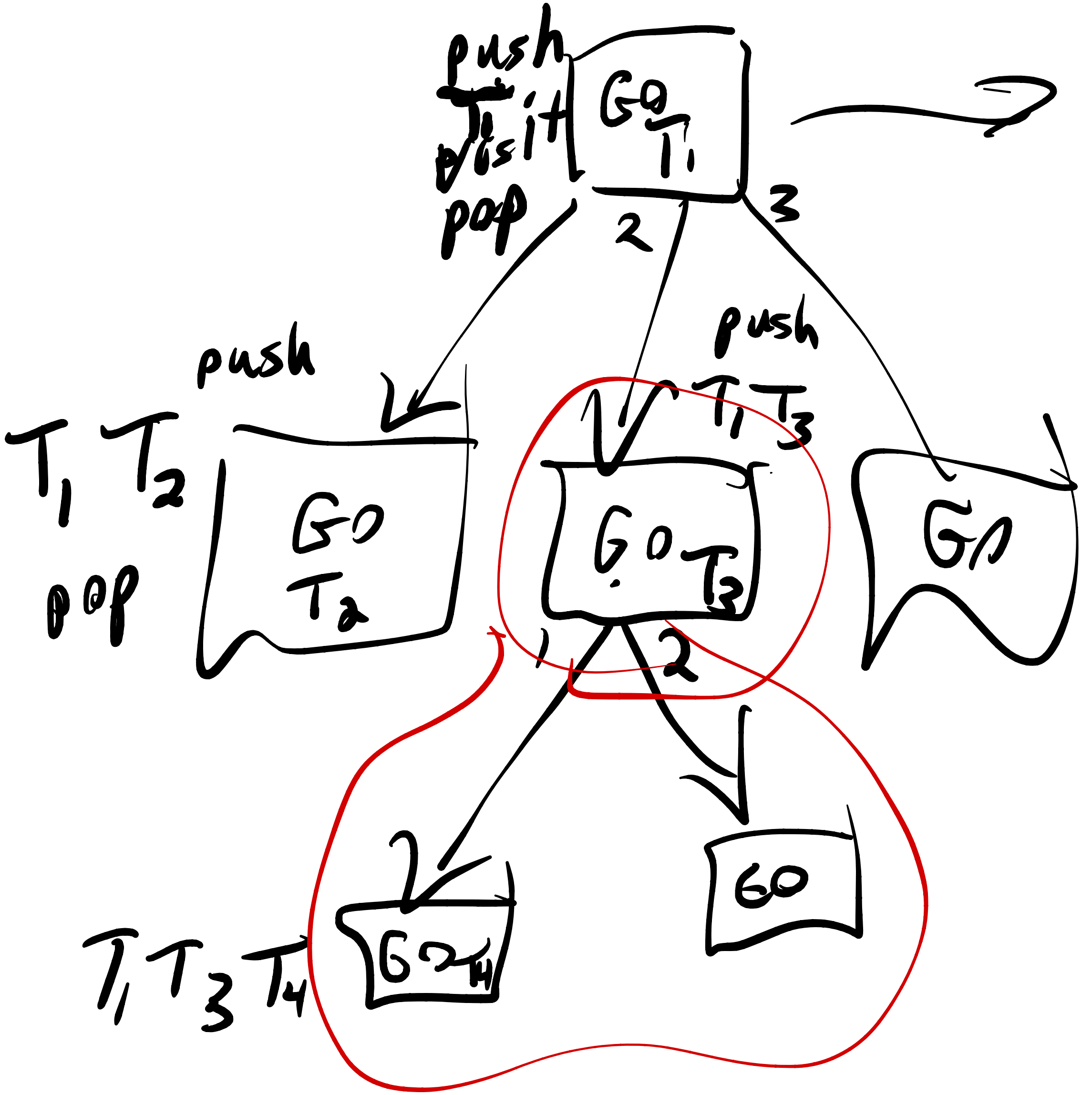
C = current transform

All vertices (x, y) are transformed by C $\quad P' = C \cdot P$



doubleSquare
push() → copy of C & push onto a stack
scale(0.5, 0.5)
square()
pop()
square()

push
translate(2, 2)
double square
pop



GO's, Object3D, . . .

base object

- transformation
- name, other properties, . . .

children

Two Kinds of Graphics Libraries

→ Immediate Mode

→ Canvas, WebGL, OpenGL

"the comands I issue are executed immediately"

→ Retained Mode

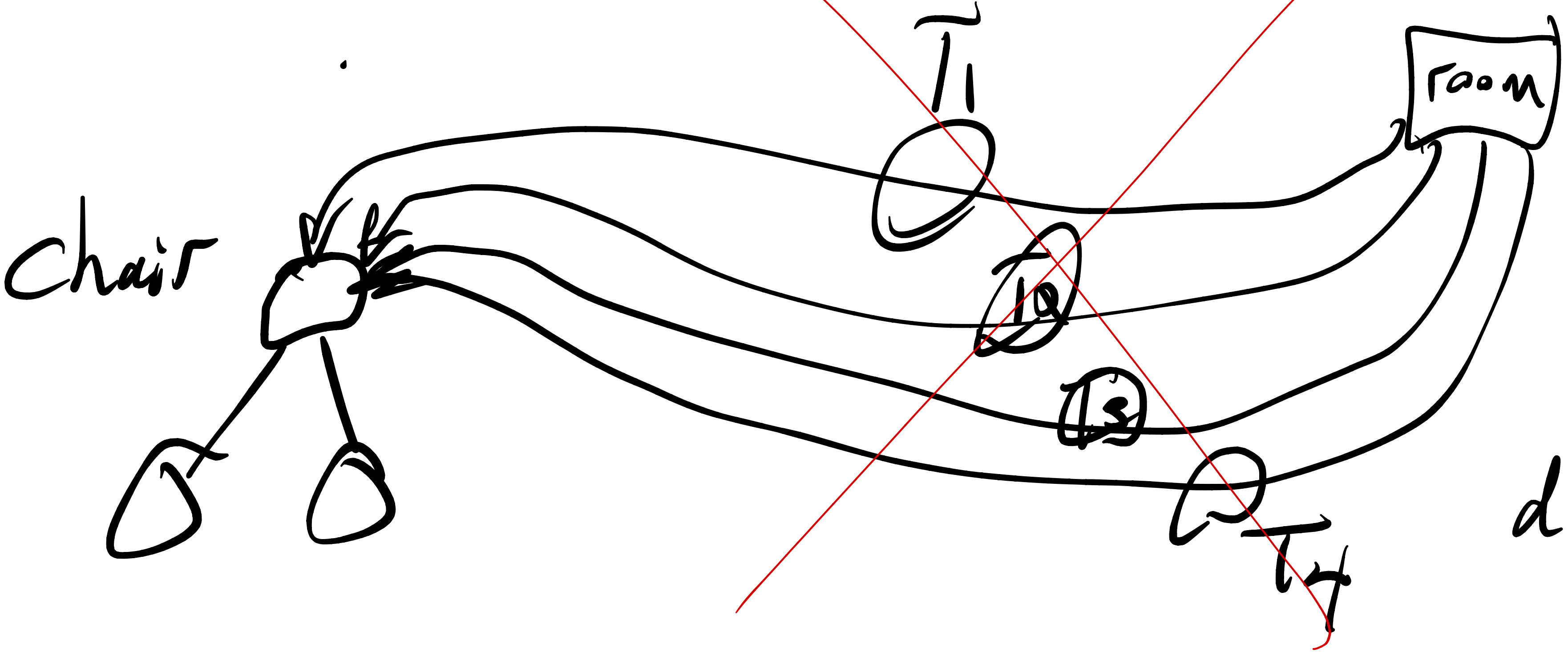
→ Three.js, Unity, ...

Build a graph

The system renders

With a S.G.

Limited to a "graph"



Want 4 chairs

different ~~x~~form to move the chairs