Scalar a

vector $\vec{a}$ $[a_1, a_2, a_3]$

matrix M $\begin{bmatrix} a_{11} & a_{21} & a_{31} \\ a_{12} & a_{22} & a_{32} \\ a_{13} & a_{23} & a_{33} \end{bmatrix}$

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add vect + vect = vect

$\vec{u} + \vec{v} = (u_1 + v_1, u_2 + v_2, u_3 + v_3)$

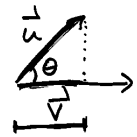
$(3,2) + (6,4) = (9,6)$

multiply vect · vector = scalar

dot product

$(a_1, a_2, a_3) \cdot (b_1, b_2, b_3)$

$a_1 * b_1 + a_2 * b_2 + a_3 * b_3$



$u \cdot v = |u||v| \cos\theta$

$u \cdot v = 0$ perpendicular

$\perp$

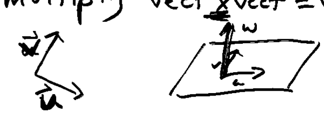
$[6,1,2] \cdot [1,7,3]$

$6 \cdot 1 + 1 \cdot 7 + 2 \cdot 3$

$6 + 7 + 6$

19

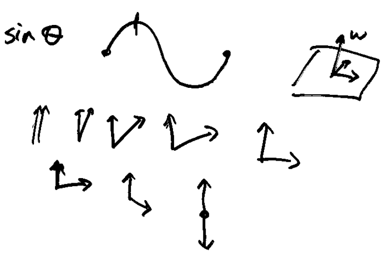
multiply vect x vect = vect



arbitrary convention · right handed

$|u \times v| = |u||v| \sin\theta$

$\sin\theta$



if $u \times v = 0$ parallel lines

$||$

spaces

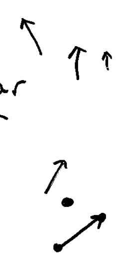
vector space

vector * scalar

vect + vect

affine

points too!



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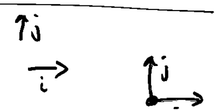
basis

i, j

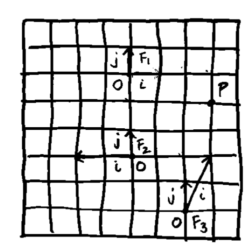
coordinate system



origin + basis

$\boxed{\text{frame}}$

Frames



$P = O + xi + yj$

F_1: $x = 3$ $y = -1$

F_2: $x = 1.5$, $y = 2$

F_3: $x = 1$ $y = 4$? no!

$4 - 2 = 2$

i basis vector has both x and y components!

$p = [p_1, p_2, p_3]$ row

$p = \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix}$ column

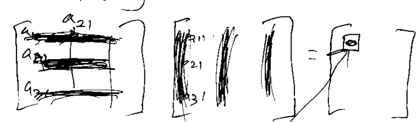
$[p_1', p_2', p_3'] = [p_1, p_2, p_3] \begin{bmatrix} M \end{bmatrix}$

row

$\begin{bmatrix} p_1' \\ p_2' \\ p_3' \end{bmatrix} = \begin{bmatrix} M \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix}$

columns

multiplying matrices



row • col

$$\begin{bmatrix} r_1 \cdot c_1 & r_1 \cdot c_2 & r_1 \cdot c_3 \\ r_2 \cdot c_1 & r_2 \cdot c_2 & r_2 \cdot c_3 \\ r_3 \cdot c_1 & r_3 \cdot c_2 & r_3 \cdot c_3 \end{bmatrix}$$

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} =$$

$a_{11} \cdot b_{11} + a_{12} \cdot b_{21} + a_{13} \cdot b_{31}$

next week:

transformations

concatenating xforms

homogeneous

lab:

simple OpenGL

GLUT