Image Stitching

Computational Photography (CSCI 3240U)

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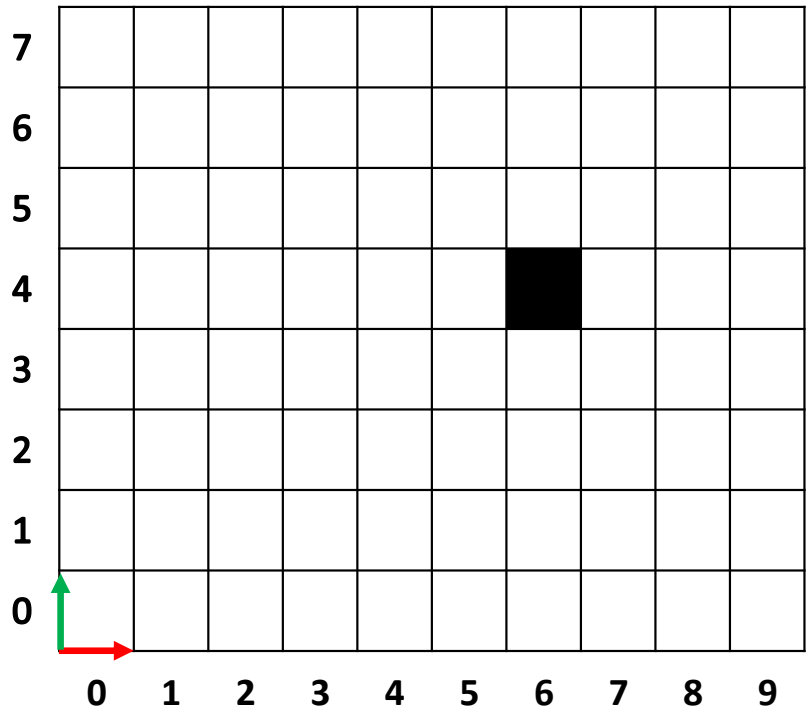
Today

- Image stitching

Cartesian coordinate system

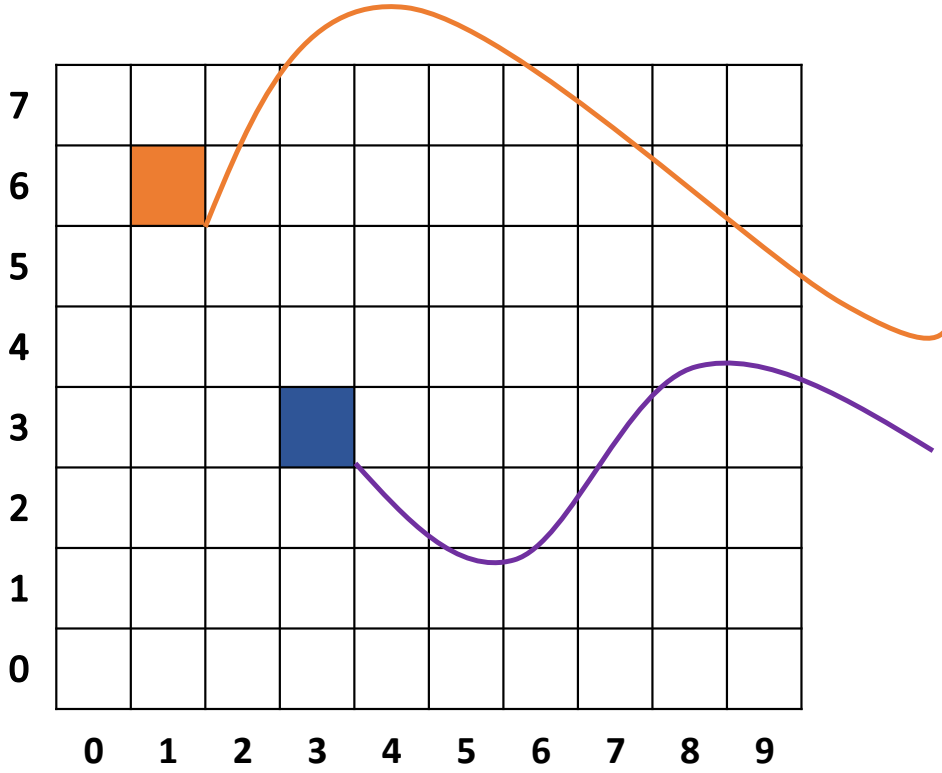


Recall

$$\begin{bmatrix} 6 \\ 4 \end{bmatrix} = 6 \begin{bmatrix} 1 \\ 0 \end{bmatrix} + 4 \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Basis vectors

Euclidean vs. Homogeneous Coordinates



Euclidean (Cartesian) to Homogeneous Coordinates

$(1,6)$ → $(1,6,1)$

$(3,3)$ → $(3,3,1)$

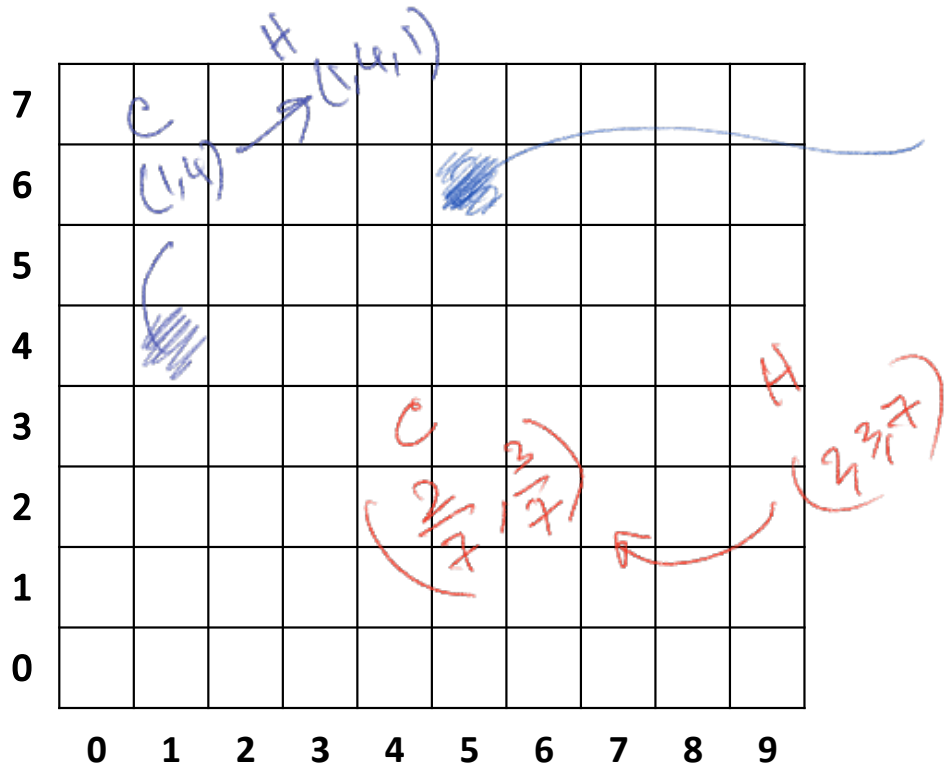
(x, y)

Standard Euclidean representation of points

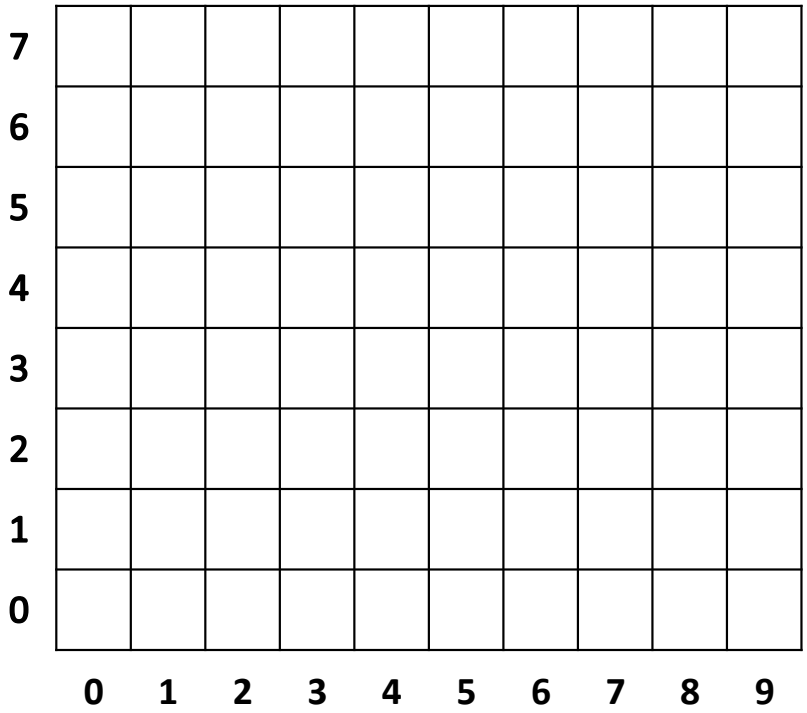
$(\lambda x, \lambda y, \lambda)$
for any $\lambda \neq 0$

Also called *projective representation* of a point

Euclidean vs. Homogeneous Coordinates



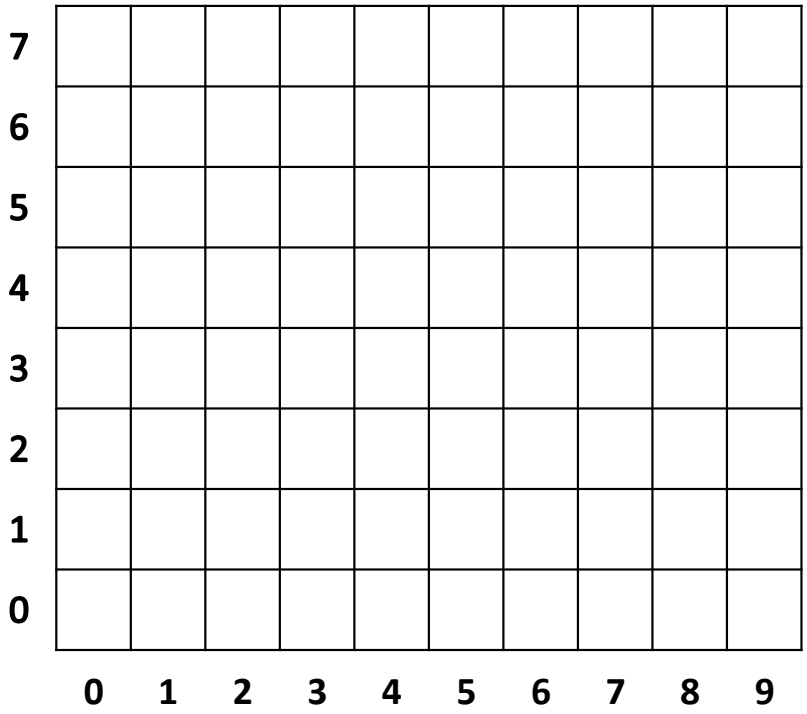
Points at infinity



Say you are given a homogeneous point $(6,4,2)$

How do represent it in Cartesian coordinates?

Points at infinity



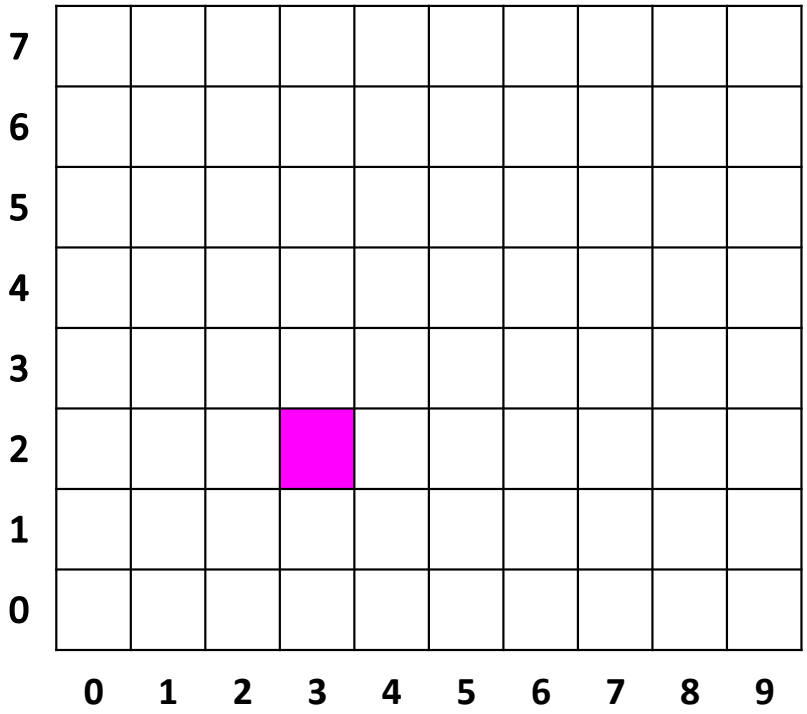
Say you are given a homogeneous point $(6,4,2)$

How do represent it in Cartesian coordinates? **Ans: (3,2)**

Say you are given a homogeneous point $(6,4,0)$

How do represent it in Cartesian coordinates? Divide by 0

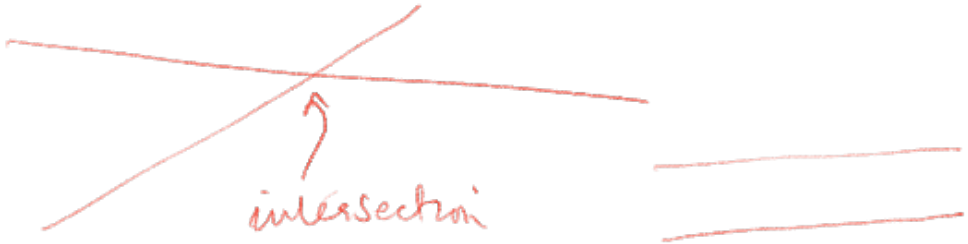
Points at infinity

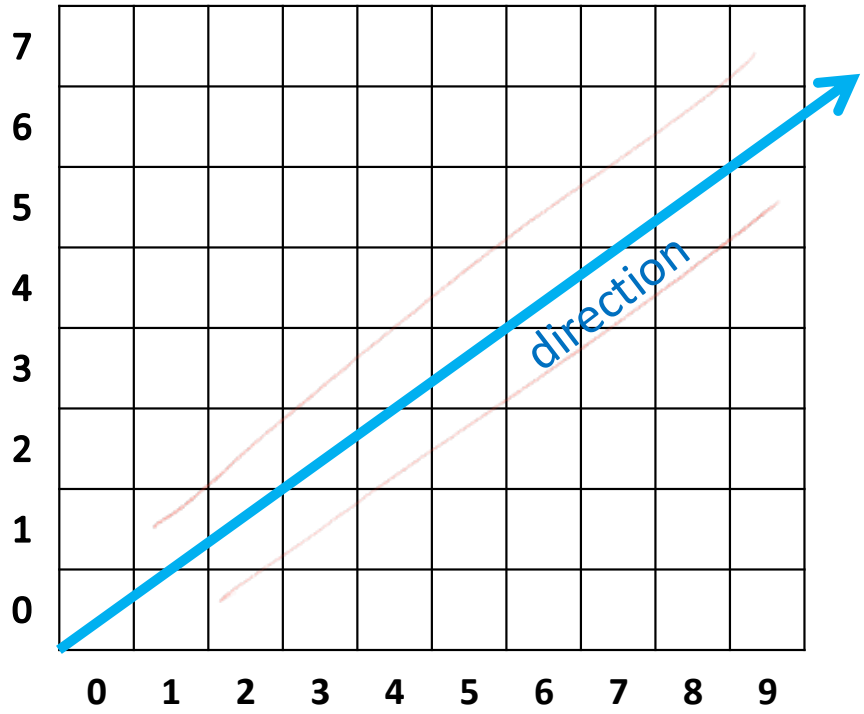


Say you are given a homogeneous point $(6,4,2)$

How do represent it in Cartesian coordinates? **Ans: (3,2)**

Points at infinity





Say you are given a homogeneous point $(6,4,2)$

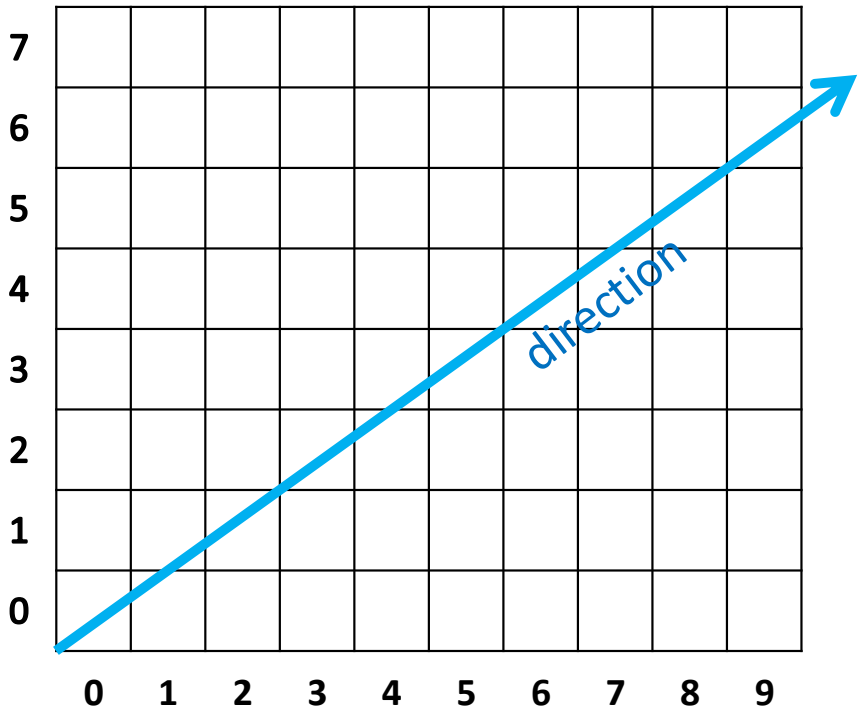
How do represent it in Cartesian coordinates? **Ans: (3,2)**

Say you are given a homogeneous point $(6,4,0)$

How do represent it in Cartesian coordinates? Ans: **direction (6,4)**

This is not a Cartesian point. Rather it denotes a direction

Points at infinity



Case 1

Say you are given a homogeneous point $(6,4,2)$

How do represent it in Cartesian coordinates? **Ans: (3,2)**

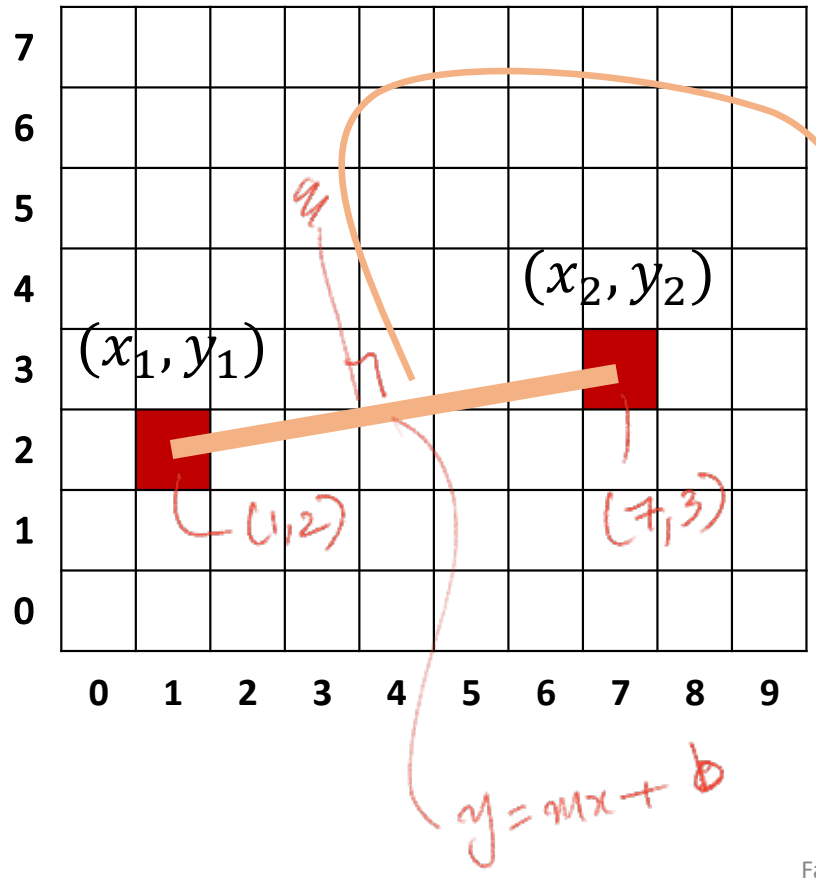
Case 2

Say you are given a homogeneous point $(6,4,0)$

How do represent it in Cartesian coordinates? Ans: **direction (6,4)**

This is not a Cartesian point. Rather it denotes a direction

Line equations in homogeneous coordinates



Equation of a line

parameters (a, b, c)

$$ax + by + c = 0$$

$a(1) + b(2) + c = 0$ ✓

$a(7) + b(3) + c = 0$ ✓

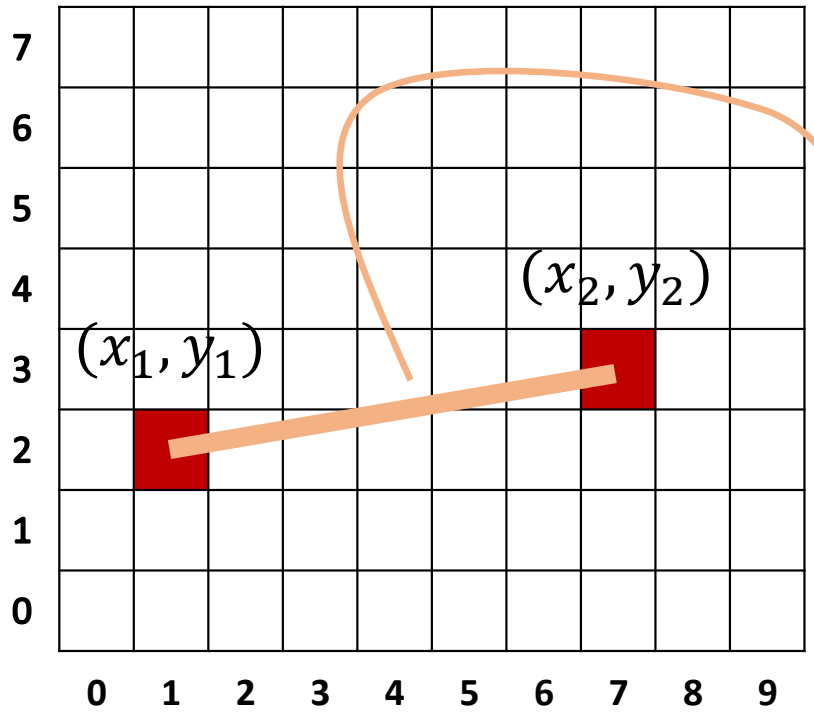
$a(4) + b(4) + c = 0$ ✗

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = 0$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} = 0$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} \begin{bmatrix} 7 \\ 3 \\ 1 \end{bmatrix} = 0$$

Line equations in homogeneous coordinates



Equation of a line

$$ax + by + c = 0$$

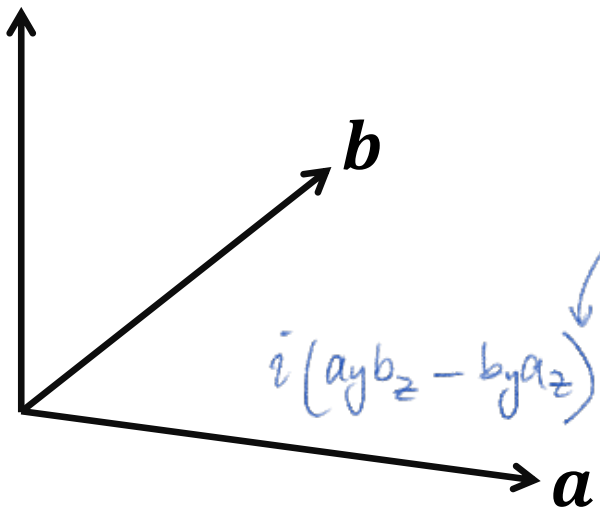
$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = 0$$

Cool observation

Dot-product

Cross-product of two vectors

$$\boldsymbol{c} = \boldsymbol{a} \times \boldsymbol{b}$$

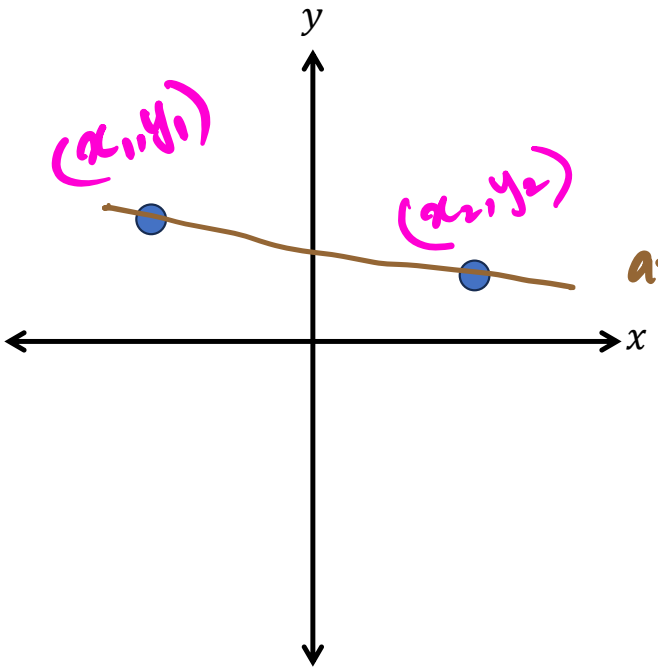


$$\boldsymbol{a} \times \boldsymbol{b} = \begin{vmatrix} \boldsymbol{i} & \boldsymbol{j} & \boldsymbol{k} \\ \boldsymbol{a_x} & \boldsymbol{a_y} & \boldsymbol{a_z} \\ \boldsymbol{b_x} & \boldsymbol{b_y} & \boldsymbol{b_z} \end{vmatrix}$$

$$\boldsymbol{a} \times \boldsymbol{b} = \begin{bmatrix} \boldsymbol{0} & \boldsymbol{-a_z} & \boldsymbol{a_y} \\ \boldsymbol{a_z} & \boldsymbol{0} & \boldsymbol{-a_x} \\ \boldsymbol{-a_y} & \boldsymbol{a_x} & \boldsymbol{0} \end{bmatrix} \boldsymbol{b}$$

$$i(a_y b_z - b_y a_z) - j(a_x b_z - b_x a_z) + k(a_x b_y - b_x a_y)$$

The line passing through two points

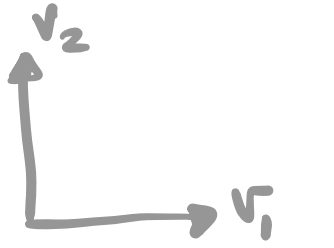


$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} = 0$$

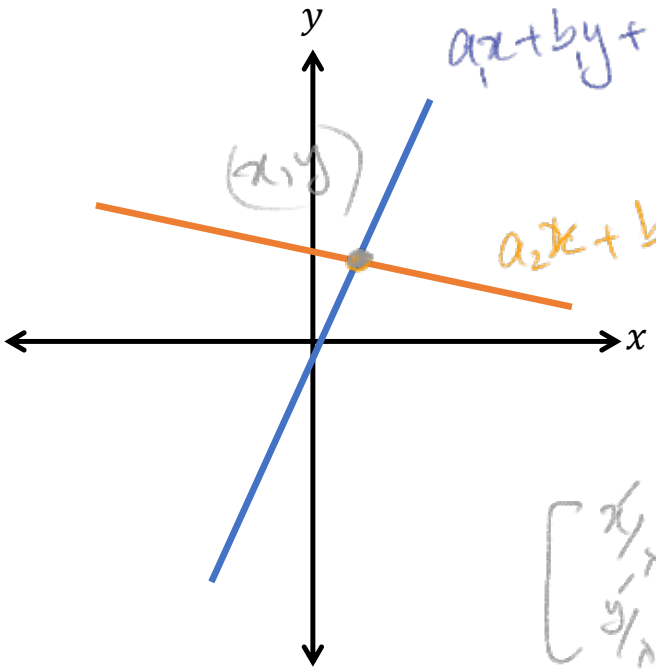
$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} \cdot \begin{bmatrix} x_2 \\ y_2 \\ 1 \end{bmatrix} = 0$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} \times \begin{bmatrix} x_2 \\ y_2 \\ 1 \end{bmatrix}$$

c line



The point of intersection of two lines



$a_1x + b_1y + c_1 = 0$ → $\begin{bmatrix} a_1 \\ b_1 \\ c_1 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = 0$

$a_2x + b_2y + c_2 = 0$ → $\begin{bmatrix} a_2 \\ b_2 \\ c_2 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = 0$

$\begin{bmatrix} x' \\ y' \\ w \end{bmatrix} = \begin{bmatrix} a_1 \\ b_1 \\ c_1 \end{bmatrix} \times \begin{bmatrix} a_2 \\ b_2 \\ c_2 \end{bmatrix}$ → $\begin{bmatrix} x'/w \\ y'/w \end{bmatrix}$