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MACHINE LEARNING

Learning from Data

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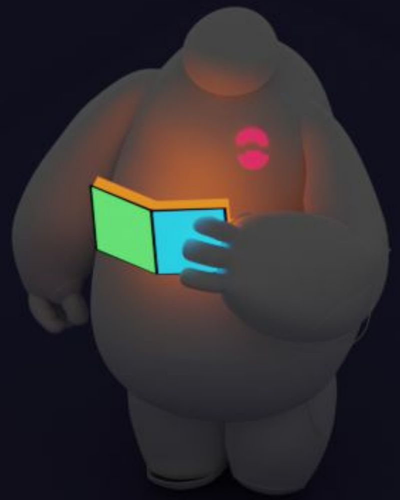

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|00 INTRODUCTION

Pattern Recognition

Study **Correlations** Between **Data Domains**

Tune a **Parametric Model** with **Data**

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|00 INTRODUCTION

SUPERVISED

Learn parameters from
Labeled Data

Regression

Classification

UNSUPERVISED

Learn parameters from
Unlabeled Data

Clustering

Latent Space

REINFORCEMENT

Autonomous Agent Learning
from **Experience**

Q-Learning

01|

LINEAR ALGEBRA

The Last Space Bender

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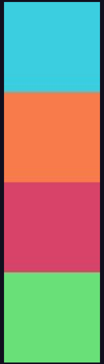
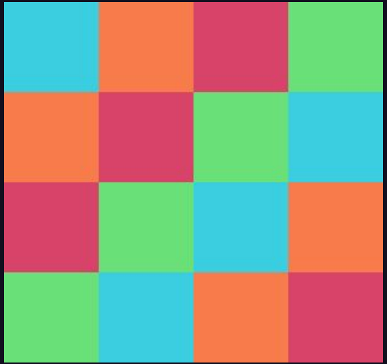
|01 LINEAR ALGEBRA

VECTOR



MATRIX



TENSOR

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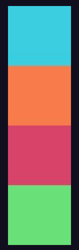
VECTOR

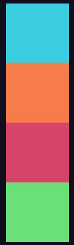


$$\vec{v} = \begin{pmatrix} v_x \\ v_y \end{pmatrix}$$

LENGTH

$$||\vec{v}|| = \sqrt{v_x^2 + v_y^2}$$

VECTOR



ADDITION / SUBTRACTION

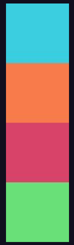
$$\vec{v} = \begin{pmatrix} v_x \\ v_y \end{pmatrix}$$

$$\vec{u} = \begin{pmatrix} u_x \\ u_y \end{pmatrix}$$

$$\vec{v} + \vec{u} = \begin{pmatrix} v_x + u_x \\ v_y + u_y \end{pmatrix}$$

|01 LINEAR ALGEBRA

VECTOR



$$\vec{v} = \begin{pmatrix} v_x \\ v_y \end{pmatrix}$$

$$\vec{u} = \begin{pmatrix} u_x \\ u_y \end{pmatrix}$$

SCALAR (DOT) PRODUCT

$$\vec{v}.\vec{u} = v_x u_x + v_y u_y = |v|\,|u|\,cos\theta$$

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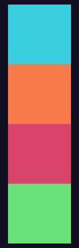
VECTOR



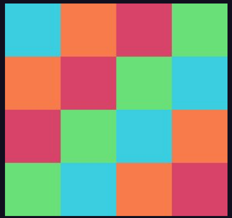
$$\vec{v} = \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix}$$

$$\vec{u} = \begin{pmatrix} u_x \\ u_y \\ u_z \end{pmatrix}$$

CROSS PRODUCT

$$\vec{v} \times \vec{u} = \begin{pmatrix} v_y u_z - v_z u_y \\ v_z u_x - v_x u_z \\ v_x u_y - v_y u_x \end{pmatrix}$$

MATRIX



ADDITION / SUBTRACTION

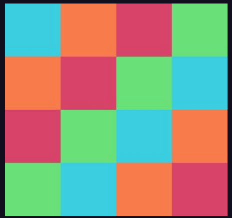
$$A = \begin{pmatrix} a_{1,1} & a_{1,2} \\ a_{2,1} & a_{2,2} \end{pmatrix}$$

$$B = \begin{pmatrix} b_{1,1} & b_{1,2} \\ b_{2,1} & b_{2,2} \end{pmatrix}$$

$$A + B = \begin{pmatrix} a_{1,1} + b_{1,1} & a_{1,2} + b_{1,2} \\ a_{2,1} + b_{2,1} & a_{2,2} + b_{2,2} \end{pmatrix}$$

|01 LINEAR ALGEBRA

MATRIX



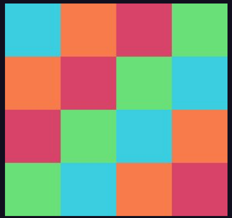
HADAMARD PRODUCT

$$A = \begin{pmatrix} a_{1,1} & a_{1,2} \\ a_{2,1} & a_{2,2} \end{pmatrix}$$

$$B = \begin{pmatrix} b_{1,1} & b_{1,2} \\ b_{2,1} & b_{2,2} \end{pmatrix}$$

$$A \odot B = \begin{pmatrix} a_{1,1}b_{1,1} & a_{1,2}b_{1,2} \\ a_{2,1}b_{2,1} & a_{2,2}b_{2,2} \end{pmatrix}$$

MATRIX



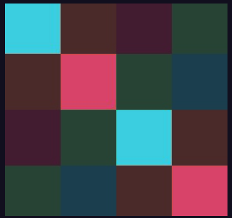
MATRIX MULTIPLICATION

$$A = \begin{pmatrix} a_{1,1} & a_{1,2} \\ a_{2,1} & a_{2,2} \end{pmatrix}$$

$$B = \begin{pmatrix} b_{1,1} & b_{1,2} \\ b_{2,1} & b_{2,2} \end{pmatrix}$$

$$A \cdot B = \begin{pmatrix} a_{1,1}b_{1,1} + a_{1,2}b_{2,1} & a_{1,1}b_{1,2} + a_{1,2}b_{2,2} \\ a_{2,1}b_{1,1} + a_{2,2}b_{2,1} & a_{2,1}b_{1,2} + a_{2,2}b_{2,2} \end{pmatrix}$$

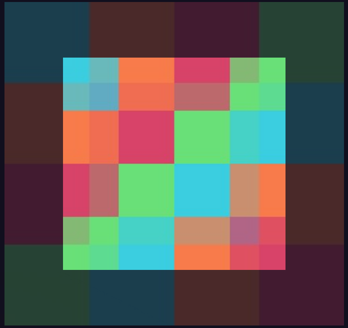
MATRIX



EYE

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

MATRIX

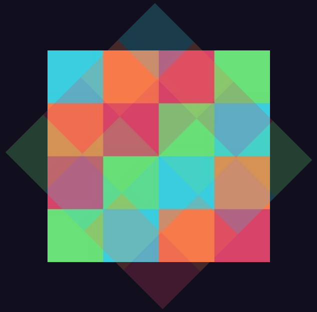


SCALE

$$\begin{pmatrix} s_x & 0 & 0 & 0 \\ 0 & s_y & 0 & 0 \\ 0 & 0 & s_z & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

|01 LINEAR ALGEBRA

MATRIX



ROTATION

$$R_x(\theta) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ cos(\theta) & -sin(\theta) & 0 & 0 \\ sin(\theta) & cos(\theta) & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$R_y(\theta) = \begin{pmatrix} cos(\theta) & 0 & sin(\theta) & 0 \\ 0 & 1 & 0 & 0 \\ -sin(\theta) & 0 & cos(\theta) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$R_z(\theta) = \begin{pmatrix} cos(\theta) & -sin(\theta) & 0 & 0 \\ sin(\theta) & cos(\theta) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

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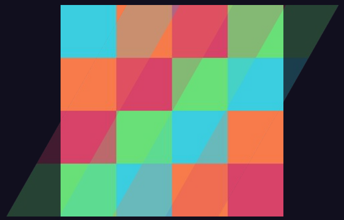
|01 LINEAR ALGEBRA

MATRIX



SHEAR

$$\begin{pmatrix} 1 & 0 & \lambda & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

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MATRIX

REFLECTION

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

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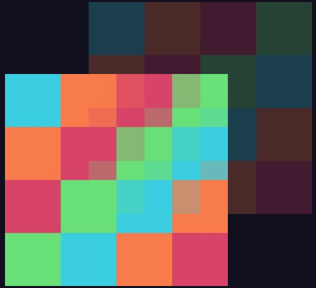
MATRIX



TRANSLATION

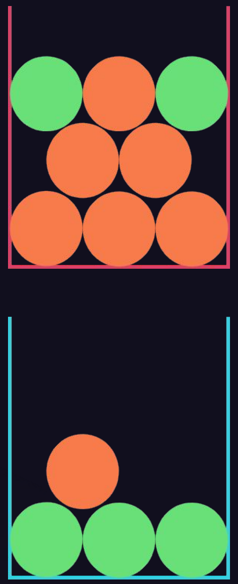
$$\begin{pmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

|02

PROBABILITIES

Roll the Dice

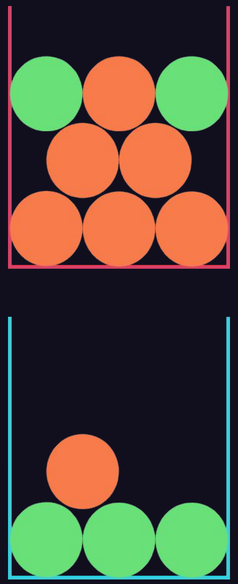
RANDOM VARIABLES



$$B = \begin{cases} r & \text{if Box is red} \\ b & \text{if Box is blue} \end{cases}$$

$$F = \begin{cases} a & \text{if Fruit is an apple} \\ o & \text{if Fruit is an orange} \end{cases}$$

PROBABILITIES



$$p(B = r) = \frac{\#\text{ red boxes picked}}{\#\text{ total boxes picked}} \in [0; 1]$$

$$p(B = r) + p(B = b) = 1$$

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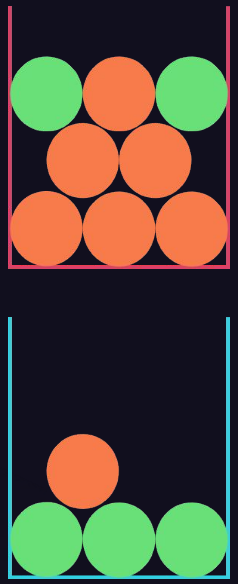
|02 PROBABILITIES



JOINT & CONDITIONAL

Sum Rule

Joint probabilties $p(B = r, F = a)$

Marginal probabilty $p(B = r) = p(B = r, F = a) + p(B = r, F = o)$

Product Rule

Conditional probabilties $p(B = r|F = o)$

$$p(B = r, F = o) = p(F = o|B = r)\, p(B = r)$$

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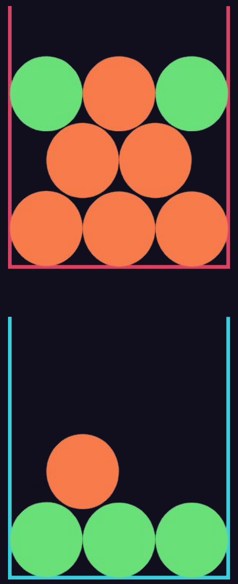
BAYES THEOREM



$$p(B=r|F=o) = \frac{p(F{=}o|B{=}r)p(B{=}r)}{p(F{=}o)}$$

$$p(B=r|F=o) = \frac{p(F{=}o|B{=}r)p(B{=}r)}{p(F{=}o|B{=}r)p(B{=}r)+p(F{=}o|B{=}b)p(B{=}b)}$$

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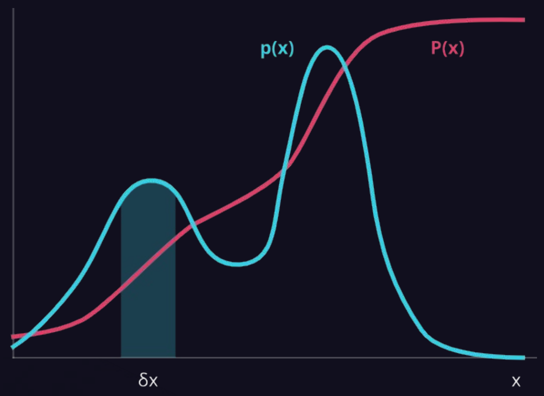

DENSITY

$$p(x \in (a,b)) = \int_a^b p(x)dx$$

$$\int_{-\infty}^{+\infty} p(x)dx = 1$$

$$p(x) \geq 0$$

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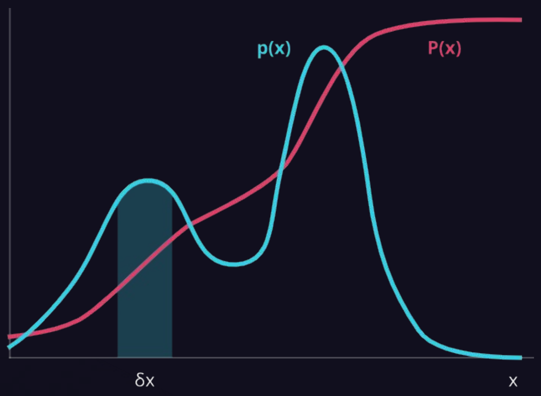
|02 PROBABILITIES

EXPECTATION & COVARIANCE



$$\mathbb{E}[f] = \int p(x) f(x) dx$$

$$var[f] = \mathbb{E}[(f(x) - \mathbb{E}[f(x)])^2]$$

$$var[f] = \mathbb{E}[f(x)^2] - \mathbb{E}[f(x)]^2$$

$$cov[x, y] = \mathbb{E}_{x,y}[xy] - \mathbb{E}[x]\mathbb{E}[y]$$

03|

OPTIMIZATION

One Method to Rule them All

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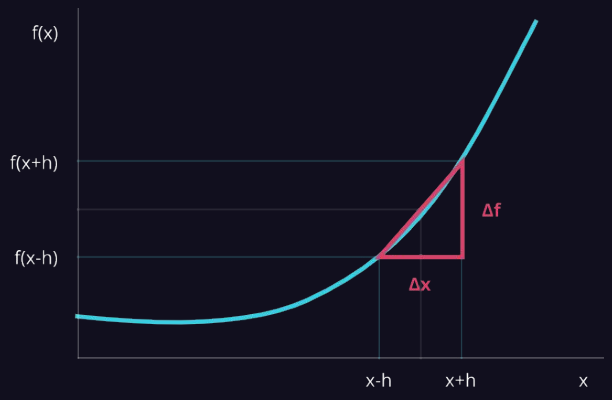
|03 OPTIMIZATION



DERIVATIVES

$$f'(x) = \lim_{h\to 0} \frac{\Delta f}{\Delta x} = \lim_{h\to 0} \frac{f(x+h)-f(x-h)}{2h}$$

First order Derivative

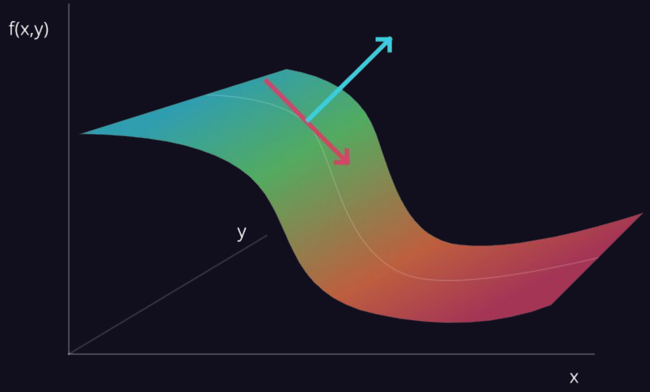
Direction of the Slope

Second order Derivative

Rate of Changes in the Slope

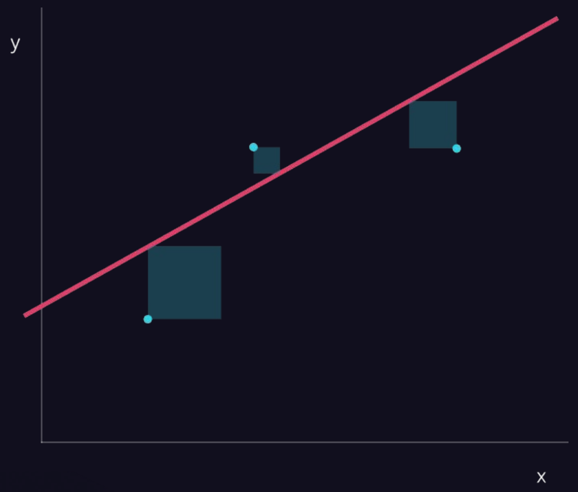
|03 OPTIMIZATION

GRADIENTS



$$\nabla f = \begin{pmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{pmatrix}$$

|03 OPTIMIZATION



LEAST SQUARES

Objective Function

Minimize Squared Distances
from Expected Value

$$\hat{y} = ax + b$$

$$\sum_i (y_i - \hat{y}_i)^2 = 0$$

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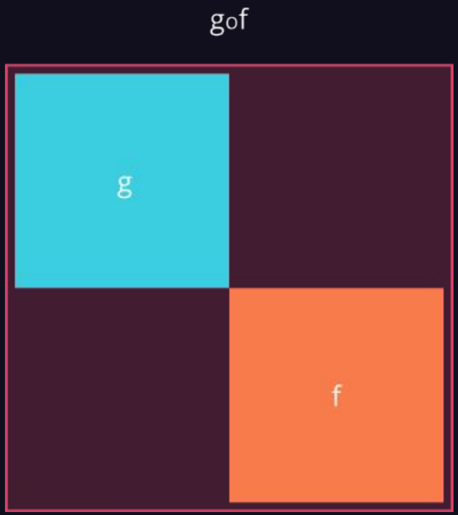


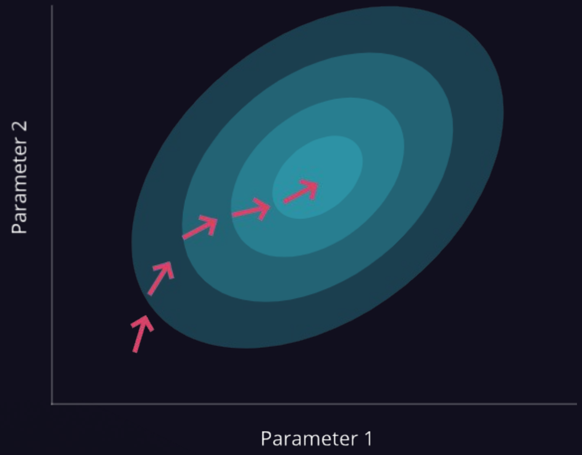
CHAIN RULE

$$h = g \circ f$$

$$h'(x) = g'(f(x))f'(x)$$

|03 OPTIMIZATION

Error Landscape



GRADIENT DESCENT

Steps

1) **Forward Propagate** Through the Chain
2) Compute Output **Error**
3) **Backpropagate** Error Through the Chain
4) **Update** Weights w/ Learning Rate
5) **Repeat** Until Convergence Threshold

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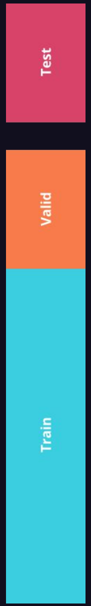
|03 OPTIMIZATION



DATASET SPLIT

Training Set

Samples used to Fit/Train the Model

Validation Set

Samples used to provide an Unbiased Evaluation of the Model Becomes Biased during Training

Testing Set

Samples used to provide an Unbiased Evaluation of the Model after Training

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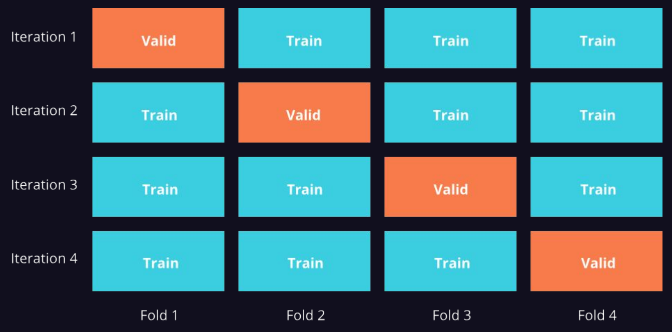
CROSS-VALIDATION



Method

1) Split Dataset into **k-Folds**
2) **Train on k-1 Folds** and Validate w/ Last
3) **Repeat** k-times
4) Use **Ensemble** Method for **Inference** or **Retrain** on all Dataset

|04

DIMENSIONALITY REDUCTION

Small Worlds are Filled with Things to See

Paul Safranek

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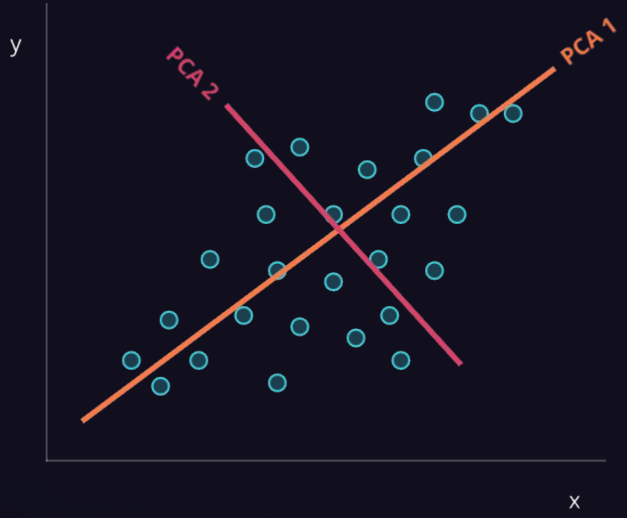
|04 DIMENSIONALITY REDUCTION



PCA

$$C = \begin{pmatrix} Var(x) & Cov(x,y) & Cov(x,z) \\ Cov(y,x) & Var(y) & Cov(y,z) \\ Cov(z,x) & Cov(z,y) & Var(z) \end{pmatrix}$$

$v_1 \quad \lambda_1 \qquad$ Big

$v_2 \quad \lambda_2$

$v_3 \quad \lambda_3 \qquad$ Small

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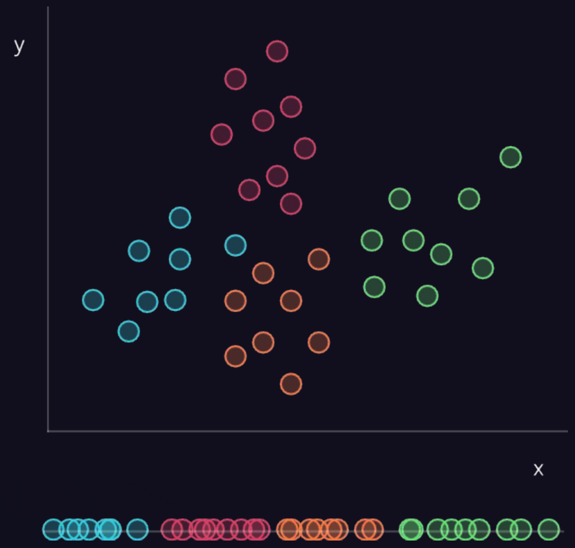
|04 DIMENSIONALITY REDUCTION



t-SNE

Steps

1) Use **Normal Distribution** to Estimate **Similarity** b/ Data Points
2) Create another Distribution (**t-distribution**) Capturing the **Same Similarity** Between Data Points using **Gradient Descent** on **KL-divergence**

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