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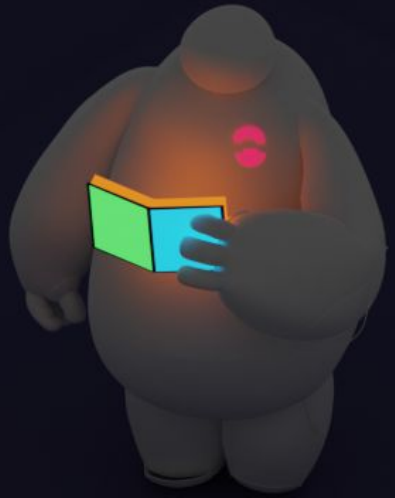
MACHINE LEARNING

Learning from Data



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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

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01|

LINEAR ALGEBRA

The Last Space Bender

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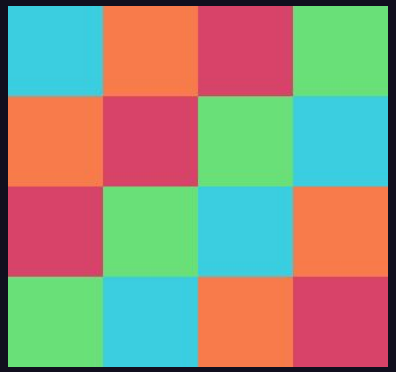
|01 LINEAR ALGEBRA

VECTOR

MATRIX



TENSOR

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|01 LINEAR ALGEBRA

VECTOR

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

LENGTH

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

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|01 LINEAR ALGEBRA

VECTOR

ADDITION / SUBTRACTION

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

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

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

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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

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

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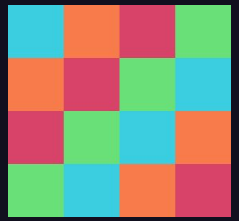
|01 LINEAR ALGEBRA

MATRIX



ADDITION / SUBTRACTION

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

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

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

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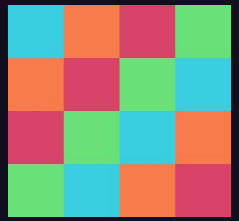
|01 LINEAR ALGEBRA

MATRIX



HADAMARD PRODUCT

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

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

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

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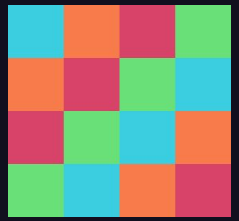
|01 LINEAR ALGEBRA

MATRIX



MATRIX MULTIPLICATION

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

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

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

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|01 LINEAR ALGEBRA

MATRIX

EYE

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

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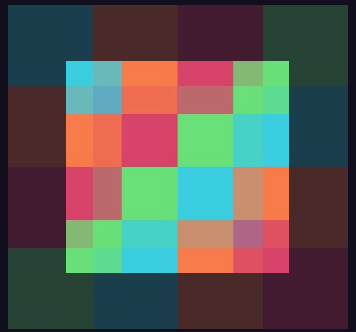
|01 LINEAR ALGEBRA

MATRIX



SCALE

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

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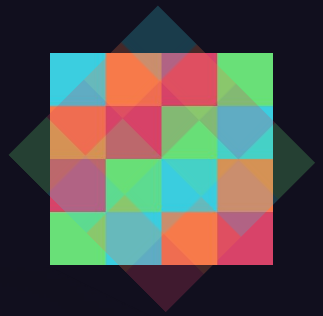
|01 LINEAR ALGEBRA

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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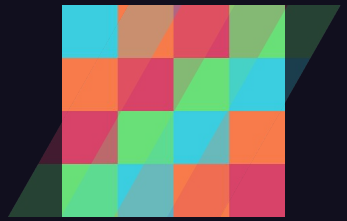
|01 LINEAR ALGEBRA

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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CENTER

|01 LINEAR ALGEBRA

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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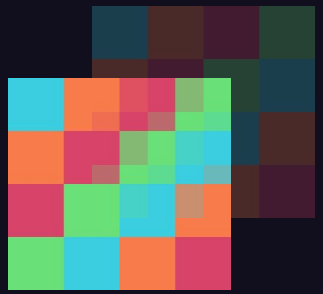
|01 LINEAR ALGEBRA

MATRIX



TRANSLATION

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

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|02

PROBABILITIES

Roll the Dice

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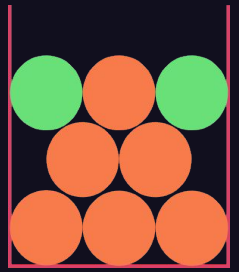
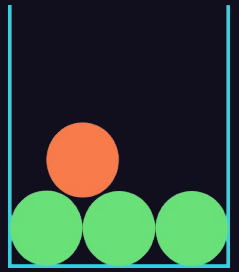


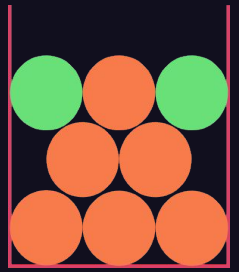


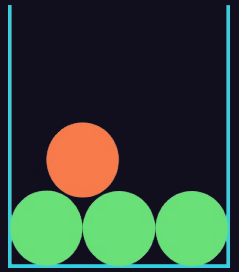
RANDOM VARIABLES

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

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

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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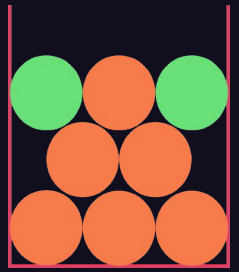

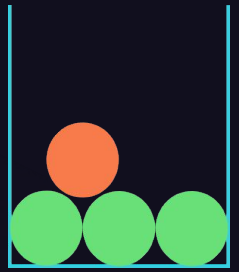

JOINT & CONDITIONAL

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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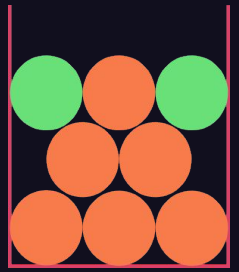
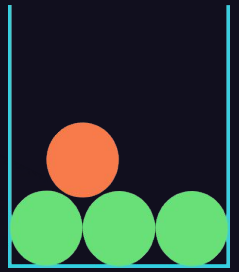
|02 PROBABILITIES





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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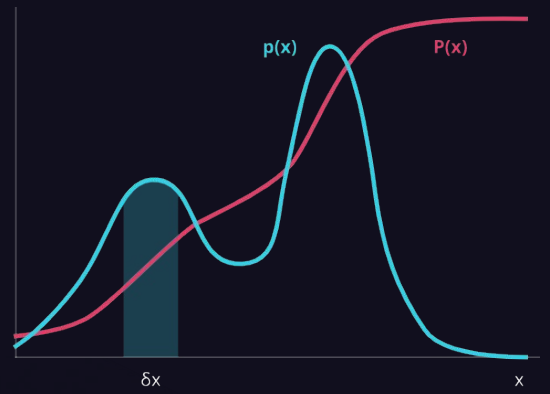
|02 PROBABILITIES



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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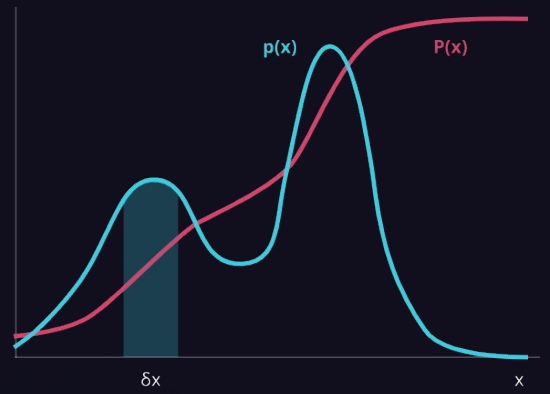

EXPECTATION & COVARIANCE

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

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

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

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

03|

OPTIMIZATION

One Method to Rule them All

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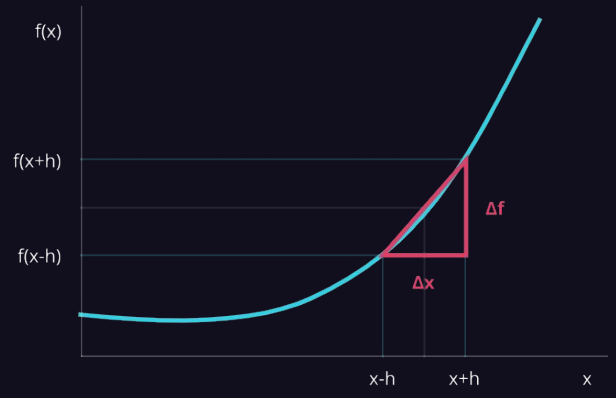
|03 OPTIMIZATION



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

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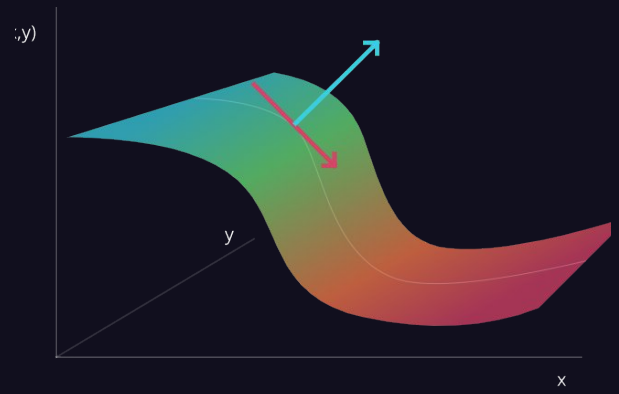
|03 OPTIMIZATION



GRADIENTS

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

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LEAST SQUARES

CHAIN RULE

BACKPROPAGATION