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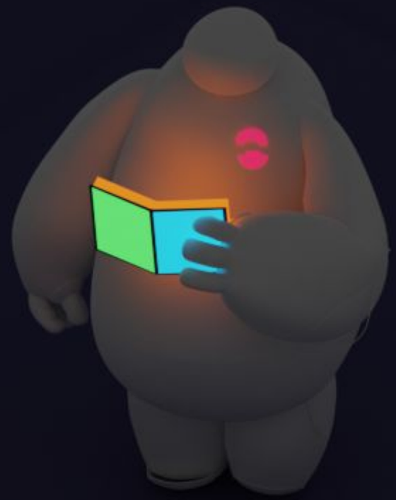
MACHINE LEARNING

Learning from Data

Ylless **HATI**

PHD Student - Computer Science

yliess.hati@**devinci.fr**



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|00 INTRODUCTION

Pattern Recognition

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

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

|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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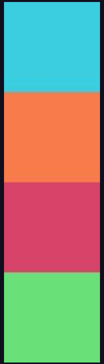
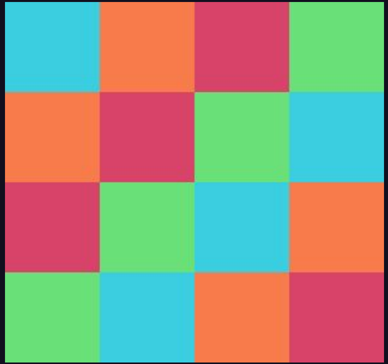
|01 LINEAR ALGEBRA

VECTOR



MATRIX



TENSOR

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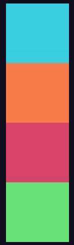
VECTOR

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

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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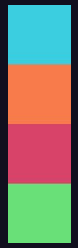
|01 LINEAR ALGEBRA

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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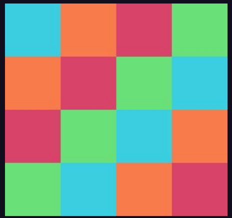
MATRIX



ADDITION / SUBTRACTION

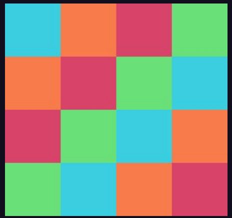
$$A = \begin{pmatrix} a_{1,1} & a_{1,2} \\ a_{2,1} & a_{2,2} \end{pmatrix}$$

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

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

|01 LINEAR ALGEBRA

MATRIX



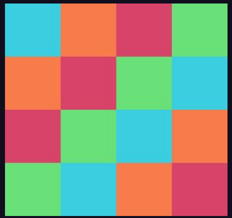
HADAMARD PRODUCT

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

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

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

MATRIX



MATRIX MULTIPLICATION

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

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

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

|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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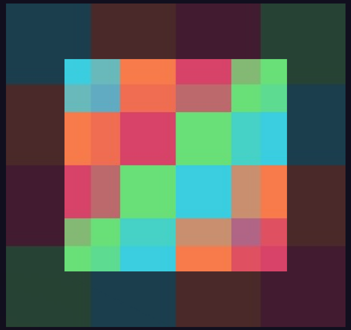
|01 LINEAR ALGEBRA

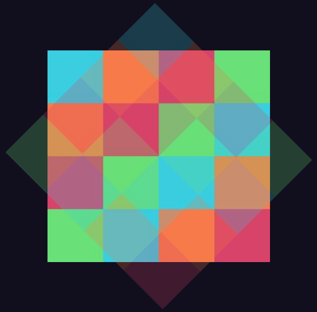
MATRIX



SCALE

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

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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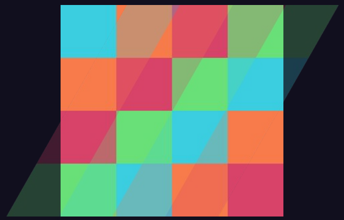
MATRIX



SHEAR

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

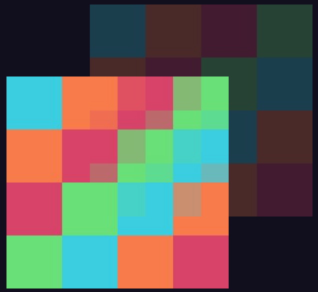
MATRIX

REFLECTION

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

|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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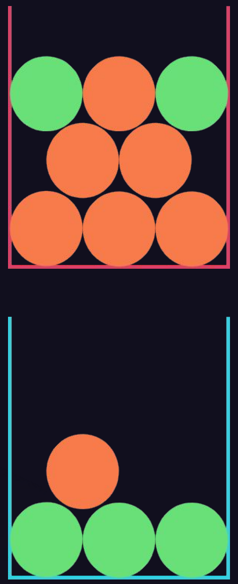

RANDOM VARIABLES

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

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

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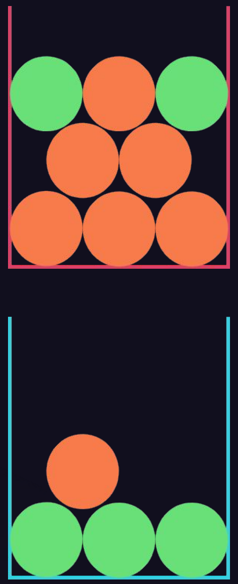
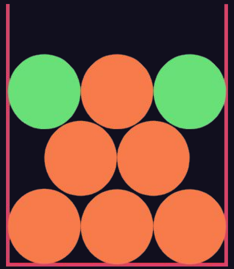
PROBABILITIES

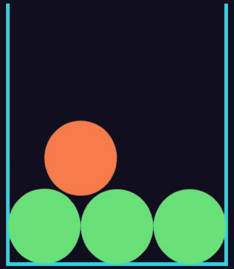


$$p(B = r) = \frac{\#\text{ red boxes picked}}{\#\text{ total boxes picked}} \in [0; 1]$$

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

JOINT & CONDITIONAL





Sum Rule

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

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

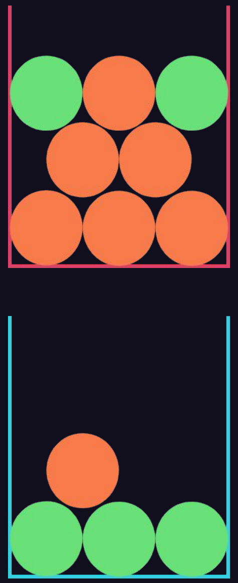
Product Rule

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

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

|02 PROBABILITIES

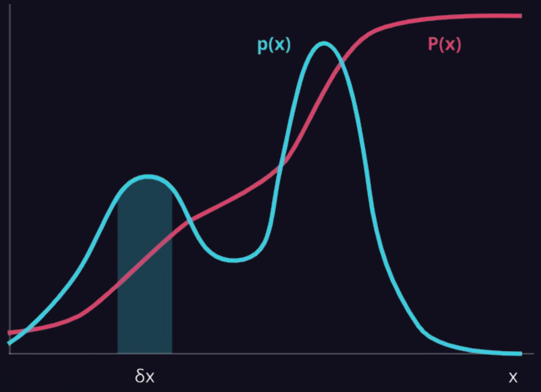
BAYES THEOREM



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

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

|02 PROBABILITIES

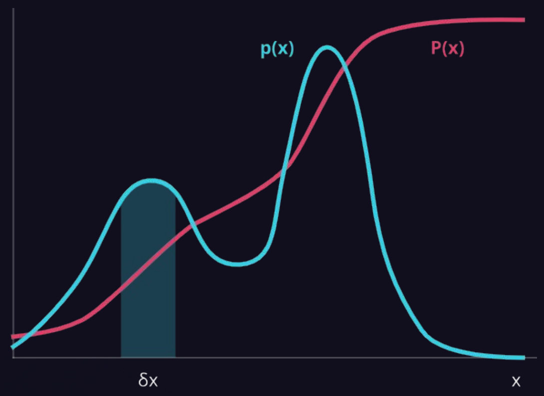


DENSITY

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

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

$$p(x) \geq 0$$



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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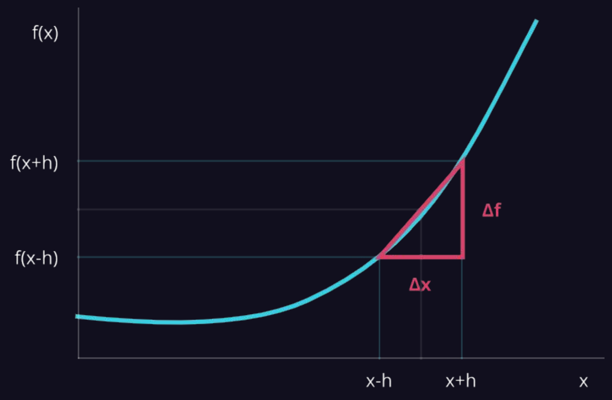

DERIVATIVES

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

First order Derivative

Direction of the Slope

Second order Derivative

Rate of Changes in the Slope

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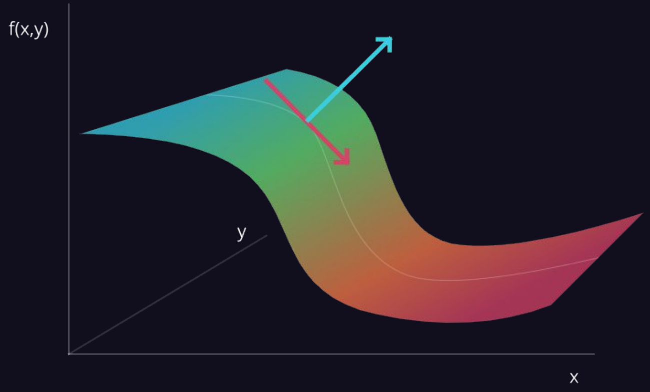
|03 OPTIMIZATION



GRADIENTS

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

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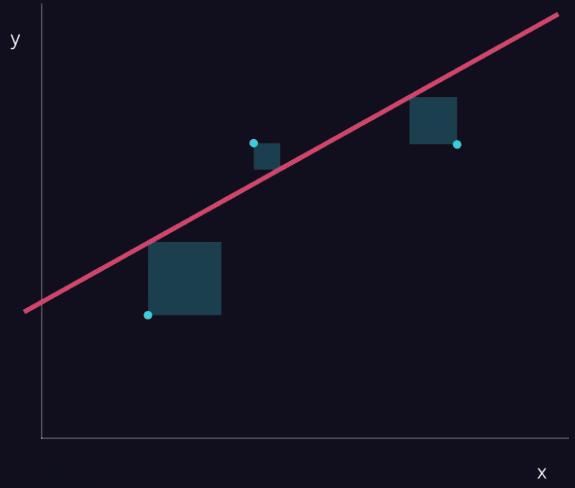
|03 OPTIMIZATION



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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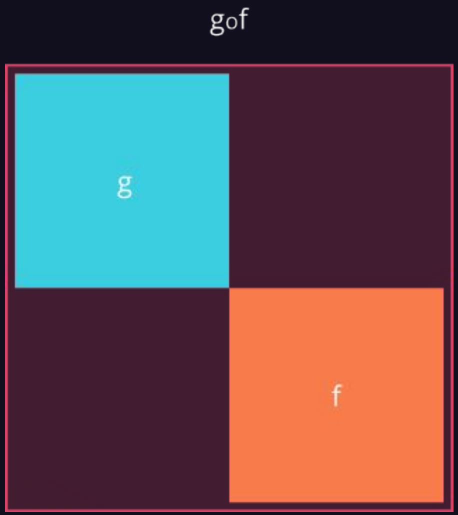
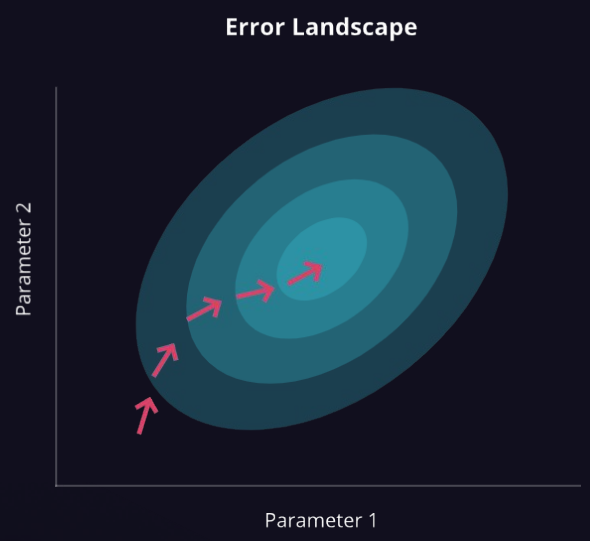


CHAIN RULE

$$h = g \circ f$$

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

|03 OPTIMIZATION



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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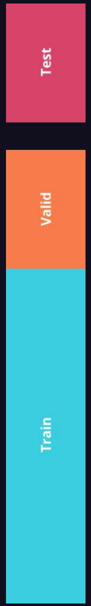

DATASET SPLIT

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

Iteration 1	Valid	Train	Train	Train
Iteration 2	Train	Valid	Train	Train
Iteration 3	Train	Train	Valid	Train
Iteration 4	Train	Train	Train	Valid
	Fold 1	Fold 2	Fold 3	Fold 4

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