SNGULAR

A financial fraud predictive AI model integrated with Spring Boot.

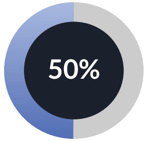
Predictive Model for Financial Industry

Contents:

- What is Machine Learning
- Key Concepts
- Supervised Learning Process
- Anomaly Detection
- Example:
  - Data Analysis
  - Logistic Regression
  - Support Vector Machine
  - Decision Tree Classifier

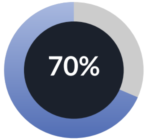
Fraud in Bank Industry in 2024

More than half banks reported an increase in business fraud.



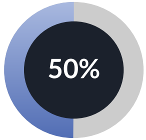
Increase of frauds

Check fraud losses in the Americas reached nearly $21 billion, and 70% of U.S. financial institutions reported check fraud.



Check Fraud

Over half report increasing investment in third-party fraud prevention.

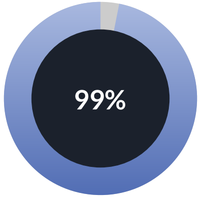


Increase of Investment

- *Thompson Reuters, Deloitte, and the Federal Trade Commission (FTC) https://www.alloy.com/state-of-fraud-benchmark-report-2024#component-marketo-embed*
- *SEC. (n.d.). https://www.sec.gov/files/fy24-oiad-sar-objectives-report.pdf*

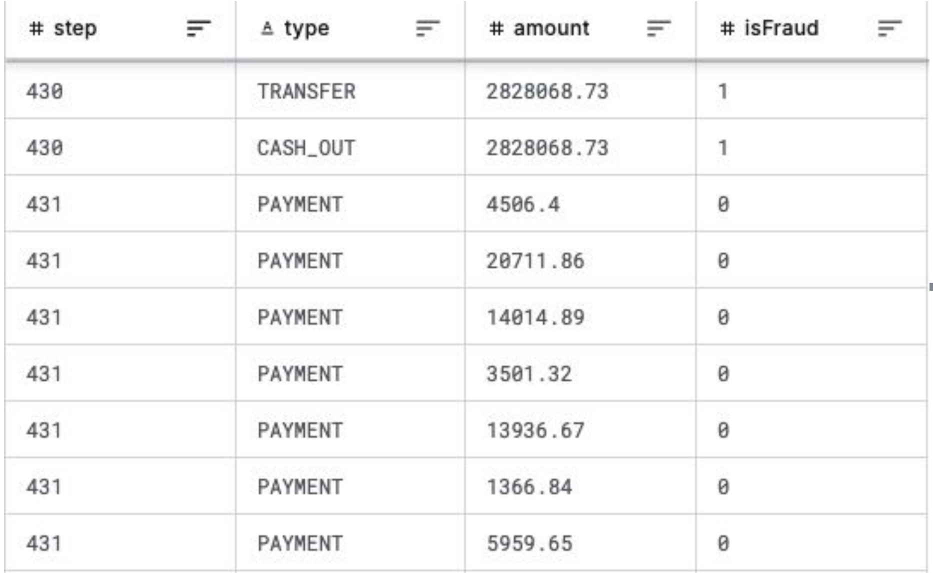
Preview Results

The predictive model obtained 99% of precision, detecting more than 13,500 frauds within one month transaction dataset.

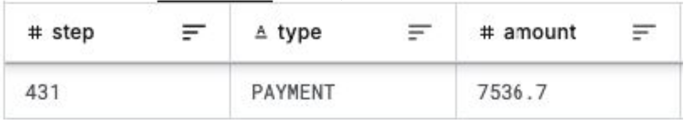


Detection of
Frauds

What is the best approach?



# step	A type	# amount	# isFraud
430	TRANSFER	2828068.73	1
430	CASH_OUT	2828068.73	1
431	PAYMENT	4506.4	0
431	PAYMENT	20711.86	0
431	PAYMENT	14014.89	0
431	PAYMENT	3501.32	0
431	PAYMENT	13936.67	0
431	PAYMENT	1366.84	0
431	PAYMENT	5959.65	0



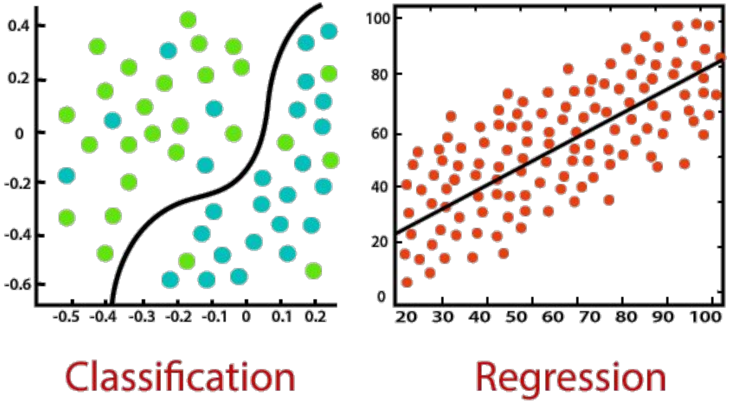
# step	A type	# amount
431	PAYMENT	7536.7

What is the best approach?

What is the best approach?

Machine learning

What Machine Learning(ML) is

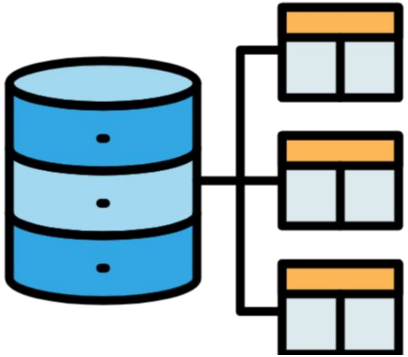


It’s a sub-topic of Artificial Intelligence field, which is focused on predicting data, through information patterns.

It learns from data to enhance automation of decision making.

ML doesn’t implement hard-coded rules. Instead, it predicts data from unseen information.

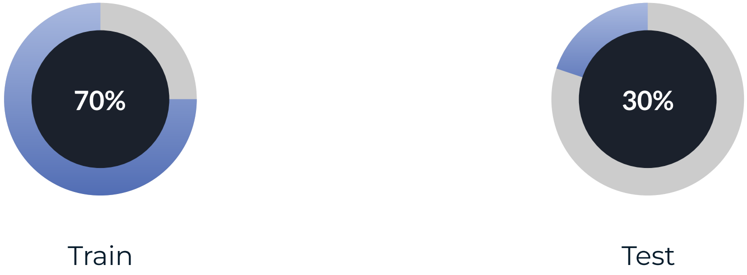
Data



01 The more data, the better.

02 Data format can be numbers, text, images, sounds.

03 It is divided into training (used to teach the model) and test (used to evaluate the model).



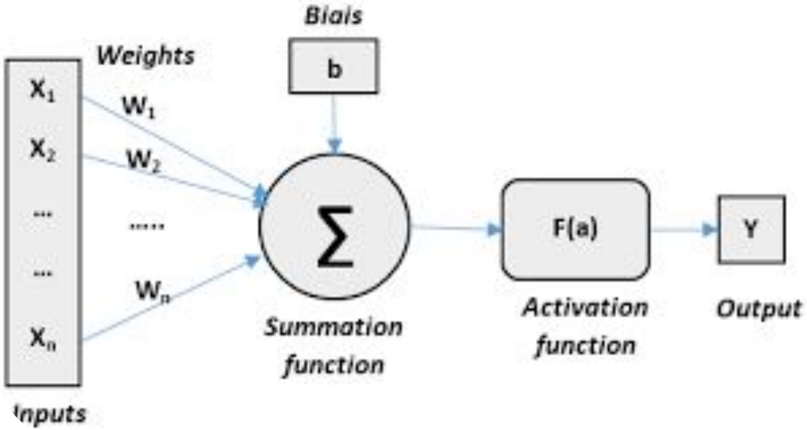
Model

01 Mathematical representation that learns from data.

02 Models capture data patterns and relationships to make predictions and decisions.

03 Typical models are:

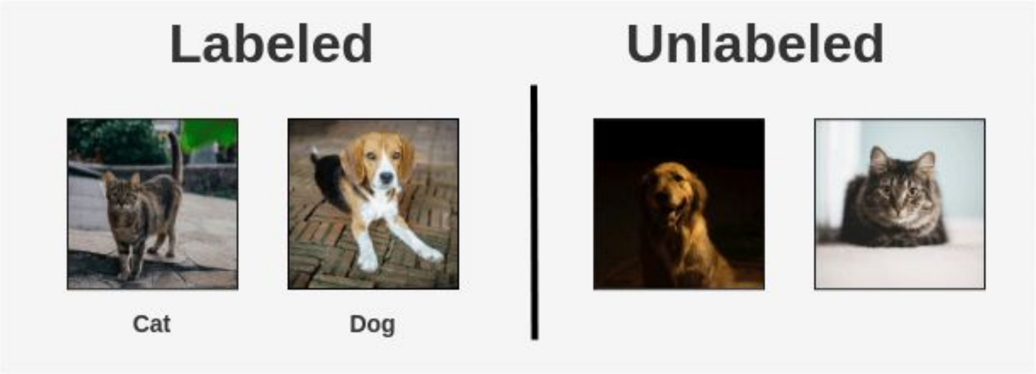
- Logistic Regression
- Support Vector Machine
- Neural Networks, etc.



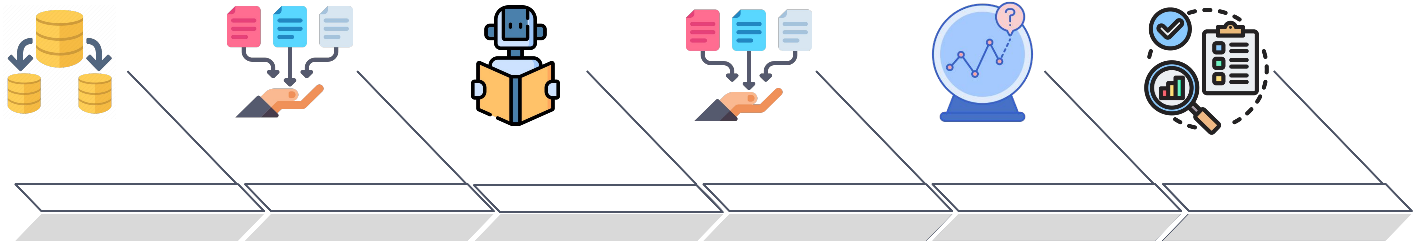
Training & Prediction

01 Training is teaching mathematical model to recognize patterns in data.

02 Data can be labeled(supervised learning) or unlabeled(unsupervised learning).



Supervised Learning Process



Split Data

Training (70%)

Testing (30%)

Provide Training Data

Training data which is labeled

Train Model

Train with labeled data

Provide Testing Data

Testing data which is unlabeled

Predict Labels

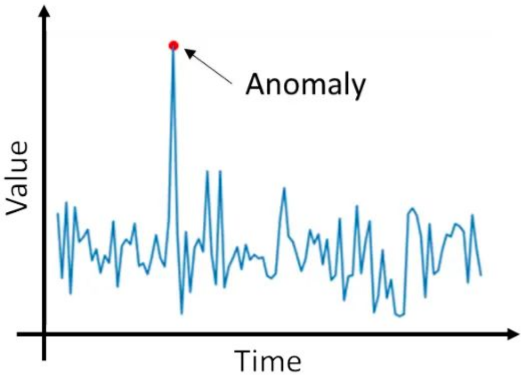
Prediction of labels based on training data

Validate model

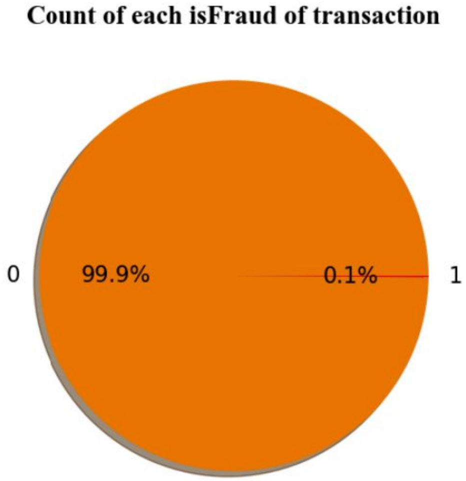
Compare predicted labels with actual labels

Anomaly Detection

Outliers



Machine learning model used to detect outliers in extreme unbalanced datasets, usually big enough to consider high-demand computational processing.



Unbalanced dataset over 24 million

Anomaly Detection Use Cases

01

Financial Fraud:

Identifying unusual spending patterns on credit cards to detect fraudulent transactions.

02

Healthcare Monitoring:

Identifying unusual vital signs in patient data that could indicate a medical emergency.

03

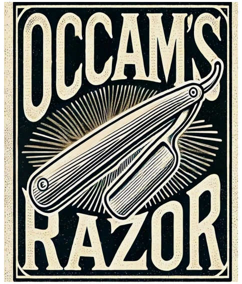
Retail Sales Analysis:

Identifying sudden spikes or drops in sales for specific products that could indicate issues with pricing or demand.

Theoretical Explanation of Data Preprocessing

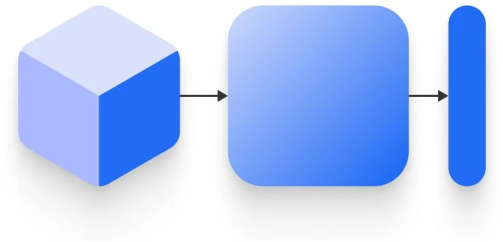
Descriptive and Inferential analysis

Need to know what the behind data.



Occam's Razor

Problem-solving principle that states the simplest explanation is usually the best.



Dimensional Reduction

Reduce feature or variables of the dataset. Retaining its most important properties.

Data Description

“PaySim is a financial simulator that simulates mobile money transactions based on an original dataset.”

The dataset has 24 million financial records.

E. A. Lopez-Rojas, A. Elmir, and S. Axelsson. "PaySim: A financial mobile money simulator for fraud detection". In: The 28th European Modeling and Simulation Symposium-EMSS, Larnaca, Cyprus. 2016

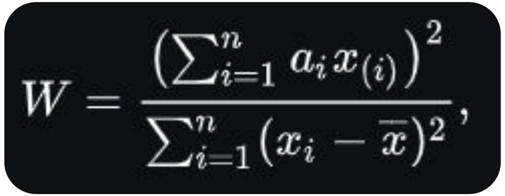
Dataset Fields

- **step:** Represents a unit of time in the real world, with 1 step equating to 1 hour.
- **type:** Transaction types include CASH-IN, CASH-OUT, DEBIT, PAYMENT, and TRANSFER.
- **amount:** The transaction amount in the local currency.
- **nameOrig:** The customer initiating the transaction.
- **oldbalanceOrg:** The initial balance before the transaction.
- **newbalanceOrig:** The new balance after the transaction.
- **nameDest:** Transaction's recipient customer.
- **oldbalanceDest:** The initial recipient's balance before the transaction.
- **newbalanceDest:** The new recipient's balance after the transaction.
- **isFraud:** Identifies transactions conducted by fraudulent agents aiming to deplete customer accounts through transfers and cash-outs.

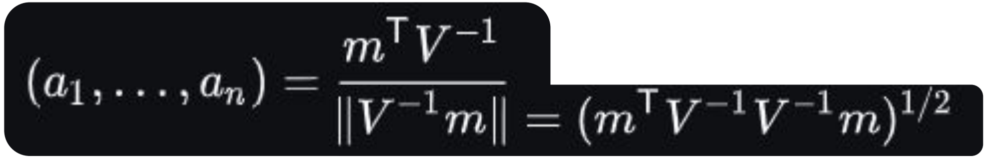
Dimensional Reduction

Feature Selection:

Shapiro-Wilk test to determine null hypothesis - > not normal distribution. > 0.05 confidence level:



$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n} (x_i - \overline{x})^2},$$



$$(a_1, \ldots, a_n) = \frac{m^\mathsf{T} V^{-1}}{\|V^{-1} m\|} = (m^\mathsf{T} V^{-1} V^{-1} m)^{1/2}$$

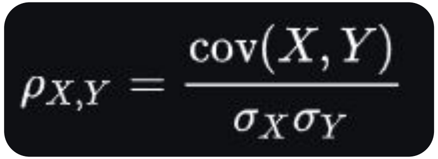
V: Variance Covariance Matrix
m: x

Dimensional Reduction

Feature Selection:

Pearson Correlation: Correlation between two normal distributed variables.

Coefficient correlation: -1 to 1



$$\rho_{X,Y} = \frac{\mathrm{cov}(X,Y)}{\sigma_X \sigma_Y}$$

Theta : Standard Deviation

Cov : Variance Covariance Matrix

Dimensional Reduction

Feature Selection:

Spearman Correlation: Correlation between two non-normal distributed variables.

Coefficient correlation: -1 to 1

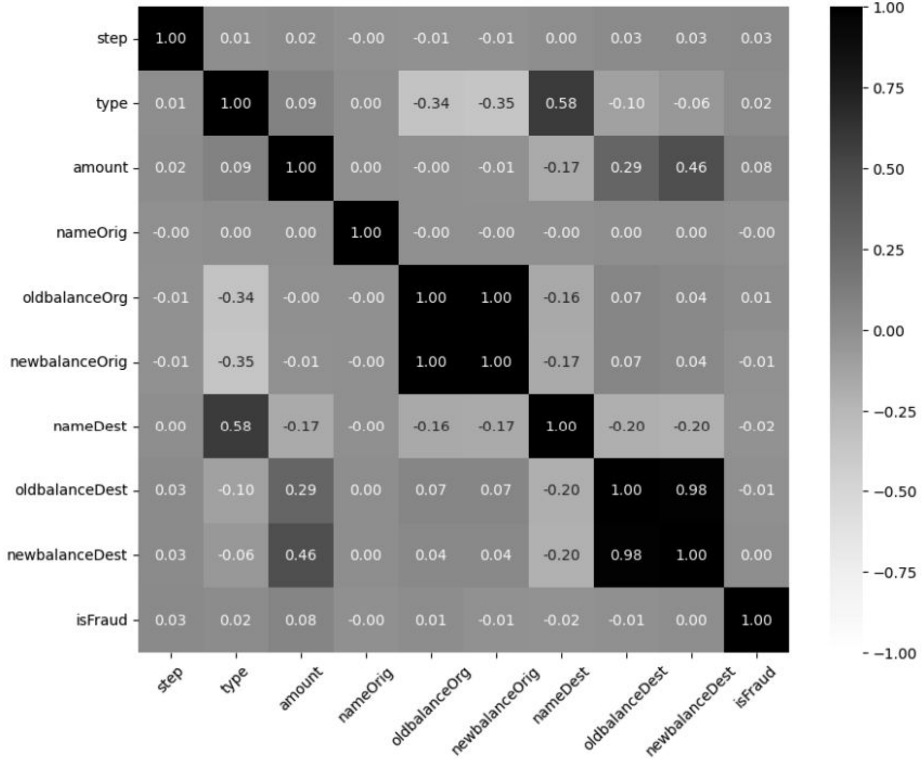
$$r_s = \rho\left[\,\mathrm{R}[X], \mathrm{R}[Y]\,\right] = \frac{\operatorname{cov}\left[\,\mathrm{R}[X], \mathrm{R}[Y]\,\right]}{\sigma_{\mathrm{R}[X]}\,\sigma_{\mathrm{R}[Y]}},$$

$\operatorname{cov}\left[\,\mathrm{R}[X], \mathrm{R}[Y]\,\right]$: Covariance of ranked variables

$\sigma_{\mathrm{R}[X]}\,\sigma_{\mathrm{R}[Y]}$: Standard Deviation

Dimensional Reduction

Pearson Correlation Matrix



	step	type	amount	nameOrig	oldbalanceOrg	newbalanceOrig	nameDest	oldbalanceDest	newbalanceDest	isFraud
step	1.00	0.01	0.02	-0.00	-0.01	-0.01	0.00	0.03	0.03	0.03
type	0.01	1.00	0.09	0.00	-0.34	-0.35	0.58	-0.10	-0.06	0.02
amount	0.02	0.09	1.00	0.00	-0.00	-0.01	-0.17	0.29	0.46	0.08
nameOrig	-0.00	0.00	0.00	1.00	-0.00	-0.00	-0.00	0.00	0.00	-0.00
oldbalanceOrg	-0.01	-0.34	-0.00	-0.00	1.00	1.00	-0.16	0.07	0.04	0.01
newbalanceOrig	-0.01	-0.35	-0.01	-0.00	1.00	1.00	-0.17	0.07	0.04	-0.01
nameDest	0.00	0.58	-0.17	-0.00	-0.16	-0.17	1.00	-0.20	-0.20	-0.02
oldbalanceDest	0.03	-0.10	0.29	0.00	0.07	0.07	-0.20	1.00	0.98	-0.01
newbalanceDest	0.03	-0.06	0.46	0.00	0.04	0.04	-0.20	0.98	1.00	0.00
isFraud	0.03	0.02	0.08	-0.00	0.01	-0.01	-0.02	-0.01	0.00	1.00

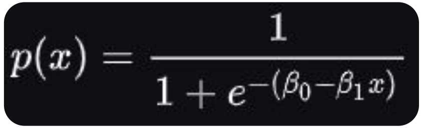
Spearman Correlation Matrix

Dimensional Reduction

Test Hypothesis

Logistic Regression: Relationship between two variables. Only applicable when dependent variable (y) is categorical, and independent variable (x) is continuous.

p-Value: 0 - 0.05 (confidence threshold)



$$p(x) = \frac{1}{1 + e^{-(\beta_0 - \beta_1 x)}}$$

Beta: Weight optimization parameter

Dimensional Reduction

Test Hypothesis

Chi-Square: Relationship between two variables. Only applicable when dependent variable (y) is categorical, and independent variable (x) is also categorical.

p-Value: 0 - 0.05 (confidence threshold)

$$\chi^2 = \sum_{i=1}^{n} \frac{O_i^2}{E_i} - N.$$

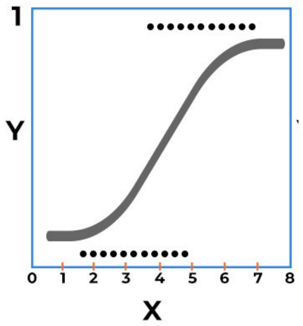
O_i: Number of observations of variable i

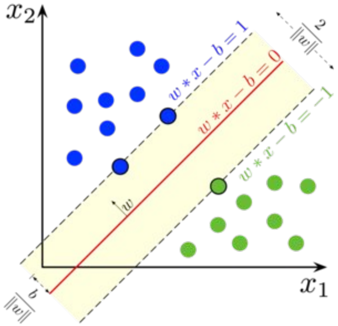
N: Total number of observations

E_i: Expected number of type i

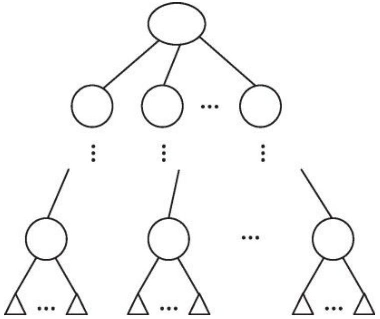
Theoretical Explanation of Predictive Models

Logistic Regression





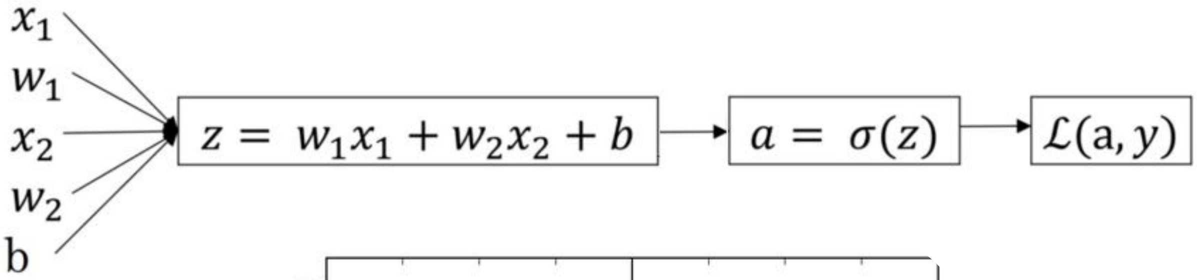
Support Vector Machine

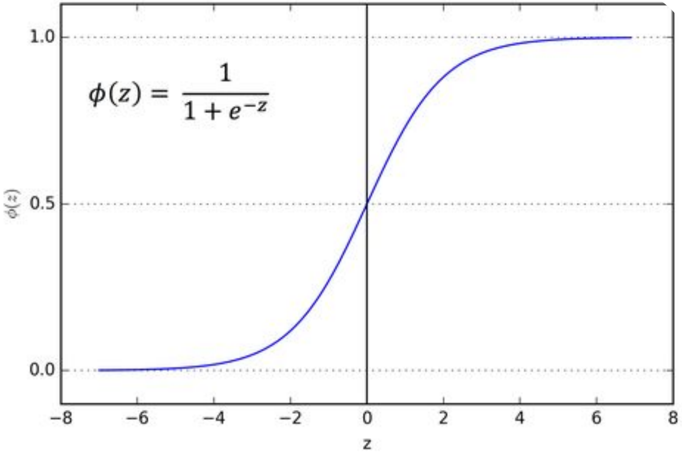


Decision Tree Classifier

Logistic Regression

Classification Function



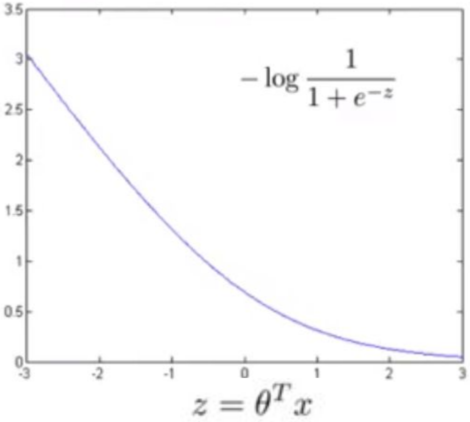


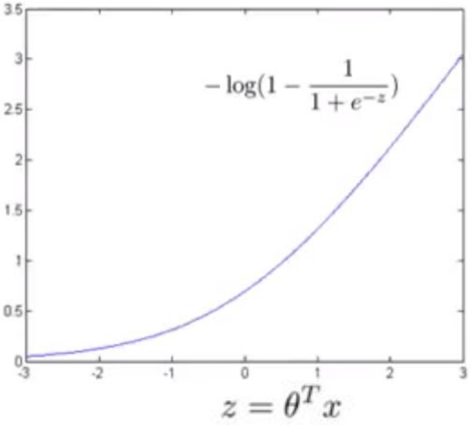
Sigmoid Function

Logistic Regression

Cost Optimization Function

$$\mathrm{Cost}(h_\theta(x), y) = -y \log \frac{1}{1+e^{-\theta^T x}} - (1-y)\log(1 - \frac{1}{1+e^{-\theta^T x}})$$

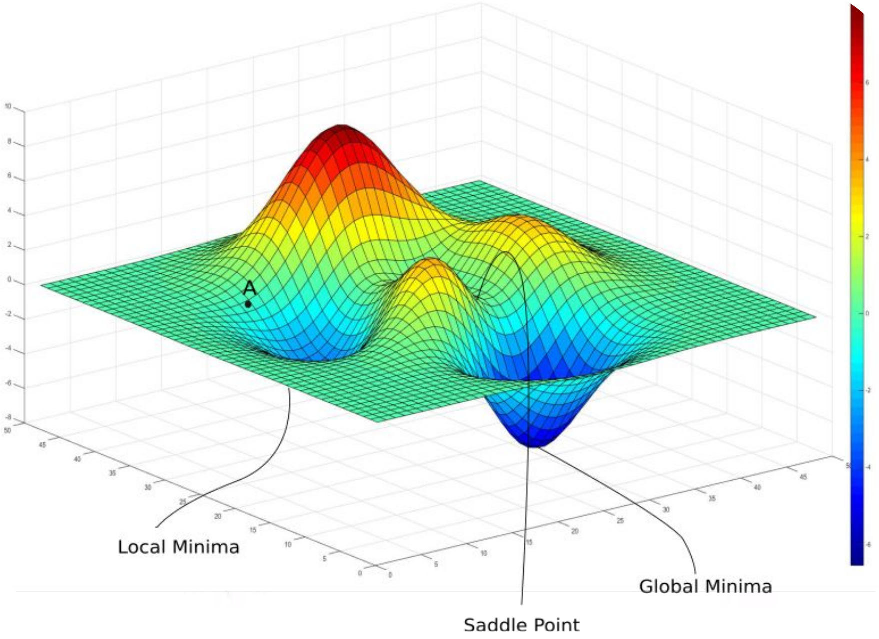




Logistic Regression

Cost Optimization Function

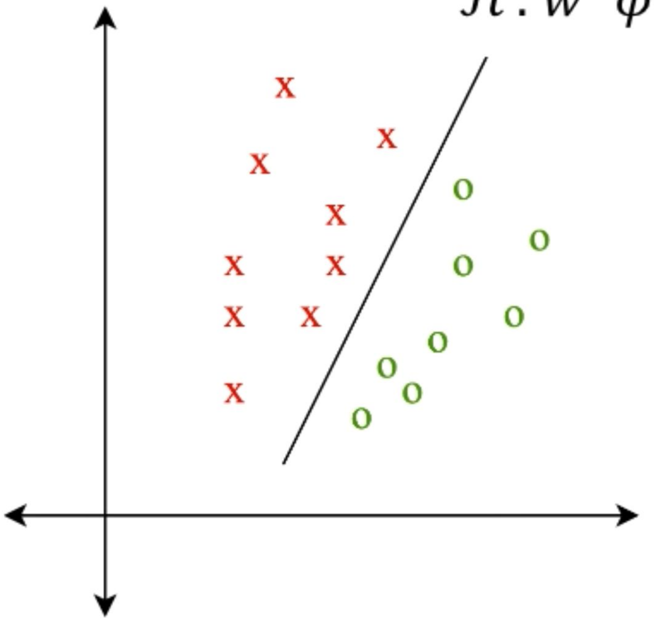
```
Repeat until convergence {
    $\theta_j \leftarrow \theta_j - \alpha \frac{\partial}{\partial \theta_j} J(\theta)$
}
```



Support Vector Machine

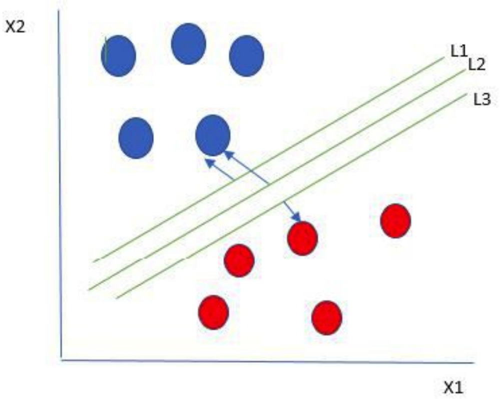
Classification Function Hyperplane Clasificator

$$\mathcal{H}: w^T\phi(x) + b = 0$$



Support Vector Machine

Optimization Function



$$d_{\mathcal{H}}(\phi(x_0)) = \frac{|w^T\phi(x_0) + b|}{\|w\|_2}$$

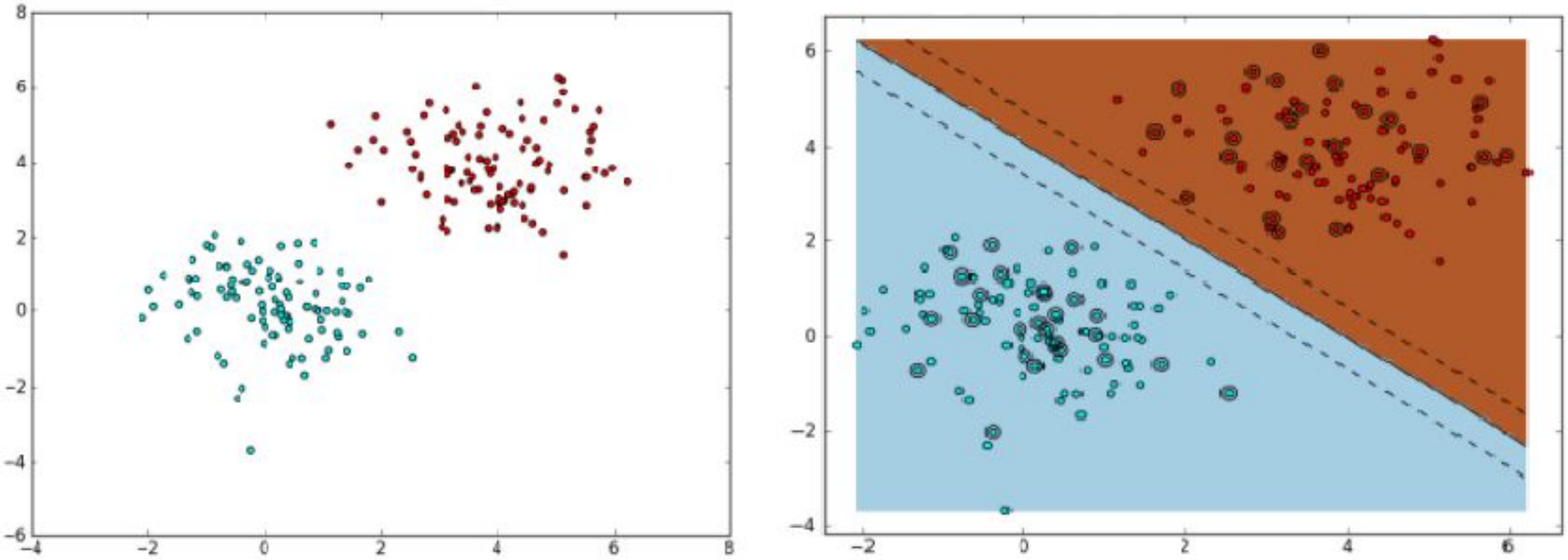
Distance of points from hyperplane

$$w^* = \arg\max_w \left[\min_n d_{\mathcal{H}}(\phi(x_n))\right]$$

Optimization function: Max distance of the hyperplane of the nearest point from the hyperplane

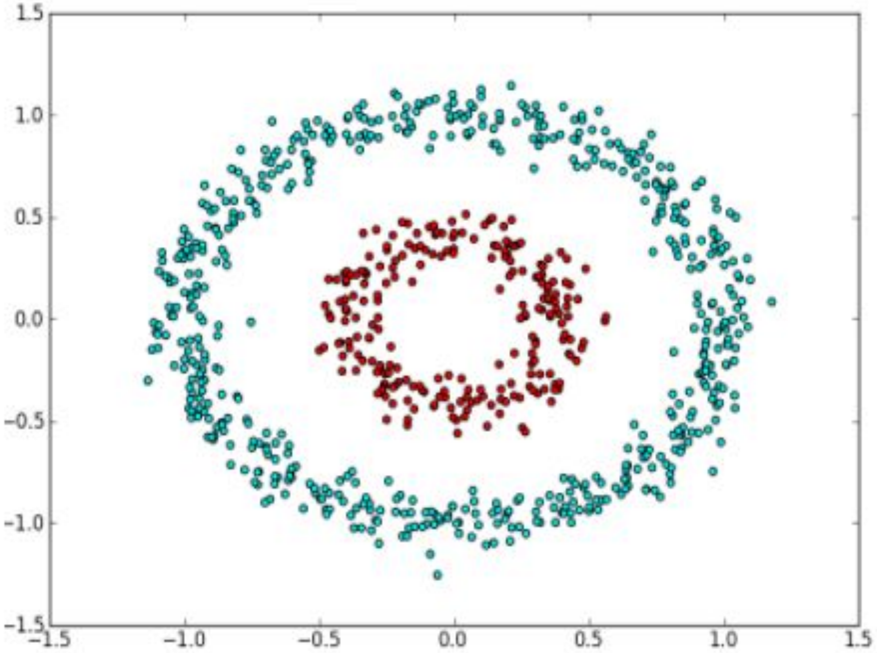
Support Vector Machine

Kernel



Support Vector Machine

Kernel

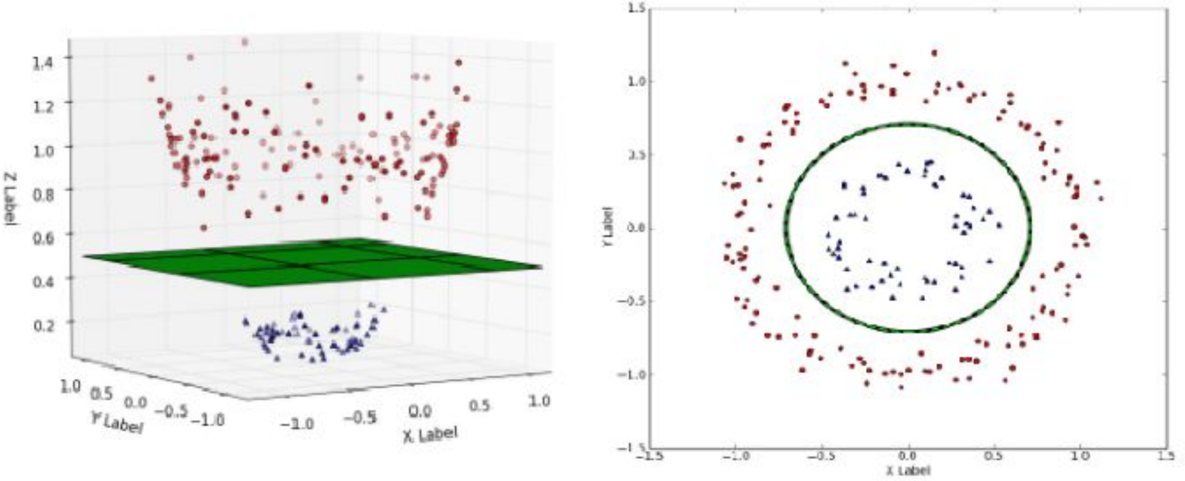


Support Vector Machine

Kernel

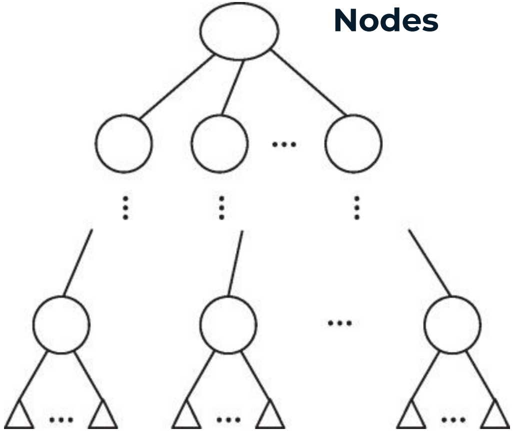
Lagrange Multipliers

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} \cdot \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} = x_1 y_1 + x_2 y_2 + x_3 y_3 \,.$$



Hilbert Space

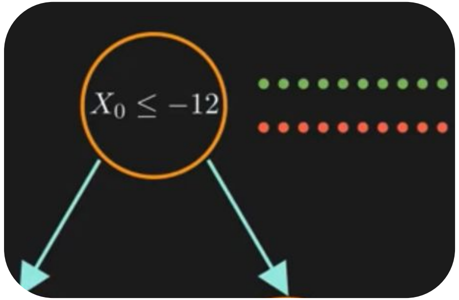
Decision Tree Classifier - Tree Creation



Nodes

Leaves

Classifications

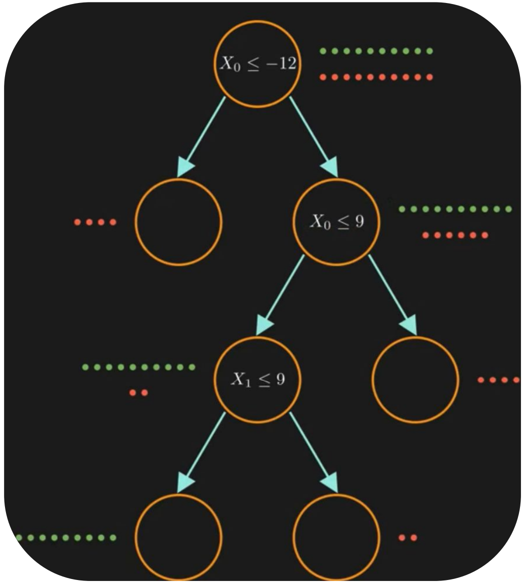


Leaves and nodes randomly generated through seeds mechanism:

$$R_{i+1} = (a \cdot R_i + c) \mod m,$$

Where
Ri *is current state*
a, c , m *are random numbers generated*

Decision Tree Classifier - Evaluation Per Node



Gini Index

$$I(D_{\text{node}}) = 1 - \sum_{c=1}^{C} p_c^2,$$

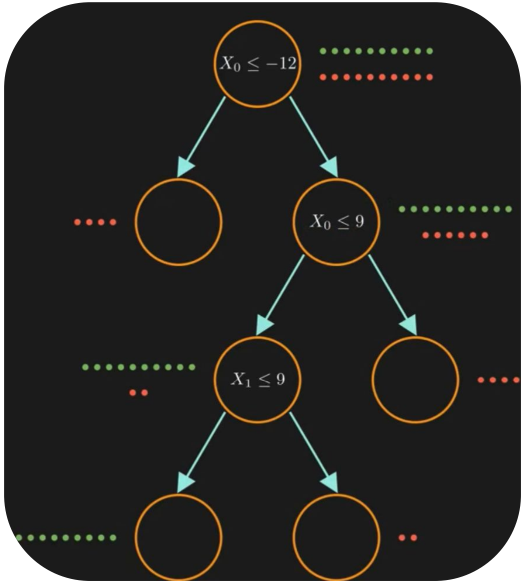
Entropy

$$I(D_{\text{node}}) = -\sum_{c=1}^{C} p_c \log(p_c),$$

Where

Pc *is the proportion of samples c, which belongs to Dnode*

Decision Tree Classifier - Evaluation Horizontally



Gini Index

$$\text{Information Gain} = I(D_{\text{node}}) - \left(\frac{|D_{\text{left}}|}{|D_{\text{node}}|} I(D_{\text{left}}) + \frac{|D_{\text{right}}|}{|D_{\text{node}}|} I(D_{\text{right}}) \right),$$

Where

Dleft and Dright *are the data subsets resulting from the split.*
*|**D**| denotes the number of samples in DDD*

Implementation

01 Inferential Analysis.

02 Data Preparation.

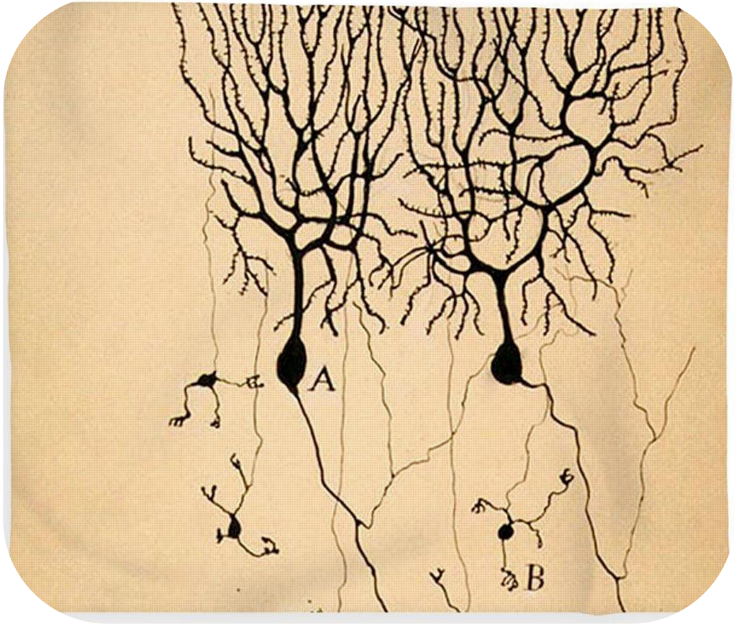
03 Implementation of Logistic Regression.

04 Implementation of Support Vector Machine.

05 Decision Tree Classifier

06 Spring Boot Integration.

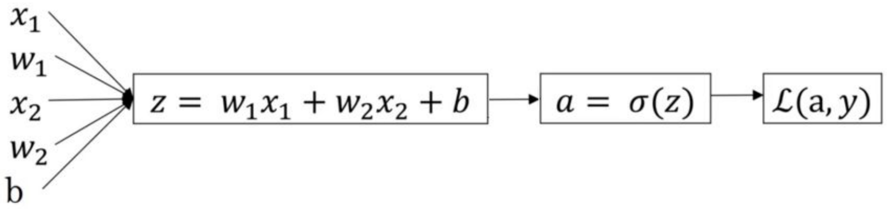
Bonus



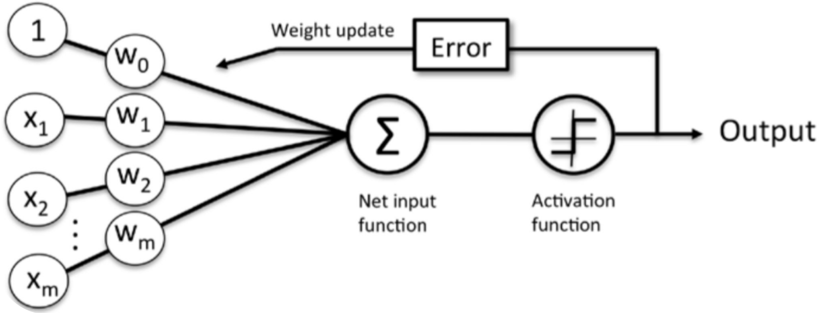
Modelo Neuronal - Santiago Ramon y Cajal (1906)

Bonus

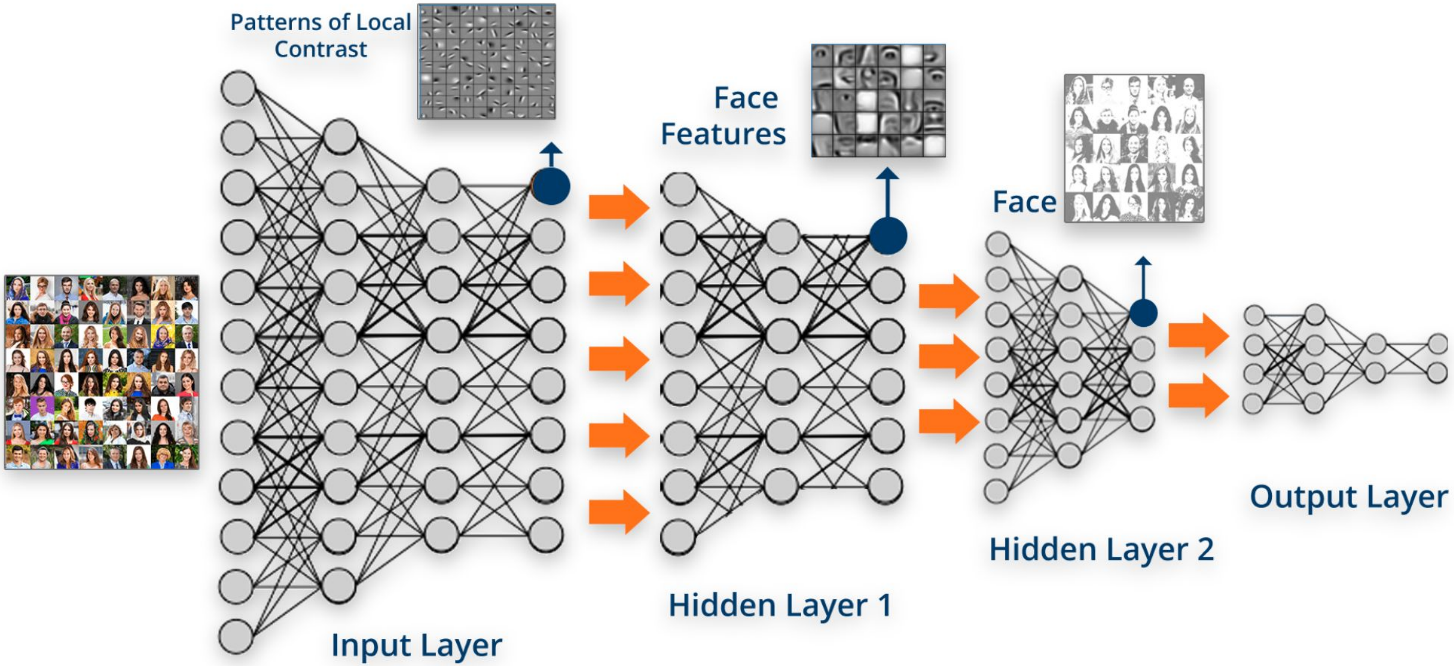
Logistic Regression Function



Neuron Model



Bonus


Patterns of Local Contrast
Face Features
Face
Input Layer
Hidden Layer 1
Hidden Layer 2
Output Layer

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Questions

Thanks for your attention!!!