Perceptron, Logistic Regression, and Artificial Neural Networks

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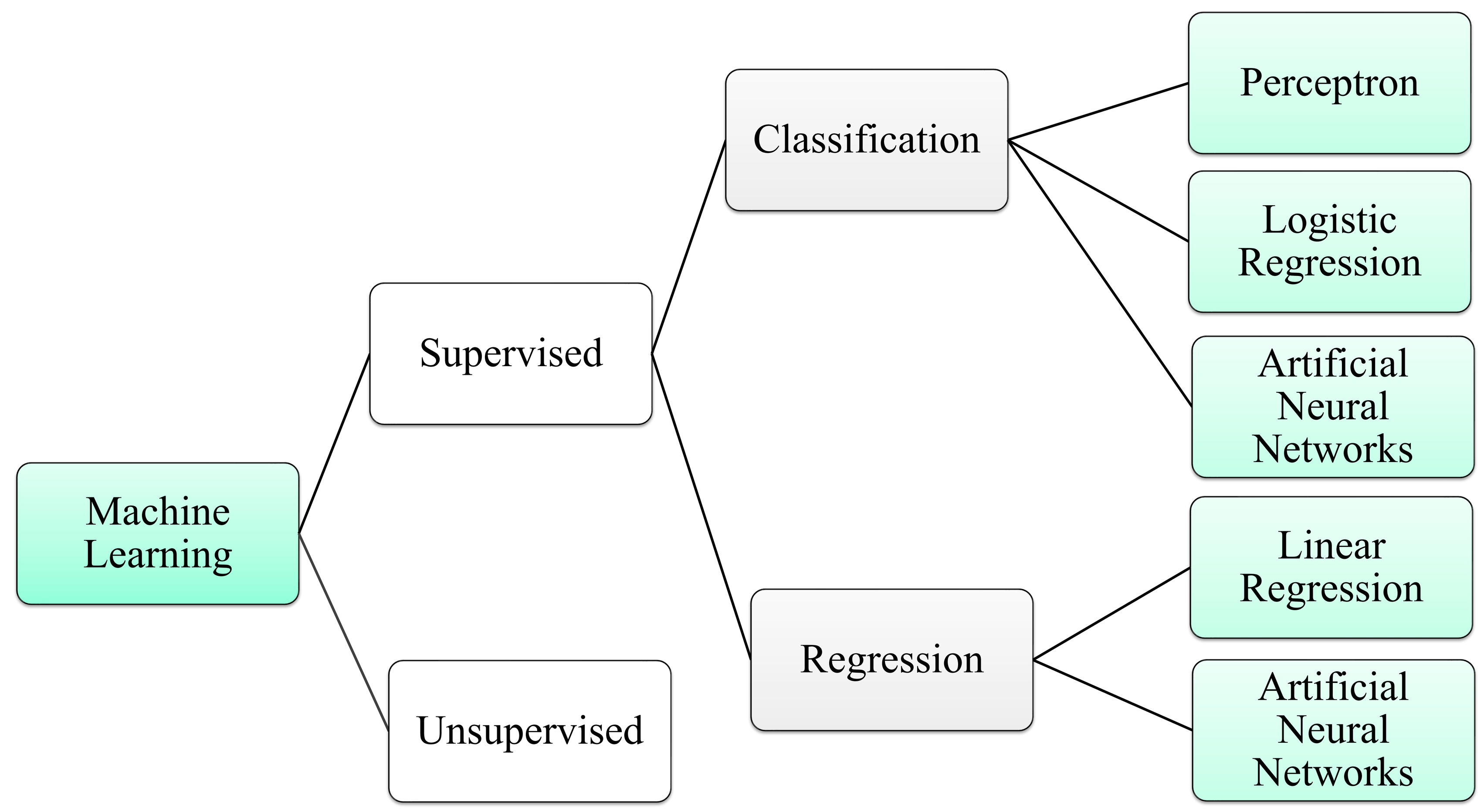
Abstract

The main goal of this research is to analyze and compare several machine learning algorithms for classification including Perceptron, Logistic Regression, and Artificial Neural Networks. Perceptron algorithm and Logistic Regression are a single neuron model with different activation functions. The activation function for Perceptron is the sign function to make predictions for a binary outcome. The predicted output in perceptron is a hard label with discrete values -1 and +1. Sigmoid function is the activation function for Logistic Regression to make predictions in the range from 0 to 1. The predicted value is considered the probability of a data instance belonging to the positive class. Compared to Perceptron, Logistic Regression uses a continuous function as an activation function and it gives a probability value as the predicted output. Artificial Neural Networks usually contain hidden layers of neurons where we have different activation functions. These algorithms have important applications in our daily lives including banking and financial systems, businesses and economics, cybersecurity, medicine and healthcare, and many other fields. By understanding these algorithms and how they are used on big data sets, we can develop more practical and efficient approaches for data analysis and predictions.

Introduction

Two main kinds of Machine Learning are supervised and unsupervised machine learning. While unsupervised machine learning models are based on data without outputs, supervised machine learning has a targeted set of outputs. In supervised machine learning, there are two main types: classification and regression. The outputs in classification are discrete values with hard labels. The outputs in regression consist of continuous numerical values. In our project, we focus on classification machine learning models including perceptron, logistic regression, and artificial neural networks.

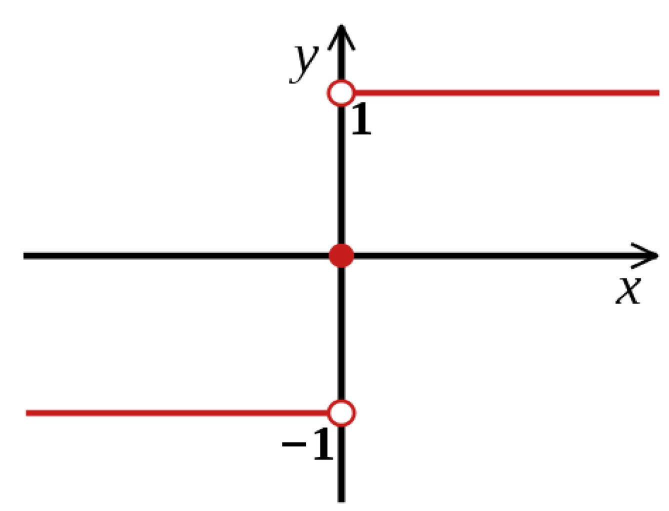


Perceptron

The hypothesis function

$$\hat{y} = h(x_1, x_2, ..x_d)$$
$$= sign(w_1x_1 + w_2x_2 + \cdots + w_d\, x_d + w_0)$$

$$sign(x) = \begin{cases} -1 & if \;\; x < 0 \\ 0 & if \;\; x = 0 \\ +1 & if \;\; x > 0 \end{cases}$$

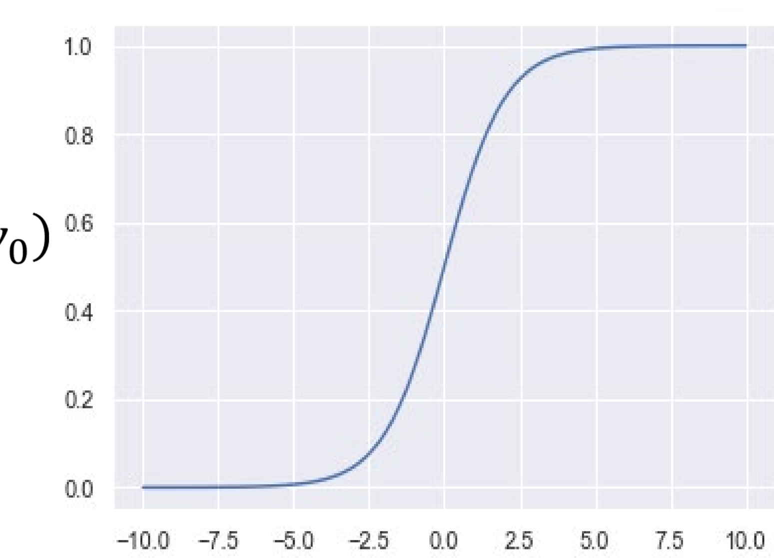


Logistic Regression

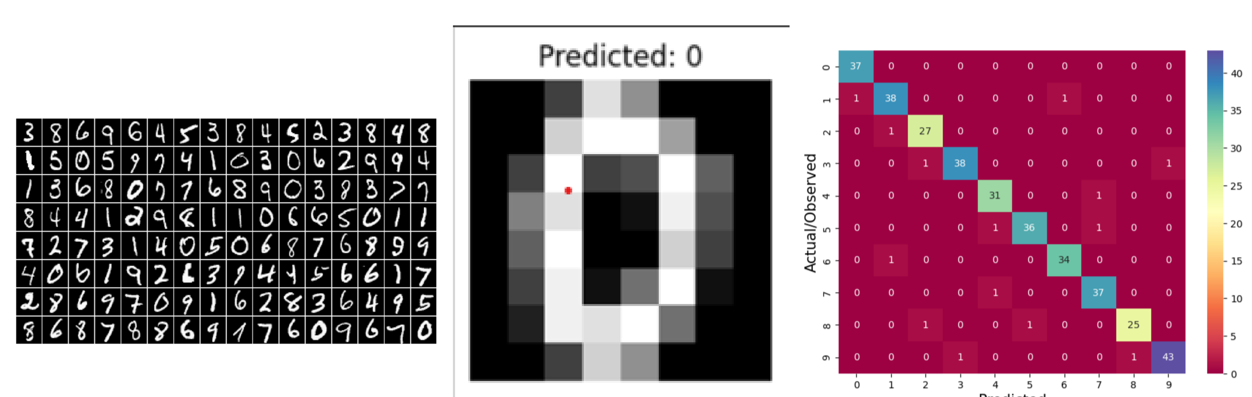
The hypothesis function

$$\hat{y} = h(x_1, x_2, ..x_d)$$
$$= sigmoid(w_1x_1 + w_2x_2 + \cdots + w_d\, x_d + w_0)$$

$$sigmoid(x) = \frac{1}{1 + e^{-x}}$$



Logistic Regression Example - MNIST Handwritten Digits Data Set



	precision	recall	f1-score	support
0	0.97	1.00	0.99	37
1	0.95	0.95	0.95	40
2	0.93	0.96	0.95	28
3	0.97	0.95	0.96	40
4	0.94	0.97	0.95	32
5	0.97	0.95	0.96	38
6	0.97	0.97	0.97	35
7	0.95	0.97	0.96	38
8	0.96	0.93	0.94	27
9	0.98	0.96	0.97	45
accuracy			0.96	360
macro avg	0.96	0.96	0.96	360
weighted avg	0.96	0.96	0.96	360

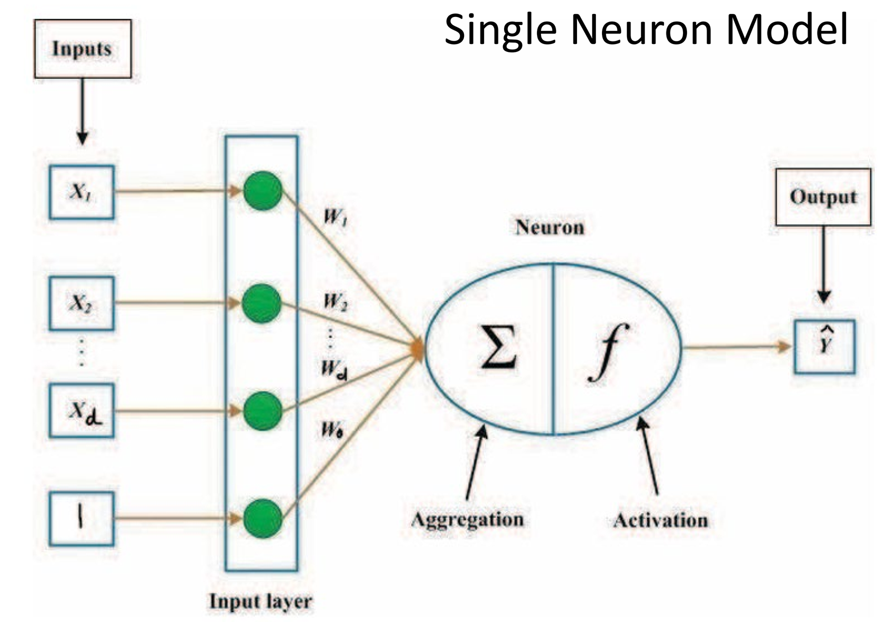
https://colab.research.google.com/drive/10GfkOwxPDrbI6PVdt9hkwoOt343zX1bR?usp=sharing

	x_1	x_2	…	x_d	y	$\hat{y}$
1						
2						
…						
n						

(n observations and d features, actual and predicted outputs)

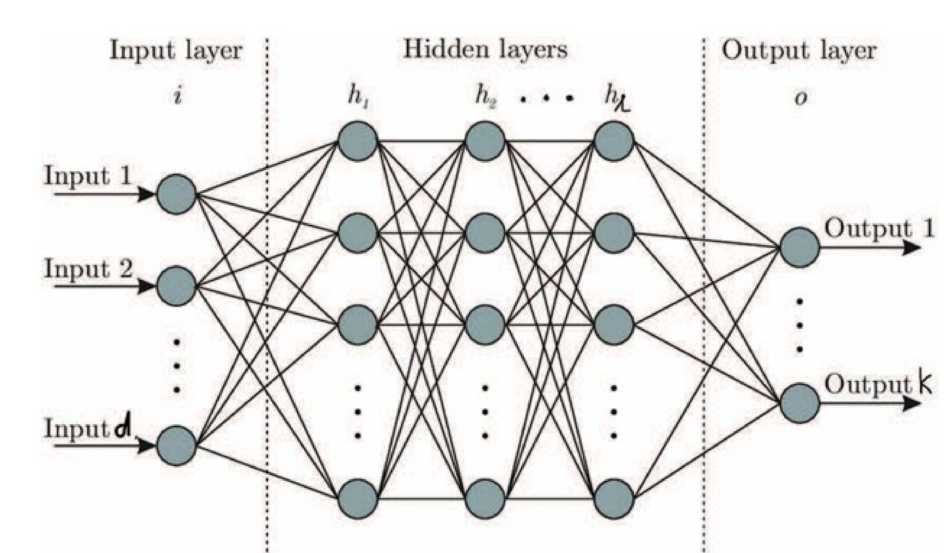
Artificial Neural Networks

Single Neuron Model

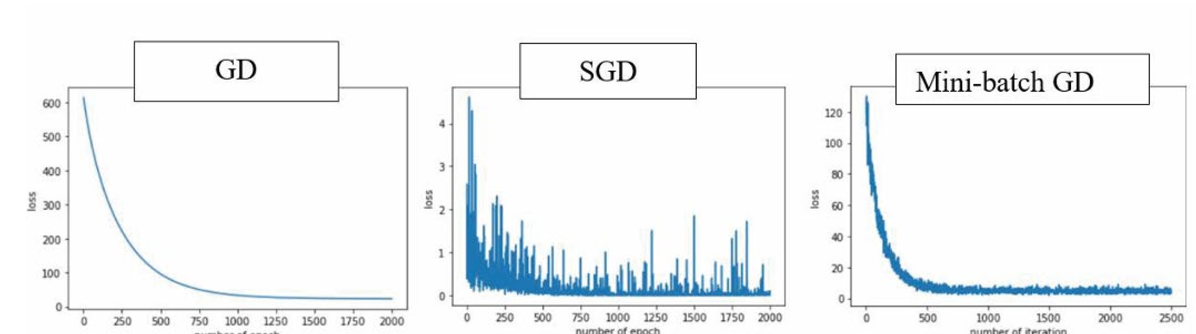


https://www.researchgate.net/figure/A-single-artificial-neuron-perceptron fig3 319857496

Multilayer Neural Networks



https://www.researchgate.net/figure/Artificial-neural-network-architecture-ANN-i-h-1-h-2-h-n-o fig1 321259051



https://towardsdatascience.com/deep-learning-optimizers-436171c9e23f
GD: Gradient Descent, SGD: Stochastic GD.

Future Work

- Study other classification machine learning models
- Apply models to other applications (text data)

References

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Jegdic, K. Lecture Notes 6. Logistic Regression.
Jegdic, K. Lecture Notes 8. Artificial Neural Networks.

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