App Physics 157

MACHINE LEARNING

Perceptron & Logistic Regression

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Background
Machine Learning

Machine learning is an application of artificial intelligence that uses statistical techniques to enable computers to learn and make decisions without being explicitly programmed. It is predicated on the notion that computers can learn from data, spot patterns, and make judgments with little assistance from humans.

It is a subset of Artificial Intelligence. It is the study of making machines more human-like in their behavior and decisions by giving them the ability to learn and develop their own programs. This is done with minimum human intervention, i.e., no explicit programming. The learning process is automated and improved based on the experiences of the machines throughout the process.

Good quality data is fed to the machines, and different algorithms are used to build ML models to train the machines on this data. The choice of algorithm depends on the type of data at hand and the type of activity that needs to be automated.

WHAT IS MACHINE LEARNING [1]

1. **A Decision Process:** In general, machine learning algorithms are used to make a prediction or classification. Based on some input data, which can be labeled or unlabeled, your algorithm will produce an estimate about a pattern in the data.
2. **An Error Function:** An error function evaluates the prediction of the model. If there are known examples, an error function can make a comparison to assess the accuracy of the model.
3. **A Model Optimization Process:** If the model can fit better to the data points in the training set, then weights are adjusted to reduce the discrepancy between the known example and the model estimate. The algorithm will repeat this "evaluate and optimize" process, updating weights autonomously until a threshold of accuracy has been met.

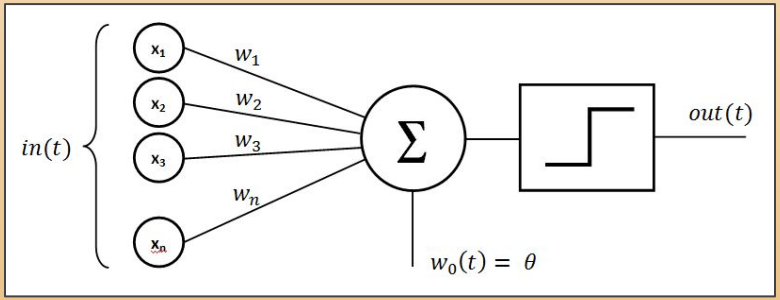
HOW MACHINE LEARNING WORKS [2]

1. **Supervised learning:** In this type of machine learning, data scientists supply algorithms with labeled training data and define the variables they want the algorithm to assess for correlations. Both the input and the output of the algorithm is specified.
2. **Unsupervised learning:** This type of machine learning involves algorithms that train on unlabeled data. The algorithm scans through datasets looking for any meaningful connection. The data that algorithms train on as well as the predictions or recommendations they output are predetermined.
3. **Semi-supervised learning:** This approach to machine learning involves a mix of the two preceding types. Data scientists may feed an algorithm mostly labeled training data, but the model is free to explore the data on its own and develop its own understanding of the data set.
4. **Reinforcement learning:** Data scientists typically use reinforcement learning to teach a machine to complete a multi-step process for which there are clearly defined rules. Data scientists program an algorithm to complete a task and give it positive or negative cues as it works out how to complete a task. But for the most part, the algorithm decides on its own what steps to take along the way.

TYPES OF MACHINE LEARNING [3]

Background
Perceptron

Perceptron was introduced by Frank Rosenblatt in 1957. He proposed a Perceptron learning rule based on the original MCP neuron. A Perceptron is an algorithm for supervised learning of binary classifiers that enables neurons to learn and process elements in the training set one at a time. Moreover, it is a neural network link that contains computations to track features and uses Artificial Intelligence in the input data. This neural links to the artificial neurons using simple logic gates with binary outputs. An artificial neuron invokes the mathematical function and has node, input, weights, and output equivalent to the cell nucleus, dendrites, synapse, and axon, respectively, compared to a biological neuron.



WHAT IS PERCEPTRON [4]

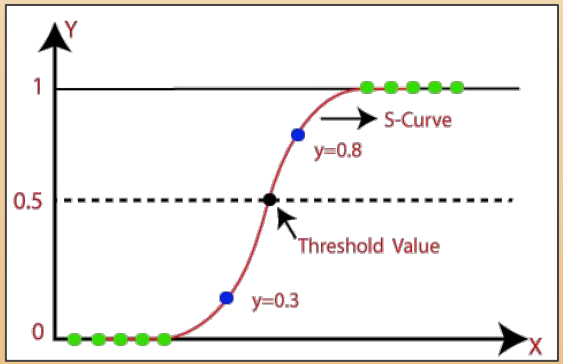
1. **Input Layer:** The input layer consists of one or more input neurons, which receive input signals from the external world or from other layers of the neural network.
2. **Weights:** Each input neuron is associated with a weight, which represents the strength of the connection between the input neuron and the output neuron.
3. **Bias:** A bias term is added to the input layer to provide the perceptron with additional flexibility in modeling complex patterns in the input data.
4. **Activation Function:** The activation function determines the output of the perceptron based on the weighted sum of the inputs and the bias term. Common activation functions used in perceptrons include the step function, sigmoid function, and ReLU function.
5. **Output:** The output of the perceptron is a single binary value, either 0 or 1, which indicates the class or category to which the input data belongs.
6. **Training Algorithm:** The perceptron is typically trained using a supervised learning algorithm such as the perceptron learning algorithm or backpropagation. During training, the weights and biases of the perceptron are adjusted to minimize the error between the predicted output and the true output for a given set of training examples.

COMPONENTS OF PERCEPTRON [4]

Background
Logistic Regression

Logistic regression is one of the most popular Machine Learning algorithms, which comes under the Supervised Learning technique. It is used for predicting the categorical dependent variable using a given set of independent variables. Therefore the outcome must be a categorical or discrete value. It can be either Yes or No, 0 or 1, true or False, etc., but instead of giving the exact value as 0 and 1, it gives the probabilistic values which lie between 0 and 1.

In Logistic regression, instead of fitting a regression line, we fit an "S" shaped logistic function, which predicts two maximum values (0 or 1). The curve from the logistic function indicates the likelihood of something such as whether the cells are cancerous or not, a mouse is obese or not based on its weight, etc.



WHAT IS LOGISTIC REGRESSION [5]

TYPES OF LOGISTIC REGRESSION [6]

1. **Binary logistic regression:** When we have two possible outcomes, like our original example of whether a person is likely to be infected with COVID-19 or not.

2. **Multinomial logistic regression:** When we have multiple outcomes, say if we build out our original example to predict whether someone may have the flu, an allergy, a cold, or COVID-19.

3. **Ordinal logistic regression:** When the outcome is ordered, like if we build out our original example to also help determine the severity of a COVID-19 infection, sorting it into mild, moderate, and severe cases.

Objective Perceptron

Procedure

1. Using your fruit feature data, take 2 classes at a time and compute the decision surface between the two classes using the perceptron algorithm.
2. Plot your data in feature space and overlay the decision line. To draw the decision line, note that an alternative form of the equation of the line is given by:

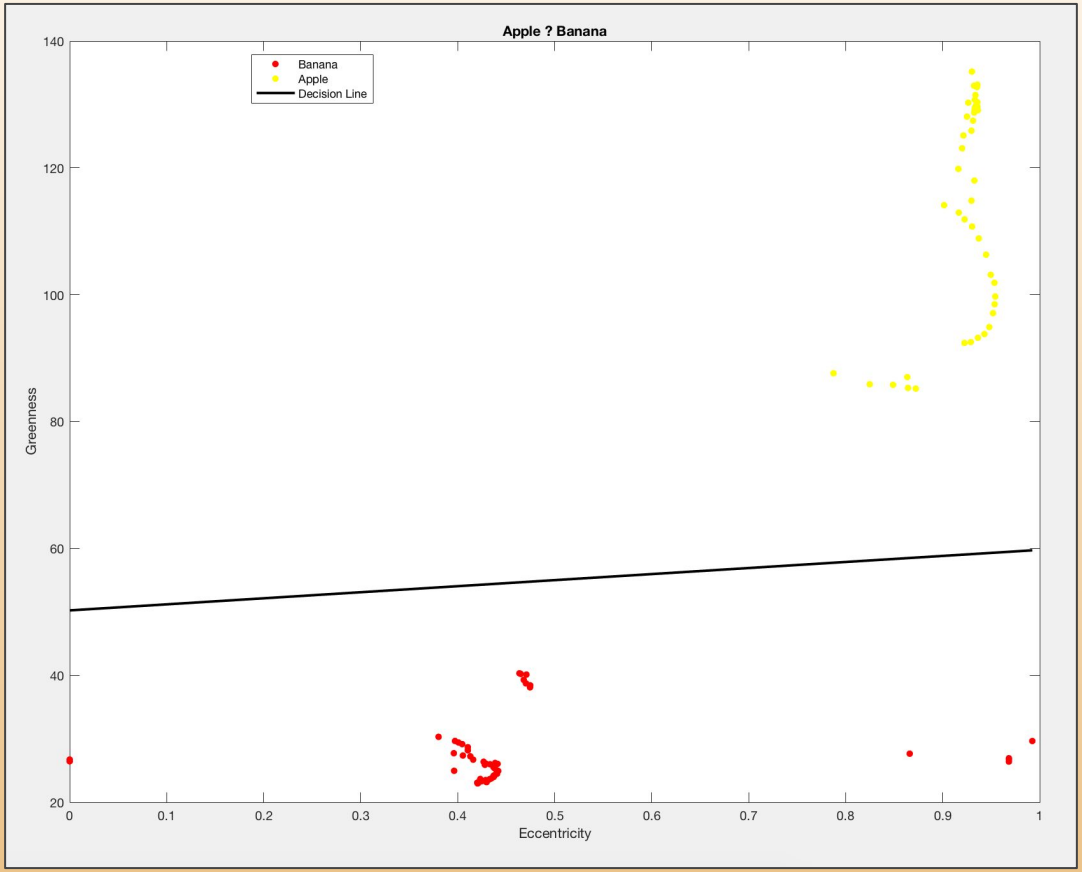
   $Ax+By=C$ or $-C+ax+By=0$.

   In terms of slope and y-intercept form, $y=\frac{C}{B}-\frac{A}{B}x$ where $m=\frac{-A}{B}$ and $b=\frac{C}{B}$.

   The product of inputs and weights make up an equation of the line:

   $w_o+w_1x_1+w_2x_2=0$ (note: $x_o=1$). With $C=-w_0$, $A=w_1$, and $B=w_2$ the decision line will have slope $m=-w_1/w_2$ and y-intercept $b=-w_0/w_2$.
3. If there are more than two classes, compute another decision line for the other pair of classes.
4. You can now test your perceptron if it can classify fruits. Using $w_o+w_1x_1+w_2x_2=0$ enter features of an unclassified fruit in x1 and x2. If the result of the equation is greater than 0 (positive) then the feature point is above the decision line so the fruit belongs to class 1, if negative then the feature point is below the decision line thus the fruit belongs to class 2.

Results Perceptron

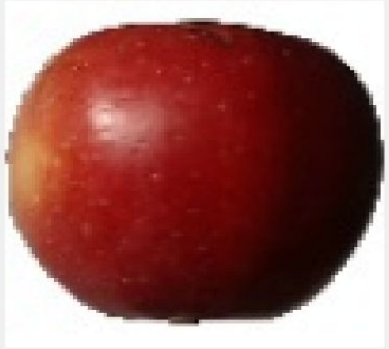


Determination of decision line
between two classes (apples and bananas)

Sample 22

Banana

Sample 36



Apple

Sample 41

Apple

Sample 69

Apple

Sample 91

Apple

Sample 98

Banana

Sample 100

Banana

Sample 124

Banana

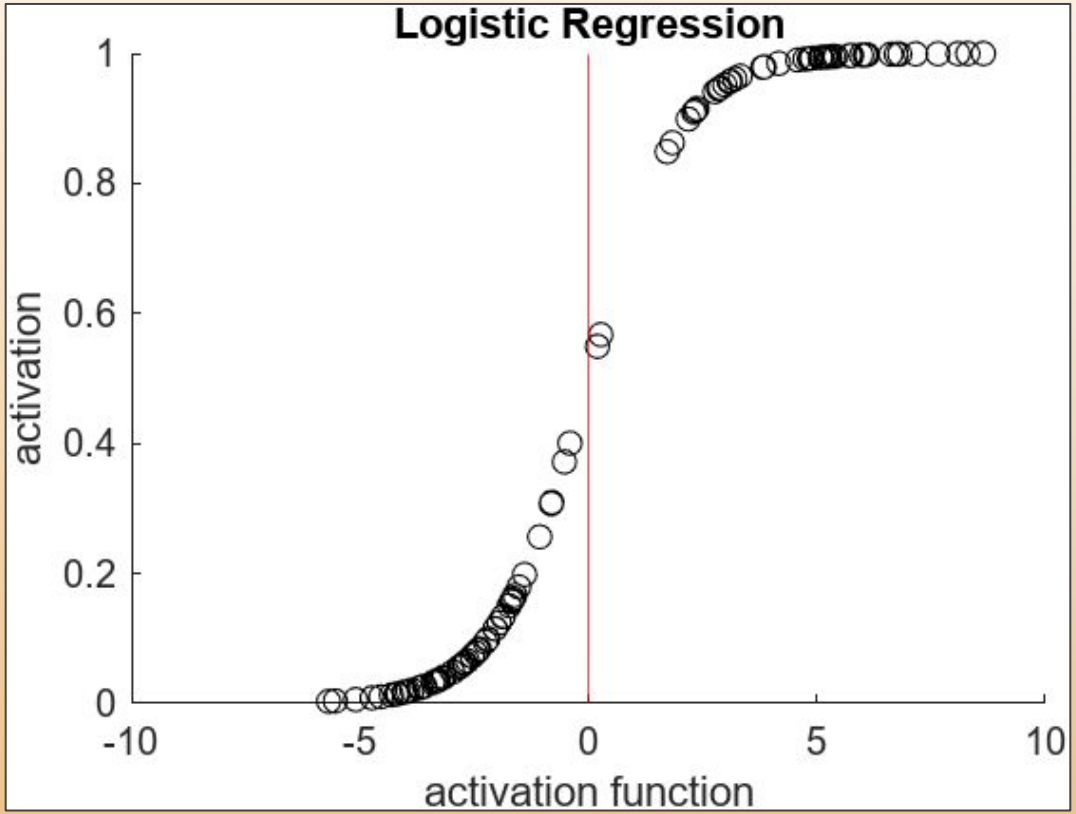
Successful differentiation between apples and bananas

Objective
Logistic Regression

Procedure

1. Select a fruit that changes color as it ripens. For example, banana or mango. Gather several images of ripe and unripe fruit, including those in between. For each image get the average red, green and blue color of the fruit (instead of a 0 to 255 digital range, normalize it to 0 to 1.0 for each channel) and label it 1 for ripe, 0 for unripe.
2. Apply logistic regression to train an artificial neuron to give the degree of ripeness of that the fruit. Plot the Test with images not yet seen by the neuron and comment if the output agrees with the visual appearance.

Results
Logistic Regression



Plotting the Function

Mango Ripeness Probability

Reflection & Analysis

The activity fascinated me to see how the perceptron learns from labeled training data, adjusting its weights and biases to find an optimal decision boundary that separates different classes. This process of iterative learning helped me appreciate the simplicity and effectiveness of the perceptron in solving linearly separable classification problems.

Logistic regression was also intriguing due to its connection to the perceptron and its extension to handle non-linearly separable data. The use of the sigmoid function as the activation function was interesting, as this maps the output of the model to a probability, enabling us to interpret the model's prediction as the likelihood of a particular class, rather than just a binary result like in perceptron.

I must admit that this activity is one of the most demanding and technical in terms of programming, which became my most significant hindrance. Nevertheless, it was a very effective introduction to machine learning for someone like me who is only now being exposed to the field.

Self Grade

CRITERIA	QUALIFICATIONS	SCORE
Technical Correctness	❑ Met all objectives ❑ Results are complete ❑ Results are verifiably correct ❑ Understood the lesson	30
Presentation Quality	❑ All text and images are good quality ❑ Code has sufficient comments/guides ❑ Plots are properly labeled and visually understandable ❑ Report is clear	33
Self Reflection	❑ Explained validity of results ❑ Discussed what went wrong/right in activity ❑ Justified self score ❑ Acknowledged sources	28
Initiative	❑ Experimented beyond what was required ❑ Made significant improvements to existing code	3

References

[1] What is machine learning? definition, types, applications, and more. (2020, May 28). *Great Learning.* Retrieved from https://www.mygreatlearning.com/blog/what-is-machine-learning/

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