App Physics 157

MACHINE LEARNING
Neural Networks

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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]

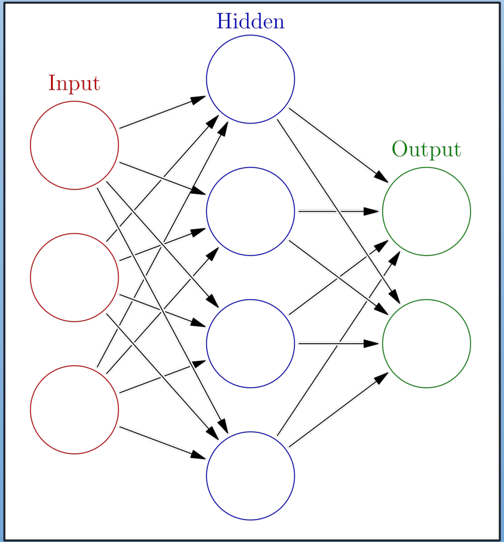
1. **Supervised learning:** In this type of machine learning, data scientists supply algorithms with labeled training data and define the variables they want the algorithm to assess for correlations. Both the input and the output of the algorithm is specified.
2. **Unsupervised learning:** This type 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
Neural Networks

A **neural network** is a program designed to mimic the functionality of the human brain. They have connected nodes that work and resemble the original neurons of the human brain. Every node consists of inputs, weights, and a bias. These nodes receive, process, and send data.

Every node consists of three layers- input, output, and hidden. A weight connects every node, and each node has a bias value or constant. Nodes get activated only if the sum of input and bias value is above a pre-decided threshold value. Activated nodes can only produce an output.



WHAT IS NEURAL NETWORK [4]

1. **Feed-Forward Neural Networks:** It conveys information in one direction through input nodes; this information continues to be processed in this single direction until it reaches the output mode.
2. **Recurrent Neural Networks:** Takes the output of a processing node and transmit the information back into the network. This results in theoretical "learning" and improvement of the network. Each node stores historical processes, and these historical processes are reused in the future during processing.
3. **Convolutional Neural Networks:** Also called ConvNets or CNNs, have several layers in which data is sorted into categories. These networks have an input layer, an output layer, and a hidden multitude of convolutional layers in between. The layers create feature maps that record areas of an image that are broken down further until they generate valuable outputs.
4. **Deconvolutional Neural Networks:** Deconvolutional neural networks simply work in reverse of convolutional neural networks. The application of the network is to detect items that might have been recognized as important under a convolutional neural network.
5. **Modular Neural Networks:** Modular neural networks contain several networks that work independently from one another. These networks do not interact with each other during an analysis process. Instead, these processes are done to allow complex, elaborate computing processes to be done more efficiently.

TYPES OF NEURAL NETWORK [5]

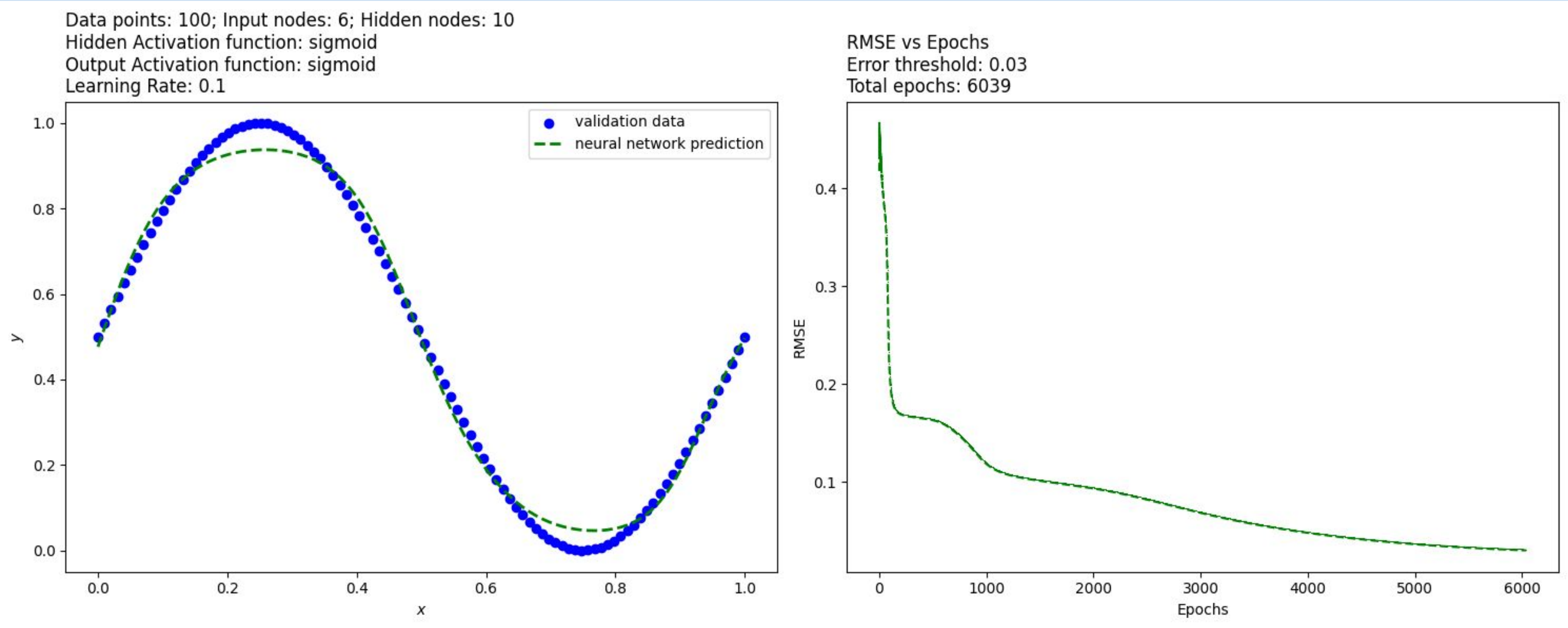
Objective
Neural Networks

Procedure

1. Neural network for regression - Program a neural network to learn a sine function. Alternatively, you may train the network to learn any function.

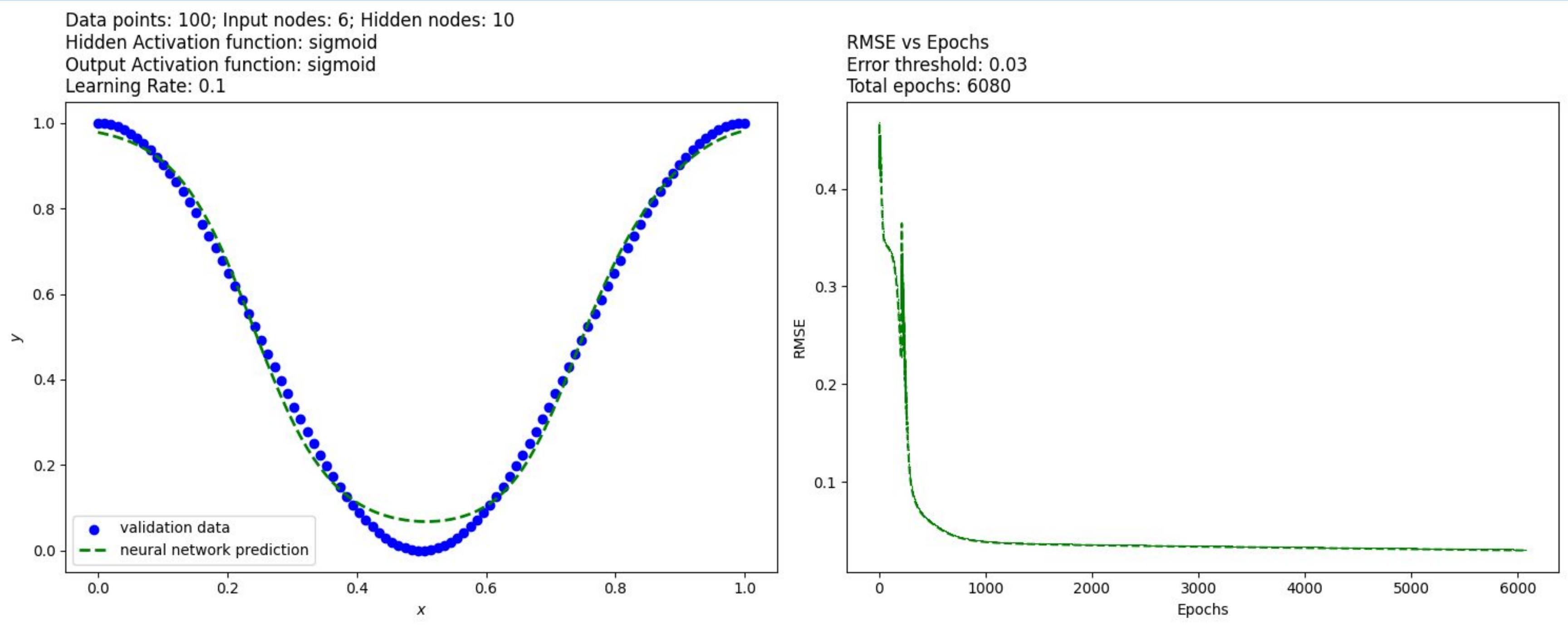
2. Neural network for classification - Program another neural network to classify your fruit data in ML2 (Perceptron). Set aside half of the data from each class as the training set and the remaining half as the test set. Using the test set determine the accuracy of your network (number of correct classification/ total test samples).

Results



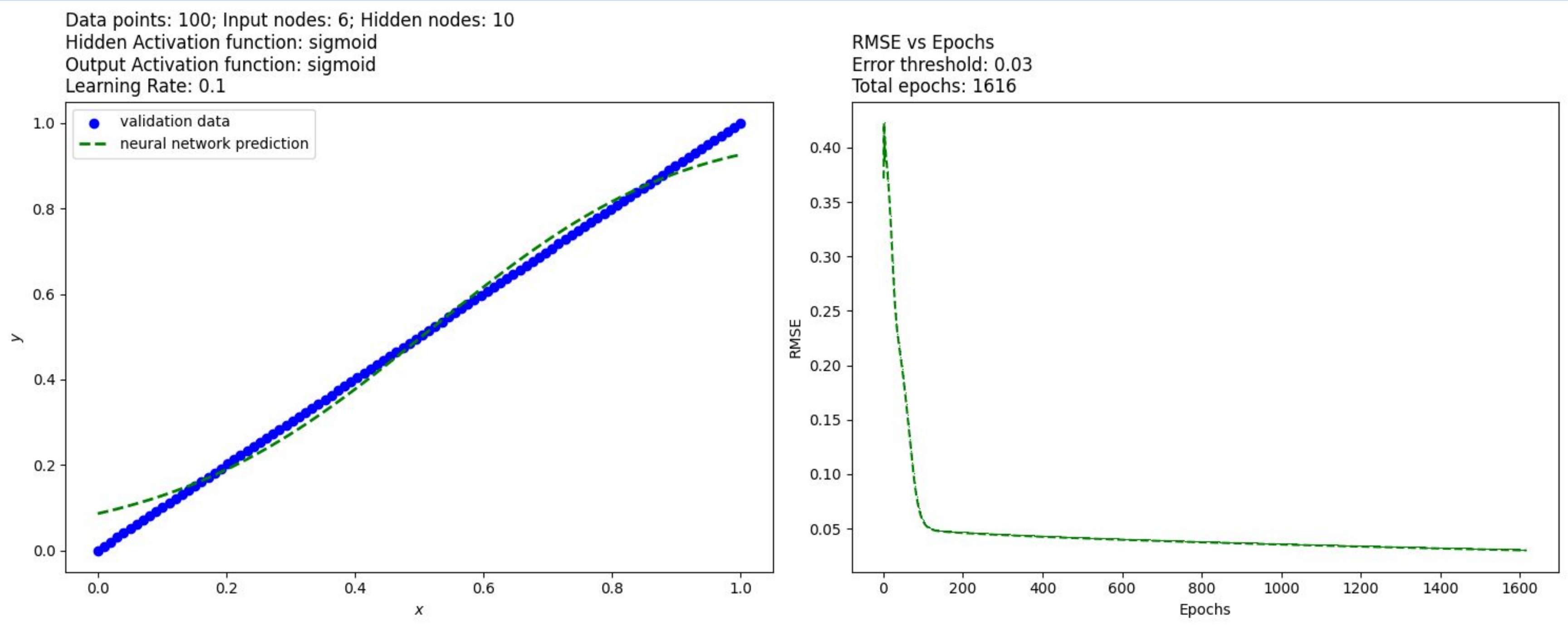
Sine Function Model

1. Learn a function (Python)



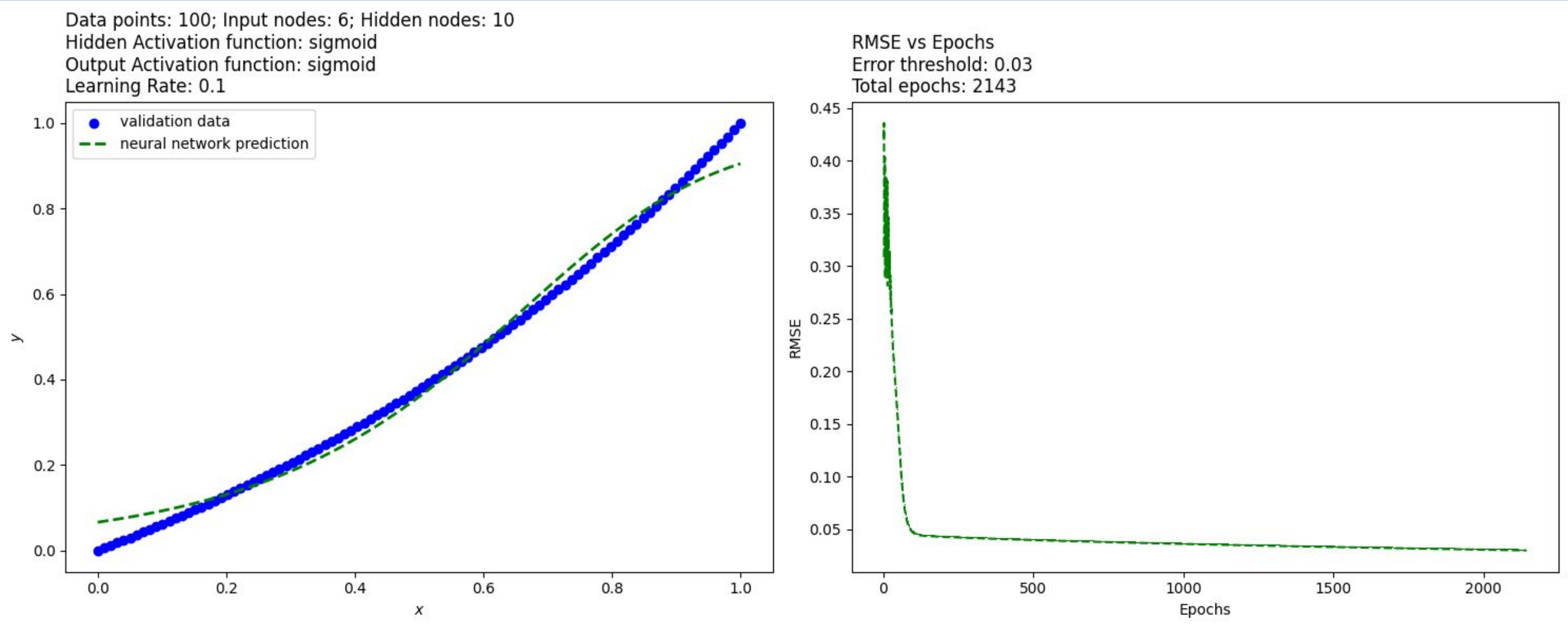
Cosine Function Model

1. Learn a function (Python)



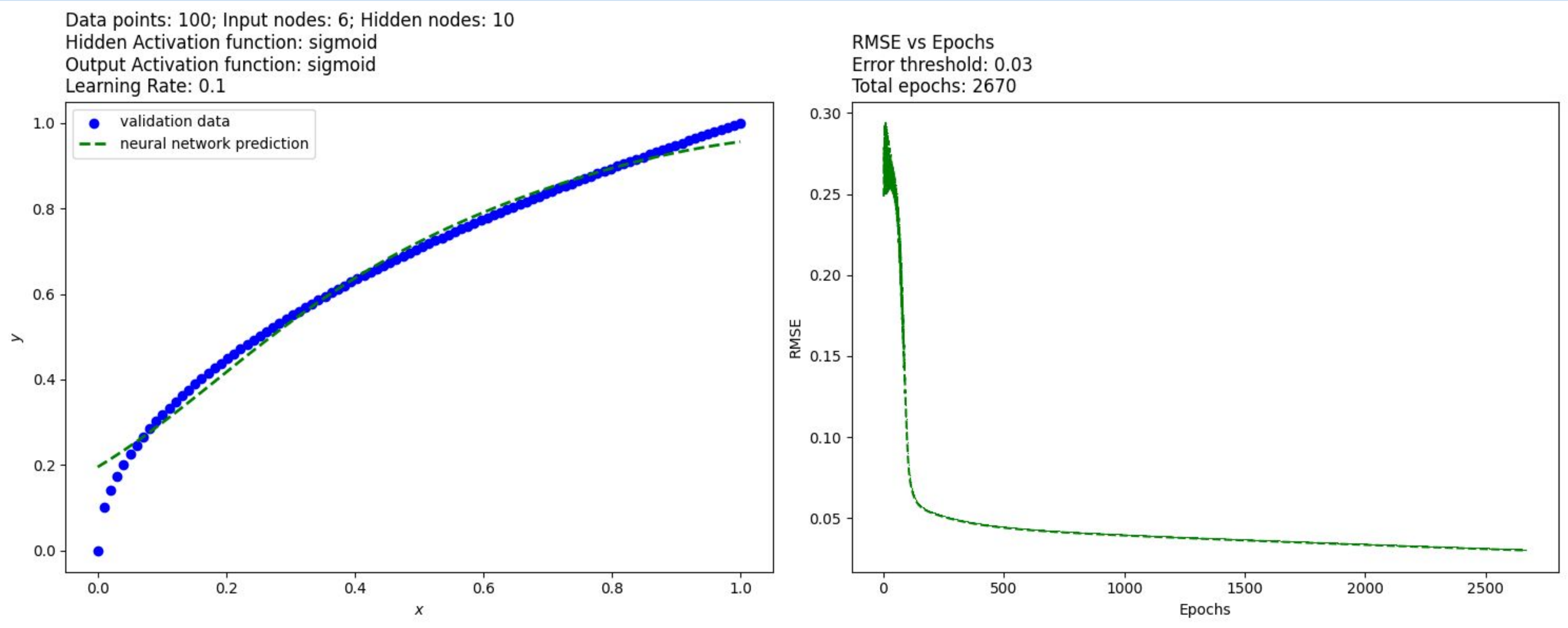
Absolute Value
Function Model

1. Learn a function (Python)



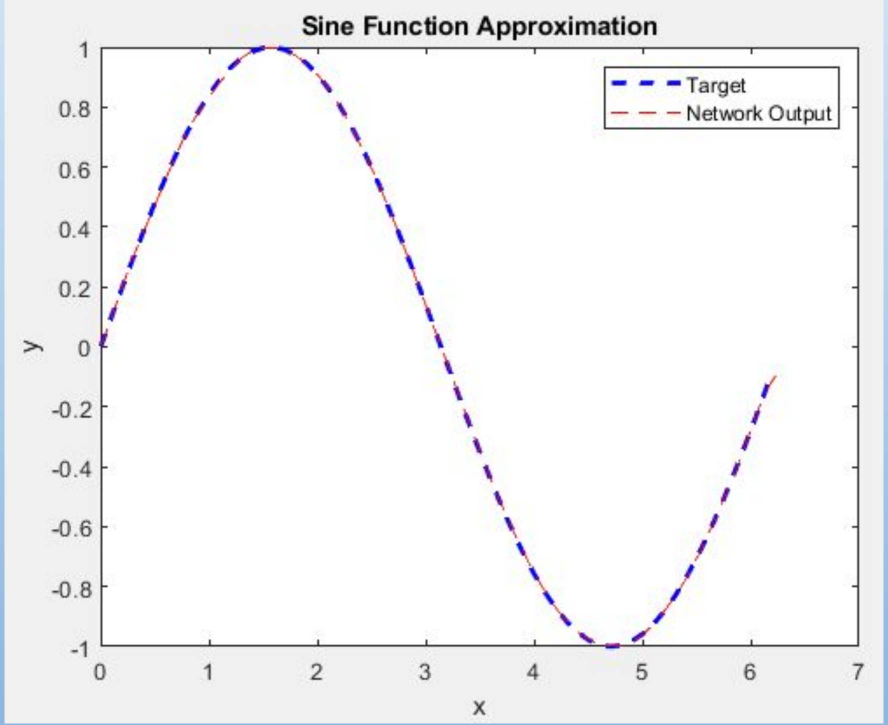
Exponential Function
Model

1. Learn a function (Python)



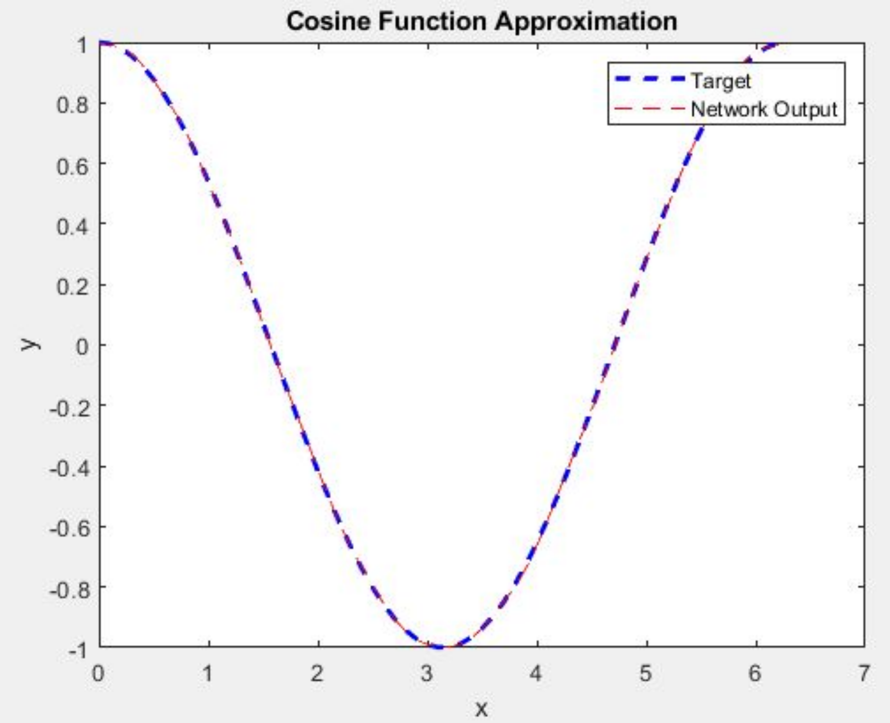
Logarithmic Function Model

1. Learn a function (Python)



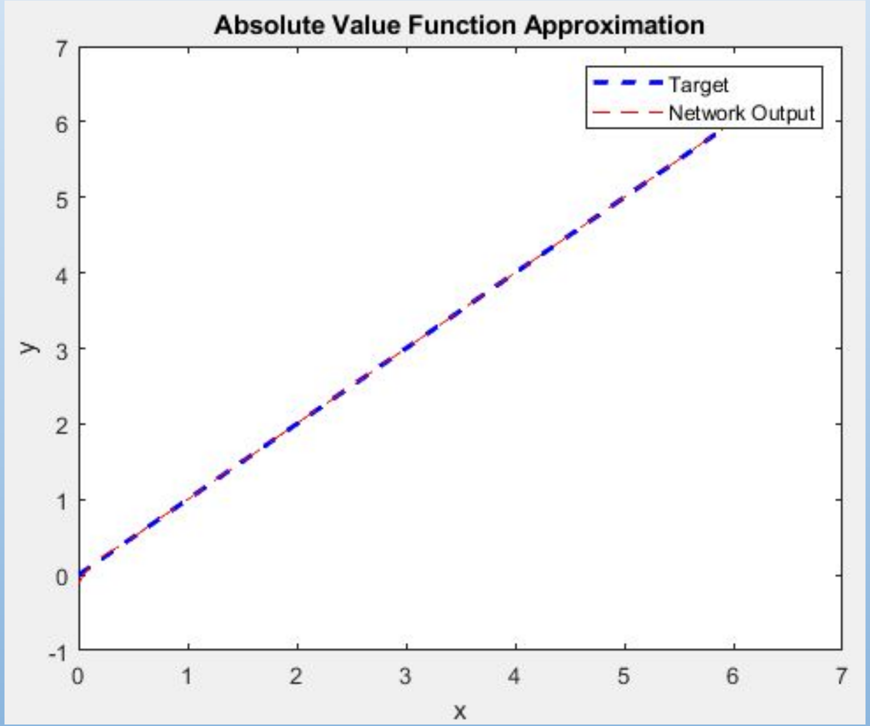
Sine Function Model

1. Learn a function (MATLAB)



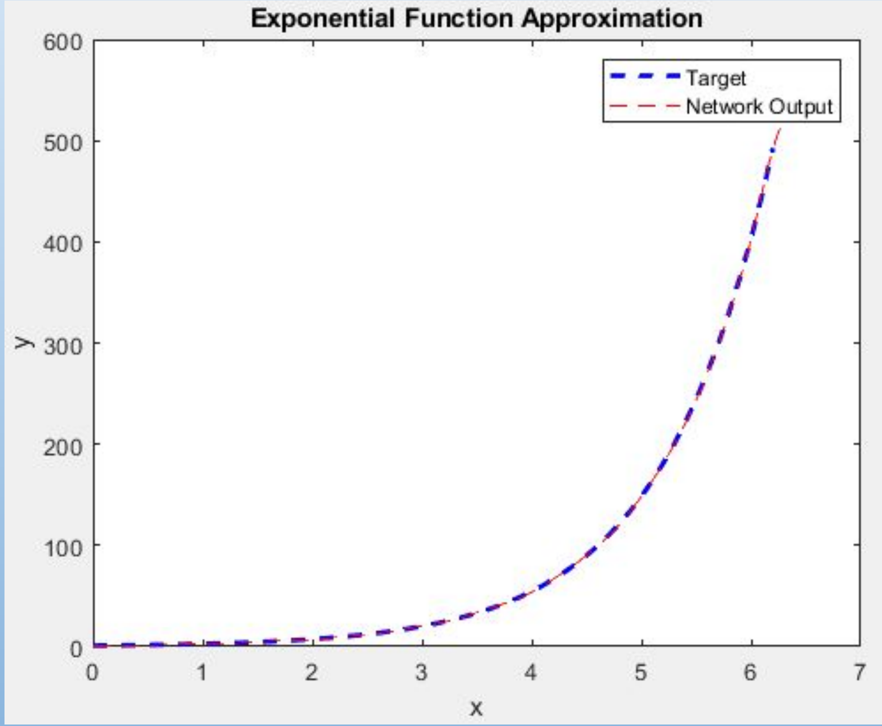
Cosine Function Model

1. Learn a function (MATLAB)



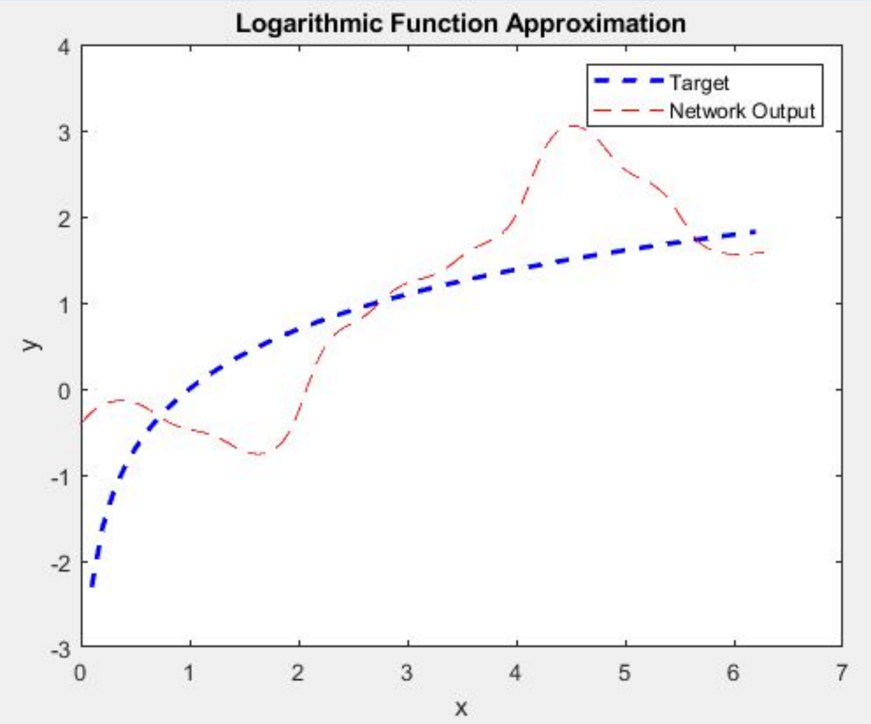
Absolute Value
Function Model

1. Learn a function (MATLAB)



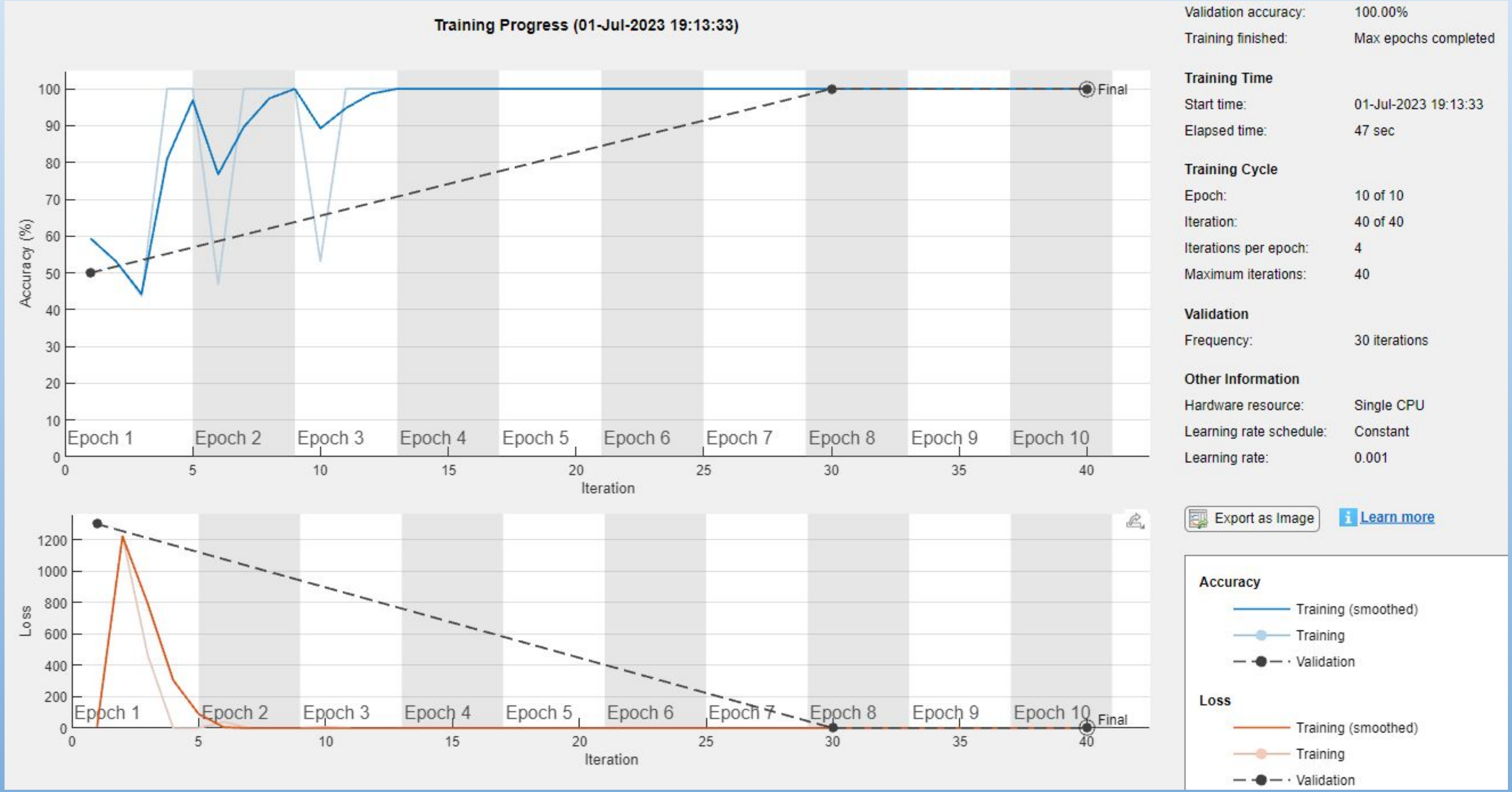
Exponential Function
Model

1. Learn a function (MATLAB)

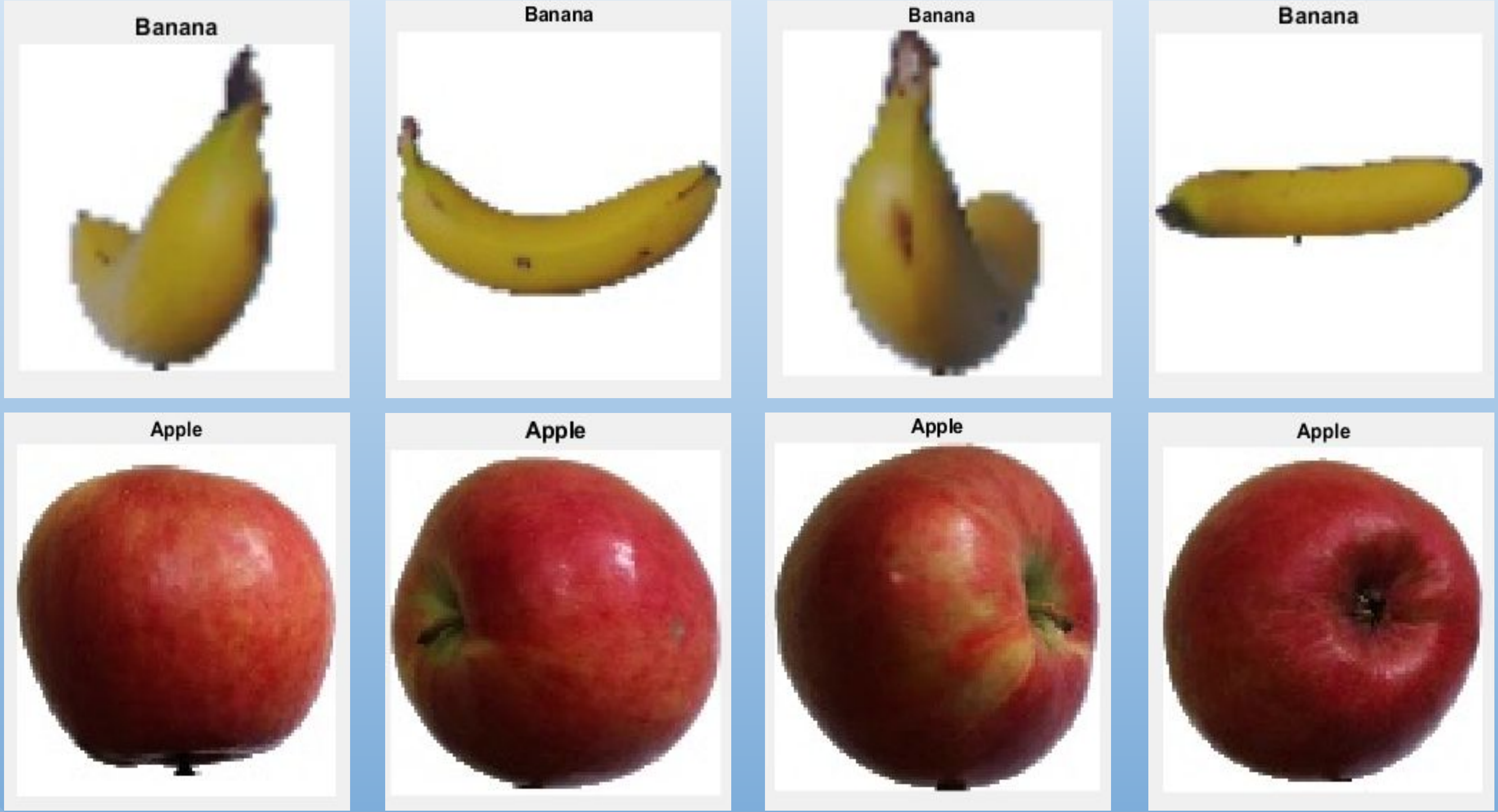


Logarithmic Function
Model

1. Learn a function (MATLAB)



2. Perceptron Classification (MATLAB)



2. Perceptron Classification (MATLAB)

```
Predicted label:
     Banana

Predicted label:
     Apple

Predicted label:
     Apple

Predicted label:
     Apple

Predicted label:
     Apple
```

```
Predicted label:
     Banana

Predicted label:
     Banana

Predicted label:
     Banana
```

Successful Differentiation of Classes

2. Perceptron Classification (MATLAB)

Reflection & Analysis

As I dive into the intricate world of artificial intelligence and machine learning, I am constantly amazed by the capabilities and potential of neural networks. These complex systems, inspired by the human brain, possess an uncanny ability to learn, adapt, and make decisions based on vast amounts of data.

However, I must admit that this specific activity is the most challenging I have dealt with in my entire AP157 class. The topic of neural networks, although seemingly straightforward conceptually, is very tedious and difficult to grasp technically. The tediousness in understanding it technically then becomes a hindrance in translating it into code, which given my personal timeframe, I could not do on my own. Thus, the programs used in this report were resourced online and/or from classmates, as I was not able to fully implement the topic alone.

Nevertheless, given that I am now introduced to the topic and have found personal gratification from it, I will surely be investing more time in learning and implementing neural networks in the future.

Self Grade

CRITERIA	QUALIFICATIONS	SCORE
Technical Correctness	❑ Met all objectives ❑ Results are complete ❑ Results are verifiably correct ❑ Understood the lesson	33
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	27
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/

[2] What is machine learning?. (n.d). *IBM.* Retrieved from https://www.ibm.com/topics/machine-learning

[3] Burns, E. (2021, March). Machine learning. *TechTarget.* Retrieved from https://www.techtarget.com/searchenterpriseai/definition/machine-learning-ML

[4] Sharma, R. (2023, March 22). A detailed guide in the meaning, importance, and future of neural networks. *Emeritus.* Retrieved from https://emeritus.org/in/learn/ai-ml-neural-networks/

[5] Chen, J. (2023, April 30). What is a neural network?. *Investopedia.* Retrieved from https://www.investopedia.com/terms/n/neuralnetwork.asp

Warm thanks to Julian Maypa for the Python code for number 1.