Lab 5

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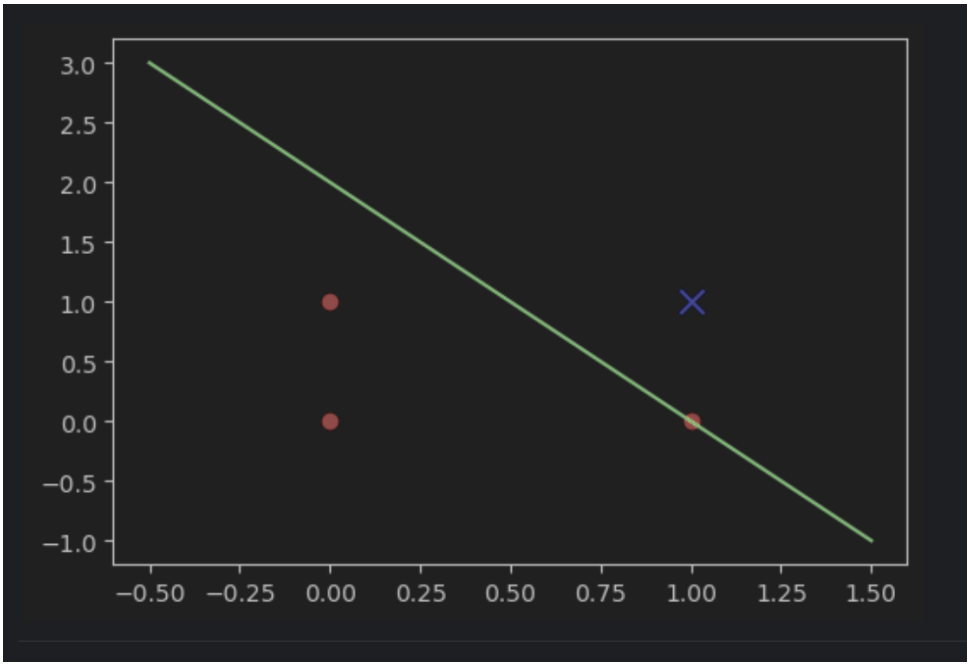
1 Part 1: The Perceptron Algorithm

1.1 Logical AND (Linearly Separable)

The logical AND dataset consists of four points:
(0,0), (0,1), (1,0) mapping to class 0
(1,1) mapping to class 1.

Implementation and Convergence Our from-scratch Perceptron, with a learning rate of 0.1, successfully converged and learned to classify the AND dataset. Convergence is achieved in only 4 epochs.

Decision Boundary



1.2 Logical XOR (Non-Linearly Separable)

The logical XOR dataset maps (0,1) and (1,0) to class 1
(0,0) and (1,1) map to class 0.

Performance We trained our Perceptron on the XOR dataset. The algorithm failed to converge, running for the maximum set 100 epochs. The final model achieved an accuracy of only 50.00%.

Analysis This failure is expected. The XOR dataset is not linearly separable, meaning no single straight line can correctly classify all four points. The Perceptron, being a linear classifier, is fundamentally incapable of solving this task.

1.3 1.3: Gaussian Dataset

We generated a 2D dataset of 200 samples from two distinct Gaussian distributions. The data was split into a 70% training set and a 30% validation set.

Performance We used the `sklearn.linear_model.Perceptron` implementation. The model achieved excellent results:

- **Training Set Accuracy:** 98.57%
- **Validation Set Accuracy:** 100.00%

2 Part 2: Exploring Activation Functions

2.1 Results and Analysis

We compared the performance of all four activation functions on the three datasets. The results are summarized in Table 1.

Table 1: Classification Accuracy and Training Time by Activation Function

Dataset	Activation	Train Accuracy	Validation Accuracy	Time (s)
AND	step	100.00%	-	0.0061
	sigmoid	75.00%	-	0.0043
	tanh	50.00%	-	0.0031
	relu	100.00%	-	0.0047
XOR	step	50.00%	-	0.0050
	sigmoid	25.00%	-	0.0054
	tanh	50.00%	-	0.0041
	relu	25.00%	-	0.0044
Gaussian	step	98.57%	100.00%	0.0495
	sigmoid	97.14%	100.00%	0.0889
	tanh	75.71%	68.33%	0.0933
	relu	97.86%	100.00%	0.1685