ASSIGNMENT 1

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Problem Statement - Implement Perceptron learning rule for OR, NOR, NAND and analyze output of each Perceptron model in terms of no. of epochs needed for error=0. Display final weights and bias values for

GATES	ACTIVATION FUNCTION	EPOCHS	EPOCH AT LOSS =0	FINAL WEIGHTS	FINAL BIAS
AND	SIGMOID	2000	1601	[4.2802, 4.2828]	[-6.6137]
AND	STEP ACTIVATION	10	6	[2,1]	[-3]
OR	SIGMOID	1000	801	[4.3010, 4.2018]	[-1.5958]
OR	STEP ACTIVATION	10	4	[1, 1]	[-1]
NAND	SIGMOID	2000	1501	[-4.3515, -4.3546]	[6.7201]
NAND	STEP ACTIVATION	10	6	[-2, -1]	[2]
NOR	SIGMOID	1000	901	[-4.1165, -4.1462]	[1.5316]
NOR	STEP ACTIVATION	10	4	[-1, -1]	[0]

Comparative Study -

1. AND Gate

Sigmoid Activation

- **Epochs**: 2000
- **Epoch at Loss = 0**: 1601
- **Final Weights**: [4.2802, 4.2828]
- **Final Bias**: [-6.6137]

Analysis:

- The **Sigmoid** activation function works well for the AND gate, with the loss approaching 0 after 1601 epochs.
- The weights are relatively large, which is typical for the Sigmoid function as it adjusts the weights to push the activation towards 1 or 0.

- The **negative bias** indicates the activation threshold is set in such a way that both inputs need to be high for the output to be activated (close to 1).

Step Activation

- **Epochs**: 10
- **Epoch at Loss = 0**: 6
- **Final Weights**: [2, 1]
- **Final Bias**: [-3]

Analysis:

- The **Step activation function** achieves perfect accuracy (loss = 0) within 6 epochs. This is because the Step function is a threshold-based binary classifier that makes decisions based on whether the weighted sum of inputs exceeds a threshold.
- The weights and bias are simpler and closer to the expected output for the AND gate, with a final bias of -3, suggesting that the threshold was set appropriately for activation.

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2. OR Gate

Sigmoid Activation

- **Epochs**: 1000
- **Epoch at Loss = 0**: 801
- **Final Weights**: [4.3010, 4.2018]
- **Final Bias**: [-1.5958]

Analysis:

- The **Sigmoid** function also performs well for the OR gate, achieving a loss of 0 after 801 epochs.
- The weights are again relatively large, and the negative bias is adjusted to allow for activation when either or both inputs are high.
- The **Sigmoid activation** ensures smooth output probabilities between 0 and 1, which is ideal for binary classification tasks like OR.

Step Activation

- **Epochs**: 10
- **Epoch at Loss = 0**: 4
- **Final Weights**: [1, 1]

- **Final Bias**: [-1]

Analysis:

- **Step activation** is very fast and effective for the OR gate. With only 4 epochs, it reaches a loss of 0, which shows that it quickly learns the OR logic.
- The weights of [1, 1] and the bias of -1 suggest that the activation threshold is set appropriately to recognize when either or both inputs are 1.

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3. NAND Gate

Sigmoid Activation

- **Epochs**: 2000
- **Epoch at Loss = 0**: 1501
- **Final Weights**: [-4.3515, -4.3546]
- **Final Bias**: [6.7201]

Analysis:

- The **Sigmoid** function for NAND gate performs similarly to AND, with the model achieving perfect classification at epoch 1501. The loss decreases as the model adjusts weights and biases to recognize the NAND logic.
- The negative weights suggest that both inputs must be low for the output to be 1. The positive bias further ensures that the NAND gate activates when both inputs are 0.

Step Activation

- **Epochs**: 10
- **Epoch at Loss = 0**: 6
- **Final Weights**: [-2, -1]
- **Final Bias**: [2]

Analysis:

- The **Step activation** also achieves perfect accuracy within just 6 epochs for NAND. The model quickly adapts to the threshold-based decision rule for the NAND gate.
- The weights and bias are adjusted similarly to the Sigmoid case but with simpler values, reflecting the binary threshold nature of the Step function.

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4. NOR Gate

Sigmoid Activation

- **Epochs**: 1000
- **Epoch at Loss = 0**: 901
- **Final Weights**: [-4.1165, -4.1462]
- **Final Bias**: [1.5316]

Analysis:

- The **Sigmoid activation** for the NOR gate converges at epoch 901, which is a reasonable number of epochs for this gate. The model correctly recognizes the NOR logic.
- The negative weights and positive bias ensure that the output is 1 only when both inputs are 0, consistent with the NOR gate truth table.

Step Activation

- **Epochs**: 10
- **Epoch at Loss = 0**: 4
- **Final Weights**: [-1, -1]
- **Final Bias**: [0]

Analysis:

- **Step activation** reaches a loss of 0 in just 4 epochs, indicating it learns very quickly for the NOR gate. The weights of [-1, -1] and bias of 0 suggest the gate operates as expected — only outputting 1 when both inputs are 0.
- As with the other gates, the **Step activation** performs well in binary classification tasks, but with simpler and faster results.

Conclusion -

Step Activation is faster and simpler, making it ideal for tasks involving binary outputs with simple thresholds, like logical gates. However, **Sigmoid Activation** provides smoother outputs and is better for problems requiring more nuanced decision boundaries, even though it takes longer to train.