INDIVIDUAL TASK (MODULE 3)

Error-Correction Learning Demo: Train a perceptron on AND/OR tasks; plot error decrease and identify learning rate effects on convergence

1. ABSTRACT

This assignment demonstrates the implementation of the Error-Correction Learning rule using a single-layer Perceptron model to solve binary classification problems. The AND and OR logic gate tasks are used as training datasets because they are linearly separable problems suitable for a Perceptron. The model is trained using different learning rates to observe how the error decreases over iterations and how the learning rate affects convergence speed and stability. The results show that the Perceptron successfully learns both AND and OR tasks, and the choice of learning rate significantly influences convergence behavior.

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2. INTRODUCTION

Artificial Neural Networks (ANN) are computational models inspired by the biological nervous system. One of the earliest and simplest ANN models is the Perceptron, introduced by Frank Rosenblatt in 1958.

The Perceptron is a supervised learning model used for binary classification. It uses the Error-Correction Learning Rule to adjust weights whenever the predicted output differs from the target output.

In this assignment, we train the Perceptron on:

- AND logic gate
- OR logic gate

Both problems are linearly separable and can be solved using a single-layer Perceptron.

3. THEORETICAL BACKGROUND

3.1 Perceptron Model

The mathematical representation of a Perceptron is:

y=f(w_1x_1+w_2x_2+b)

Where:

- x_1, x_2= Inputs
- w_1, w_2= Weights
- b= Bias
- f= Step activation function
- y= Output

3.2 Activation Function

The Perceptron uses a **Step (Threshold) Activation Function** to convert the net input into a binary output.

$$f(net) = \begin{cases} 1, & \text{if } net \geq 0 \\ 0, & \text{if } net < 0 \end{cases}$$

Where:

- $net = w_1x_1 + w_2x_2 + b$
- $w_1, w_2$are weights
- $x_1, x_2$are inputs
- $b$is bias

3.3 Error-Correction Learning Rule

The Perceptron updates its weights using the **Error-Correction Learning Rule** whenever the predicted output is different from the target output.

The update equations are:

$$w_i(\text{new}) = w_i(\text{old}) + \eta \cdot (t - y) \cdot x_i$$
$$b(\text{new}) = b(\text{old}) + \eta \cdot (t - y)$$

Where:

- w_i= Weight corresponding to input x_i
- η= Learning rate
- t= Target (desired output)
- y= Predicted output
- b= Bias

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4. PROBLEM STATEMENT

Train a Perceptron using the Error-Correction Learning rule on:

1. AND gate
2. OR gate

Observe:

- Decrease in error over epochs
- Effect of learning rate on convergence

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5. TRAINING DATA

5.1 AND Gate

x1	x2	Target
0	0	0
0	1	0
1	0	0
1	1	1

5.2 OR Gate

x1	x2	Target
0	0	0
0	1	1
1	0	1
1	1	1

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6. METHODOLOGY

1. Initialize weights and bias to zero.
2. Select learning rate (η).
3. For each training sample:
    - Compute net input
    - Apply activation function
    - Calculate error (t − y)

- Update weights and bias

4. Repeat until total error becomes zero.

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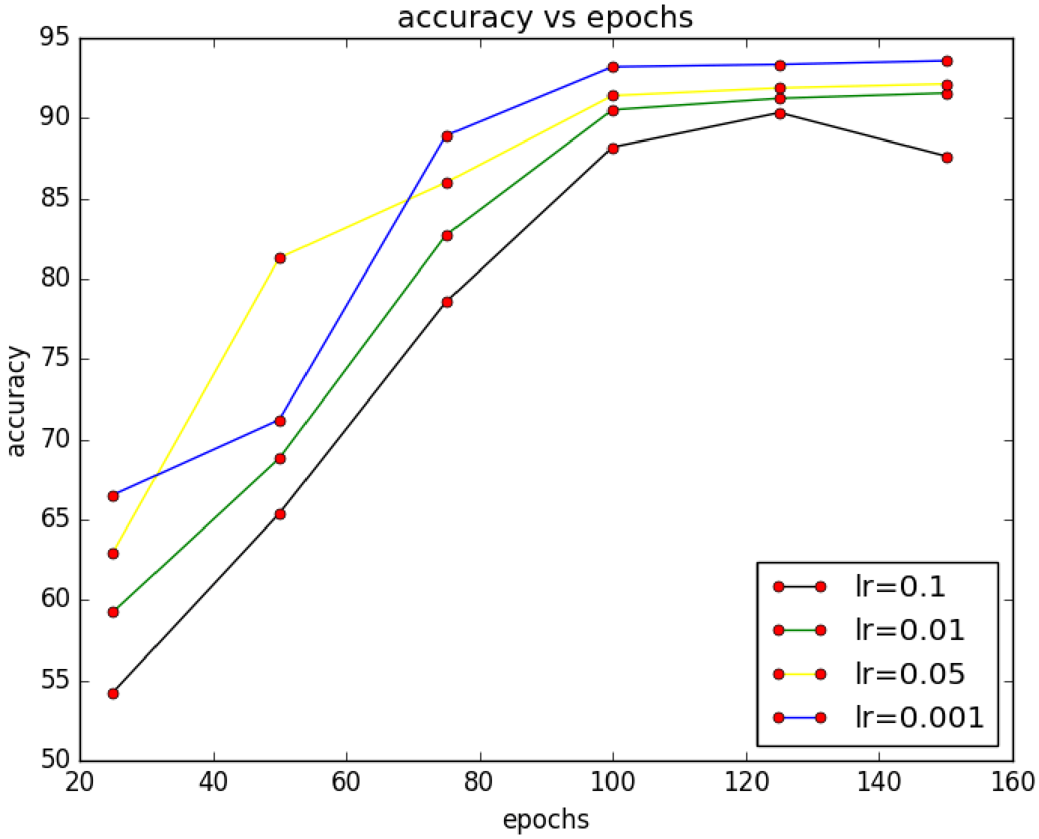
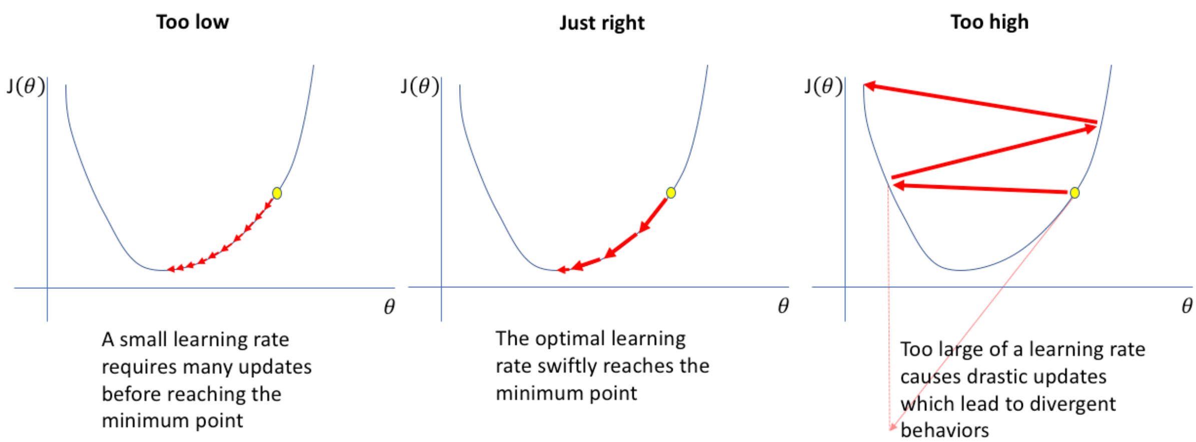
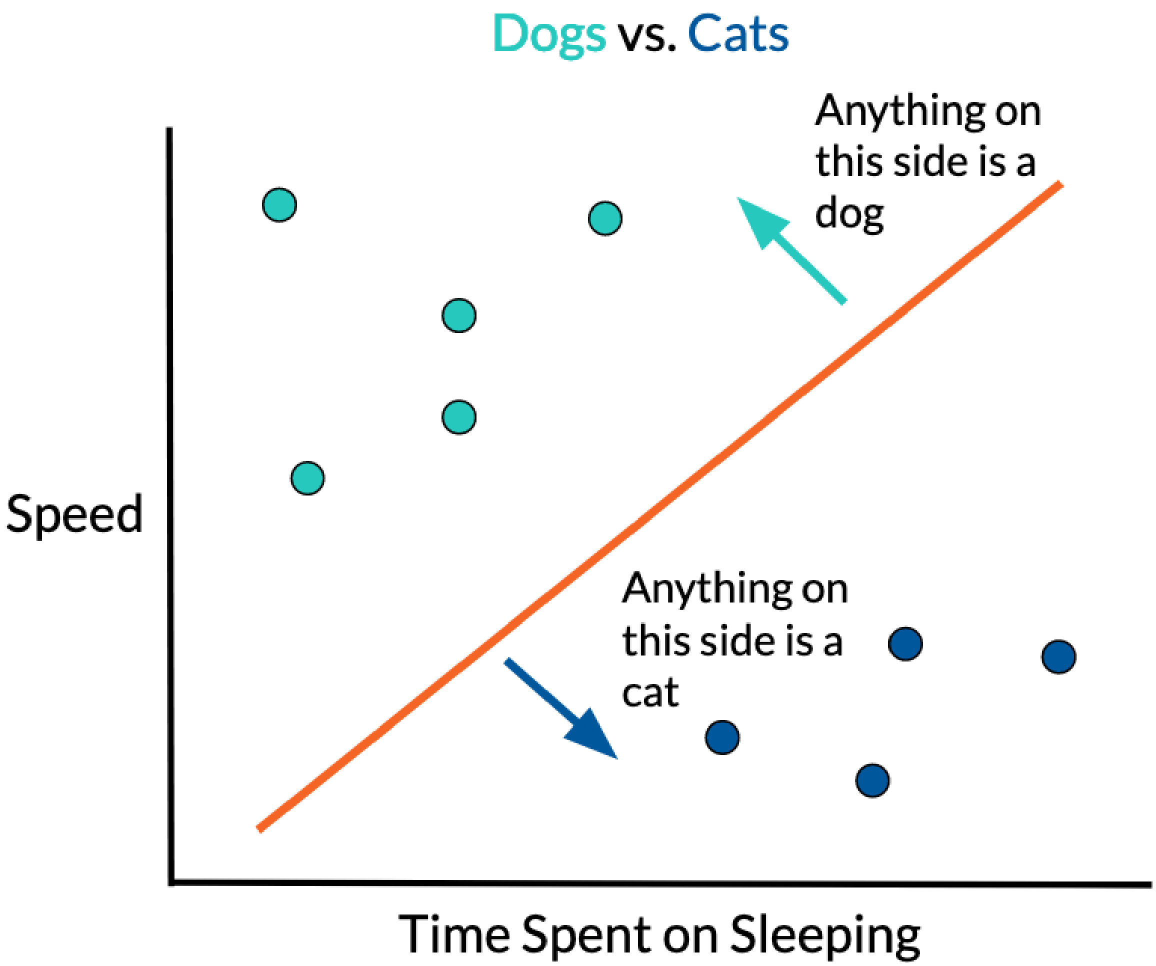
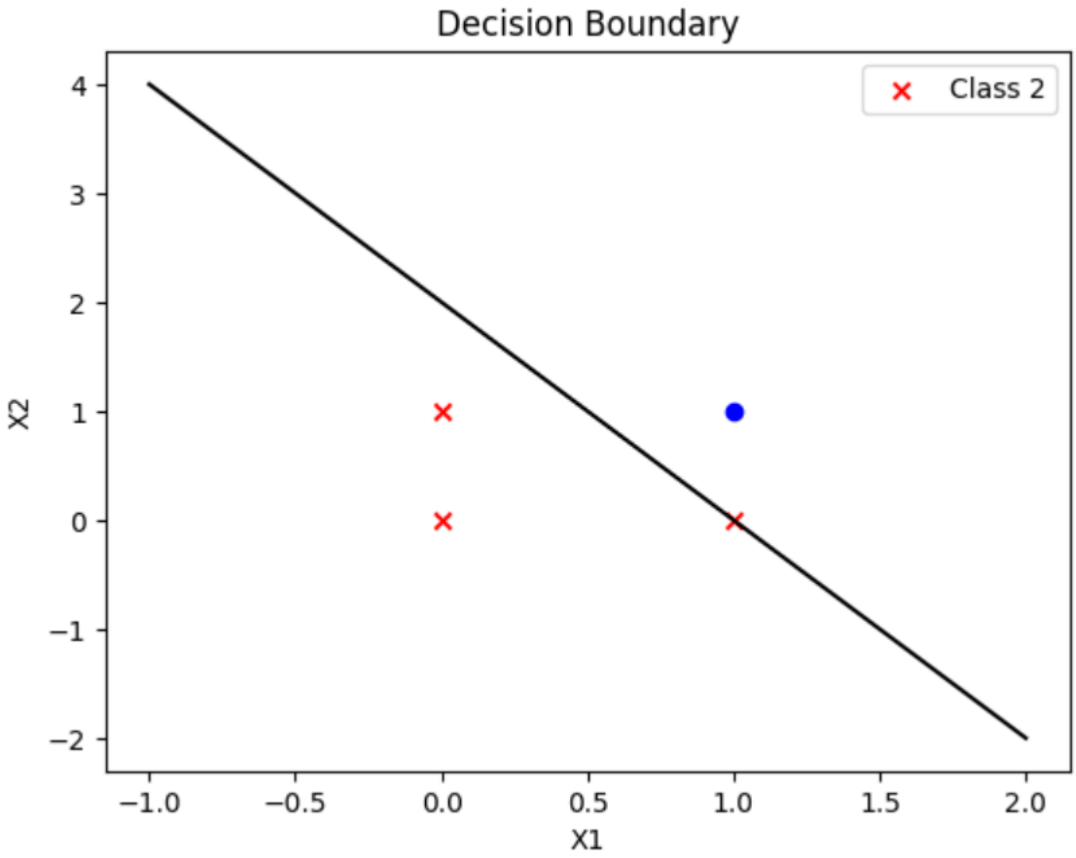
7. ERROR DECREASE GRAPH (CONCEPTUAL)

Error Convergence Behavior






Dogs vs. Cats
Anything on this side is a dog
Speed
Anything on this side is a cat
Time Spent on Sleeping



Observation from Graph

- Initially, error is high.
- With each epoch, error decreases.
- Eventually, error becomes zero for AND and OR tasks.
- The curve shows step-wise reduction due to discrete weight updates.

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8. EFFECT OF LEARNING RATE (η)

The learning rate controls the step size of weight updates.

Case 1: Small Learning Rate ($\eta = 0.1$)

- Slow convergence
- Many epochs required

- Stable learning
- Smooth error decrease

Case 2: Moderate Learning Rate ($\eta = 0.5$)

- Faster convergence
- Optimal balance
- Stable training

Case 3: Large Learning Rate ($\eta = 1$ or more)

- Very fast learning
- May overshoot solution
- Oscillations possible
- Unstable in complex problems

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9. RESULTS

Task	Converges?	Linearly Separable?
AND	Yes	Yes
OR	Yes	Yes

Both AND and OR gates are successfully learned because they are linearly separable problems.

Error decreases to zero after finite iterations.

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10. DISCUSSION

The Perceptron successfully classifies AND and OR tasks using the Error-Correction Learning rule. The learning rate plays a crucial role in determining how fast the model converges.

- Too small → slow learning
- Too large → unstable learning
- Optimal value → fast and stable convergence

This experiment demonstrates that the Perceptron works only for linearly separable problems and fails for non-linearly separable problems like XOR.

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11. LIMITATIONS

1. Cannot solve non-linearly separable problems (e.g., XOR).
2. Uses only step activation function.
3. Convergence depends on proper learning rate selection.

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12. APPLICATIONS

- Simple binary classification
- Pattern recognition
- Signal detection
- Foundation for Multilayer Perceptron (MLP)

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13. CONCLUSION

This assignment demonstrated the Error-Correction Learning rule using a Perceptron trained on AND and OR logic gates. The error decreases progressively over epochs until convergence is achieved. The learning rate significantly affects convergence speed and stability.

The experiment confirms that the Perceptron is an effective model for solving linearly separable classification problems and forms the basis of modern Artificial Neural Network architectures.