# Machine Learning Lab

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|---|---|---|---|

## Lab - 6

### Introduction

This project implements a simple feedforward neural network from scratch using NumPy. The goal is to understand the full pipeline of weight initialization, forward propagation, backpropagation, and training with early stopping. The model is applied to a regression task, and performance is evaluated using Mean Squared Error (MSE) and $R^2$ score.

### Dataset Description

- Polynomial Type: QUARTIC:
    $$y = 0.0171x^4 + 1.76x^3 - 0.37x^2 + 4.80x + 8.23$$
- Noise Level: $\varepsilon \sim N(0, 1.95)$
- Architecture: Input(1) $\rightarrow$ Hidden(64) $\rightarrow$ Hidden(64) $\rightarrow$ Output(1)
- Learning Rate: 0.015
- Architecture Type: Balanced Architecture
- Number of samples: 100,000 total (80,000 training, 20,000 testing).

### Methodology

- Weight Initialization: Xavier initialization is used to prevent vanishing/exploding gradients.
- Network Architecture: Input layer (1 unit) $\rightarrow$ Hidden Layer 1 $\rightarrow$ Hidden Layer 2 $\rightarrow$ Output layer (1 unit). Hidden layers use nonlinear activations (ReLU or alternatives), while the output layer is linear.
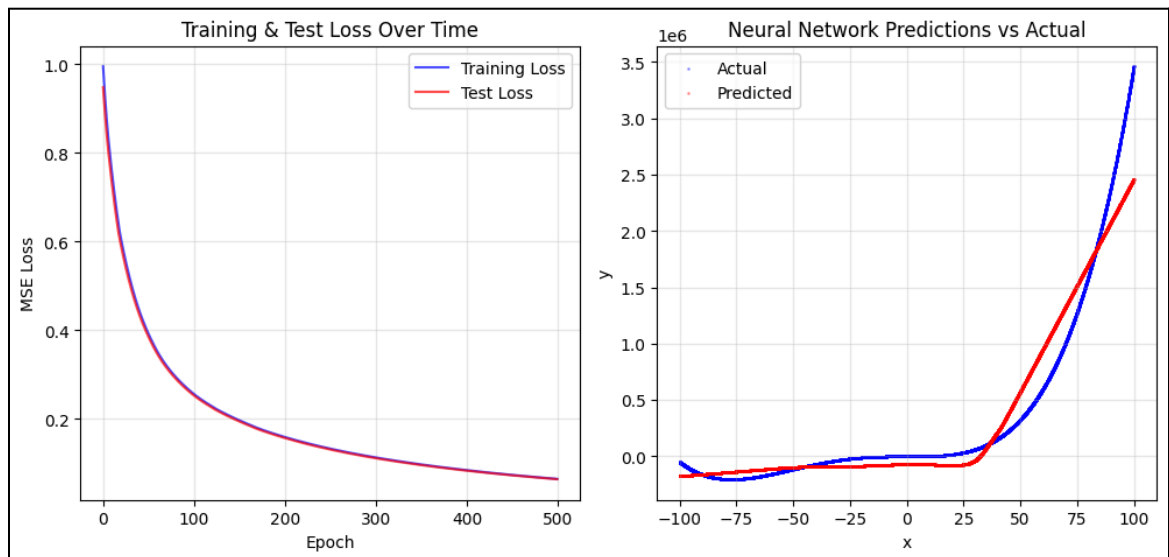
- Forward Propagation: Computes pre-activations and activations layer by layer until predictions are produced.
- Backpropagation: Uses the chain rule to calculate gradients of the MSE loss with respect
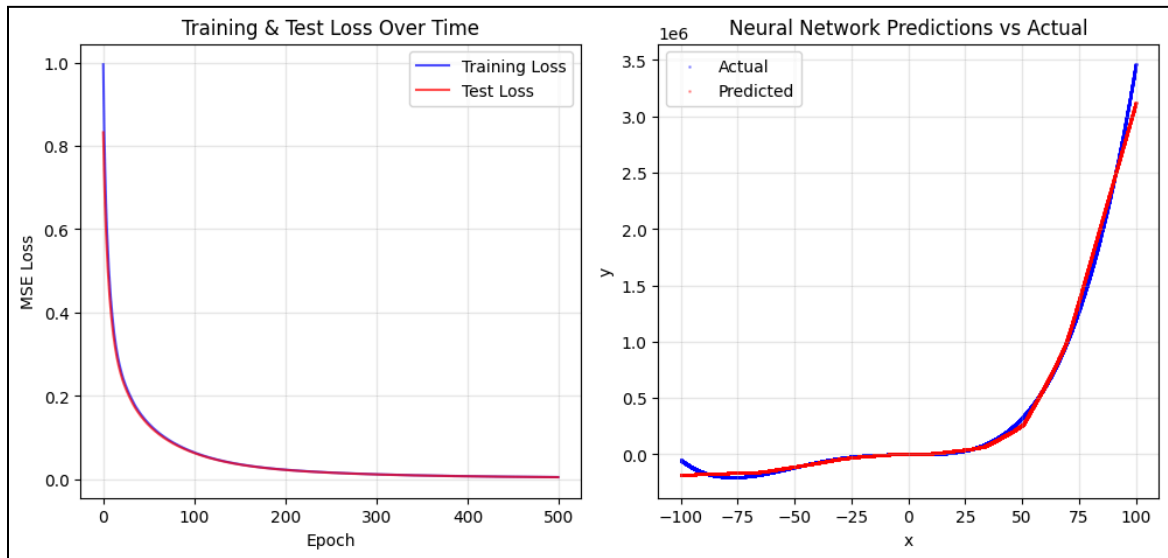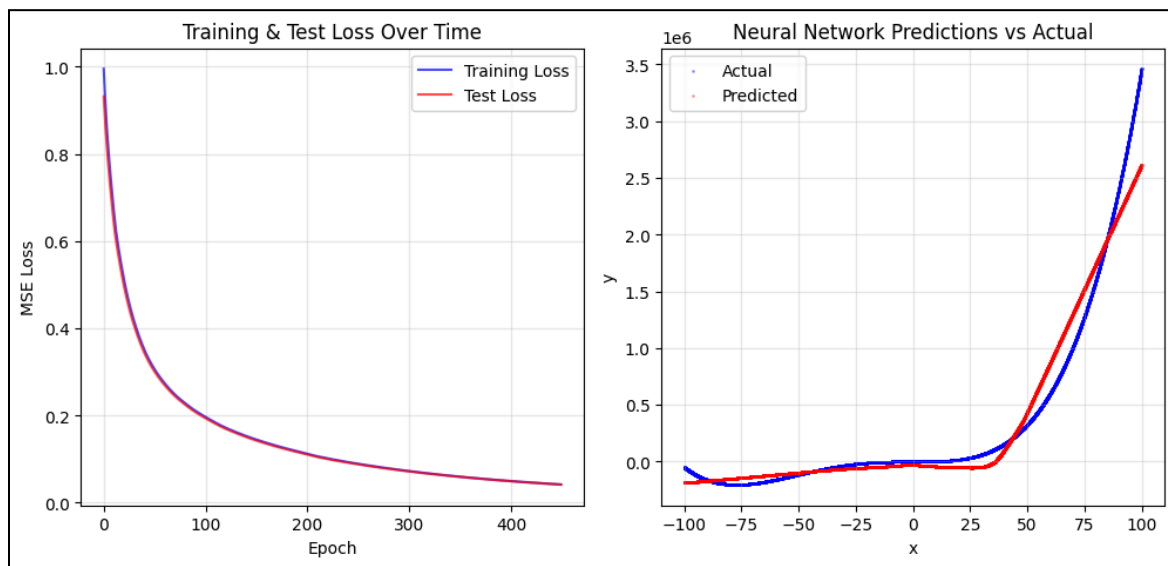
## **Results and Analysis**
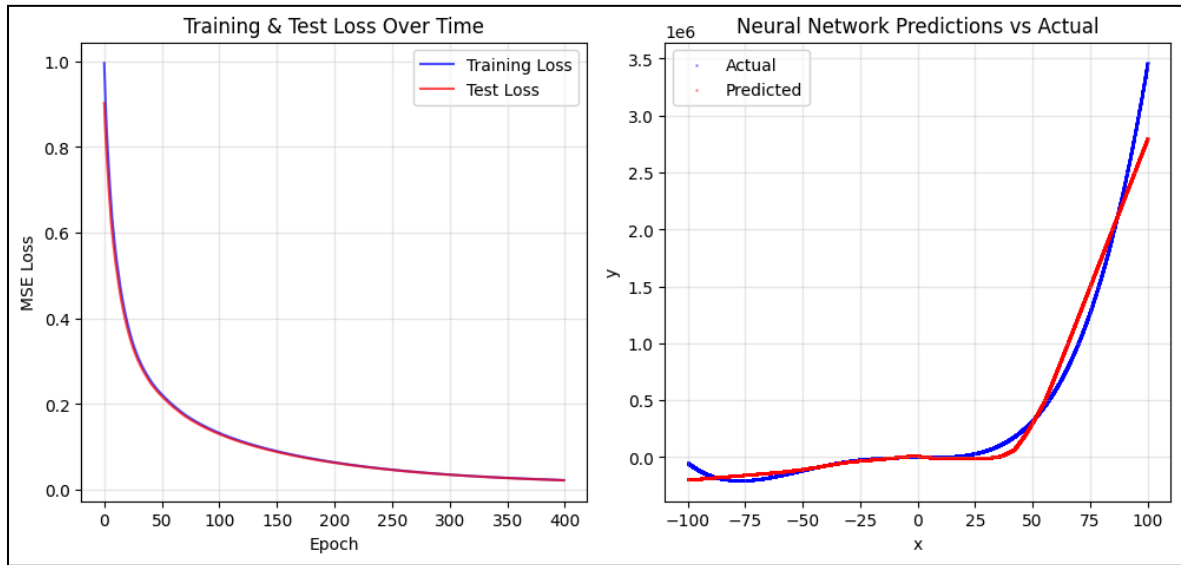
1. Exp1 (baseline)
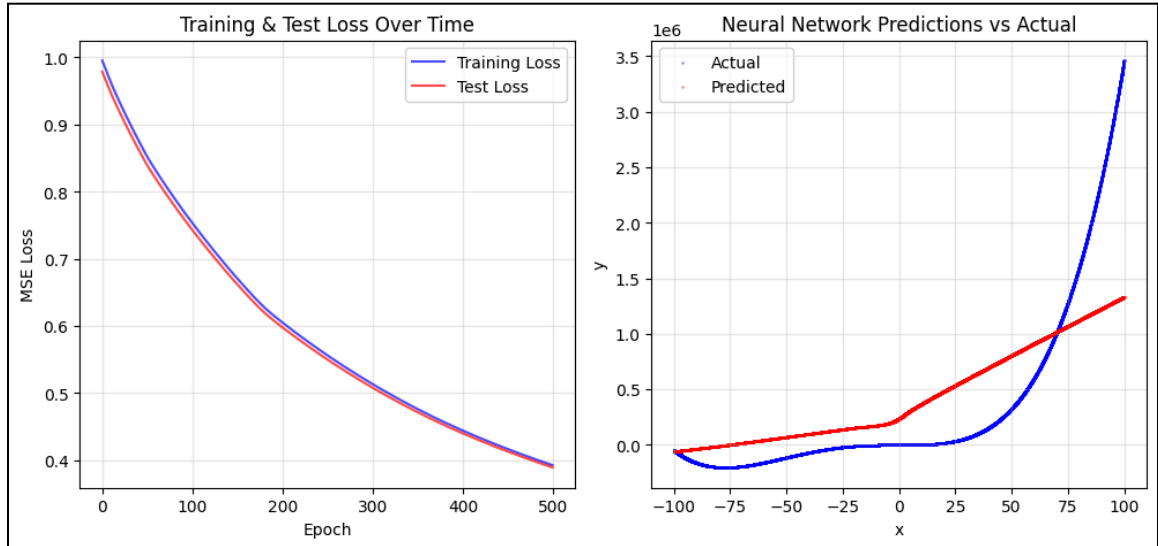


2. Exp2

## 3. Exp3



## 4. Exp4

## 5. Exp5



| Experiment | Learning Rate | No. of epochs | Optimizers | Activation function | Final Training Loss | Final Test Loss | R² Score |
|---|---|---|---|---|---|---|---|
| **Exp1 (Baseline)** | 0.001 | 500 | Gradient Descent | ReLu | 0.392330 | 0.389025 | 0.6057 |
| **Exp2** | 0.010 | 500 | Gradient Descent | ReLu | 0.064375 | 0.063714 | 0.9354 |
| **Exp3** | 0.050 | 500 | Gradient Descent | ReLu | 0.004521 | 0.004384 | 0.9956 |
| **Exp4** | 0.015 | 450 | Gradient Descent | Tanh | 0.041660 | 0.041325 | 0.9581 |
| **Exp5** | 0.025 | 400 | Gradient Descent | Sigmoid | 0.022590 | 0.022294 | 0.9774 |