Soft Senor Model in Debutanizer Column

CH512 - Course Project

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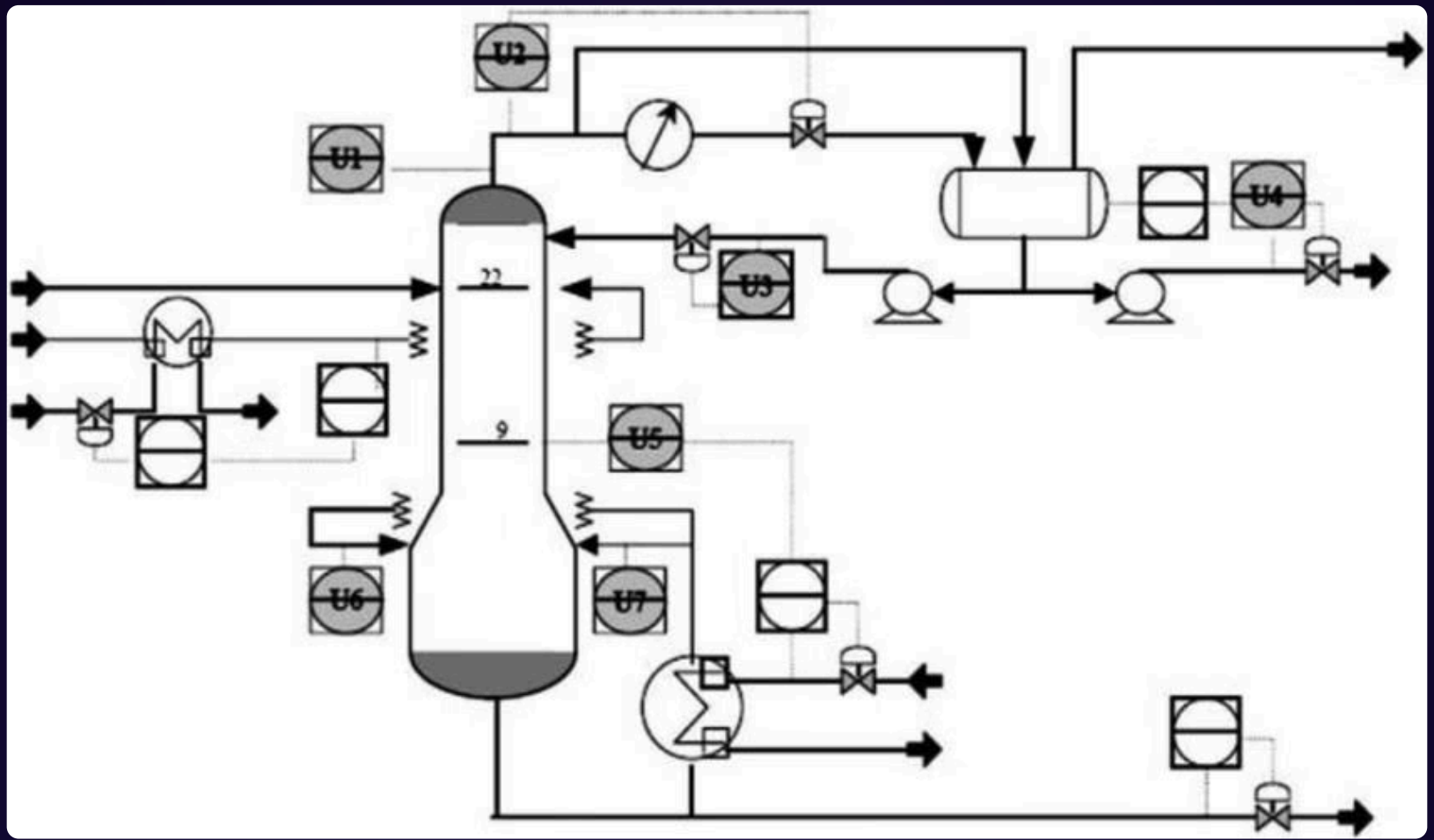
Soft Sensor System

The Debutanizer column is a crucial component in the distillation process. It is responsible for separating propane (C3) and butane (C4) from the naphtha stream. The main objectives of the column is to increase the concentration of stabilized gasoline (C5) in the overheads, which is used as the feed for the LP gas splitter, and to decrease the concentration of butane (C4) in the bottoms, which is fed into the naphtha splitter.

Two sensors, N1 and N2, provide real-time estimates of key variables: N1 measures the percentage of C5 in C4 (F_C5), while N2 assesses the percentage of C4 in C5

Debutanizer System



System Parameters

Variable	Description
u1	Top Temperature
u2	Top Pressure
u3	Reflux Flow
u4	Flow to Next Process
u5	6th Tray Temperature
u6	Bottom Temperature (repeated)
u7	Bottom Temperature (repeated)

To predict the soft sensor

- y - Percentage of C5 in C4 (F_C5)

Linear Function Approximations

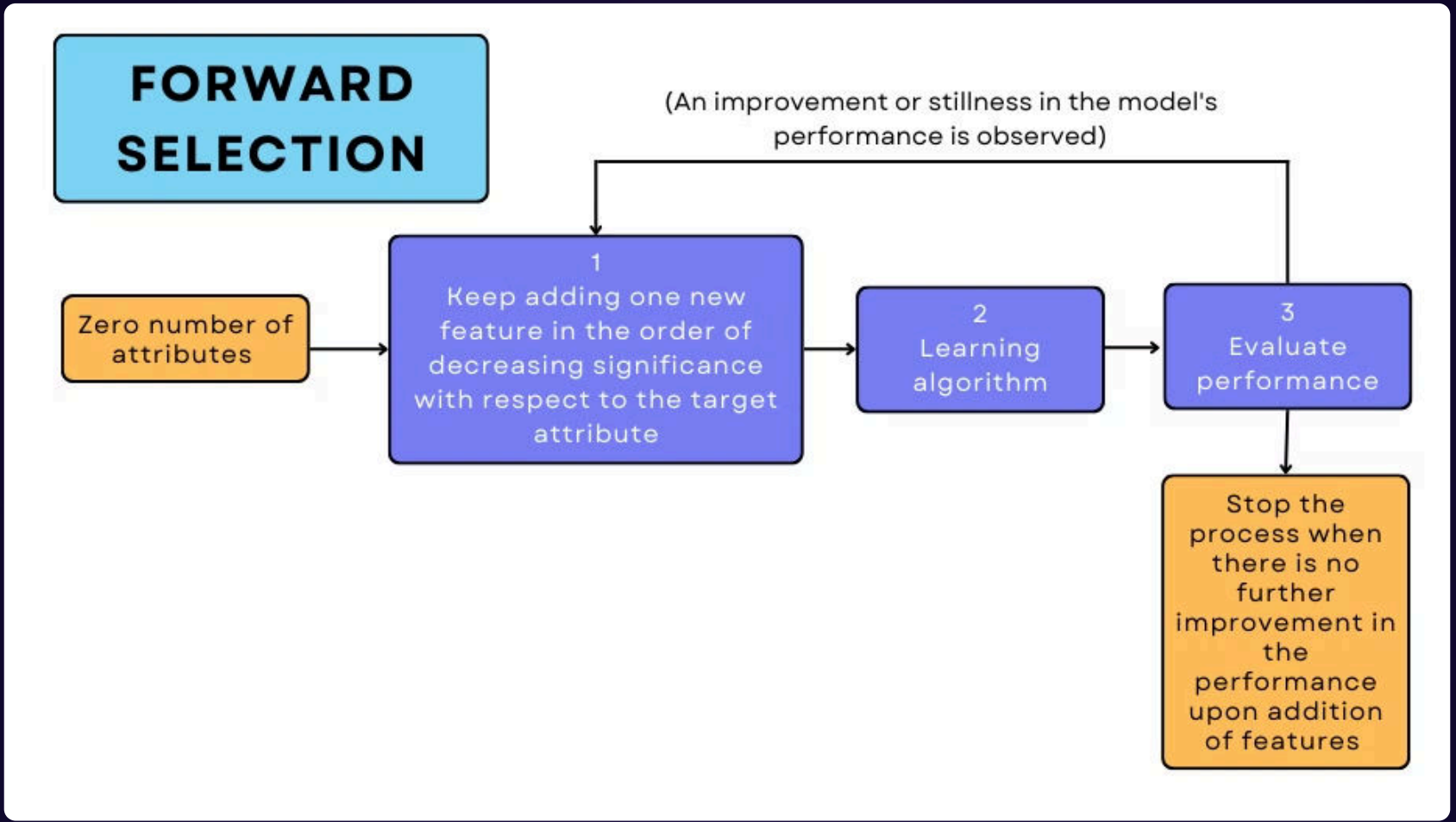
We have utilized the use of following preprocessing methods

- Forward Selection Method
- Lasso regression technique.
- PCA based feature selection.

We have also built following Models to train and evaluate the model and to predict the soft sensor value

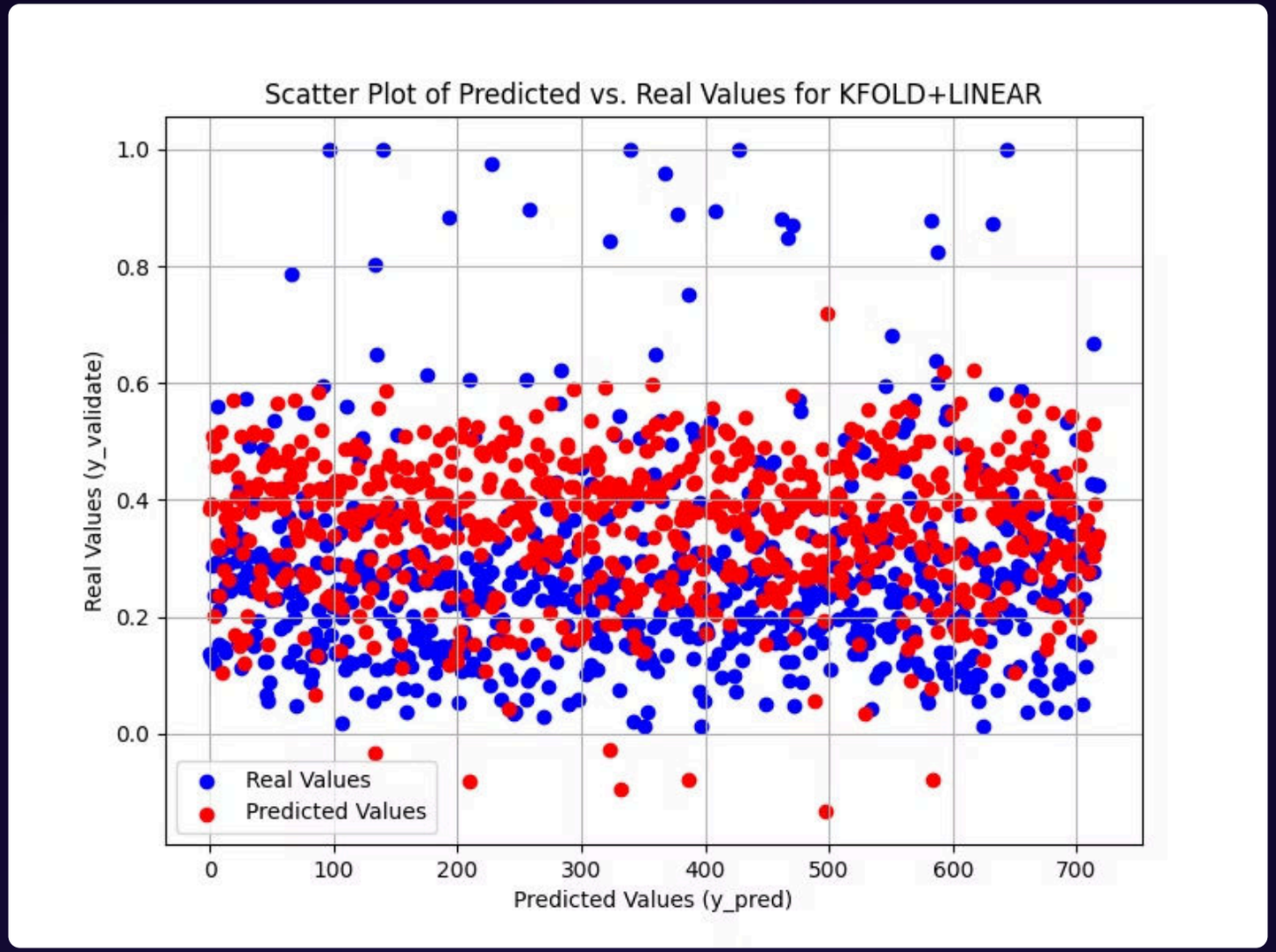
- Linear Regression Model
- Polynomial Regression Model Degree 2
- Polynomial Regression Model Degree 3

Forward Selection Method

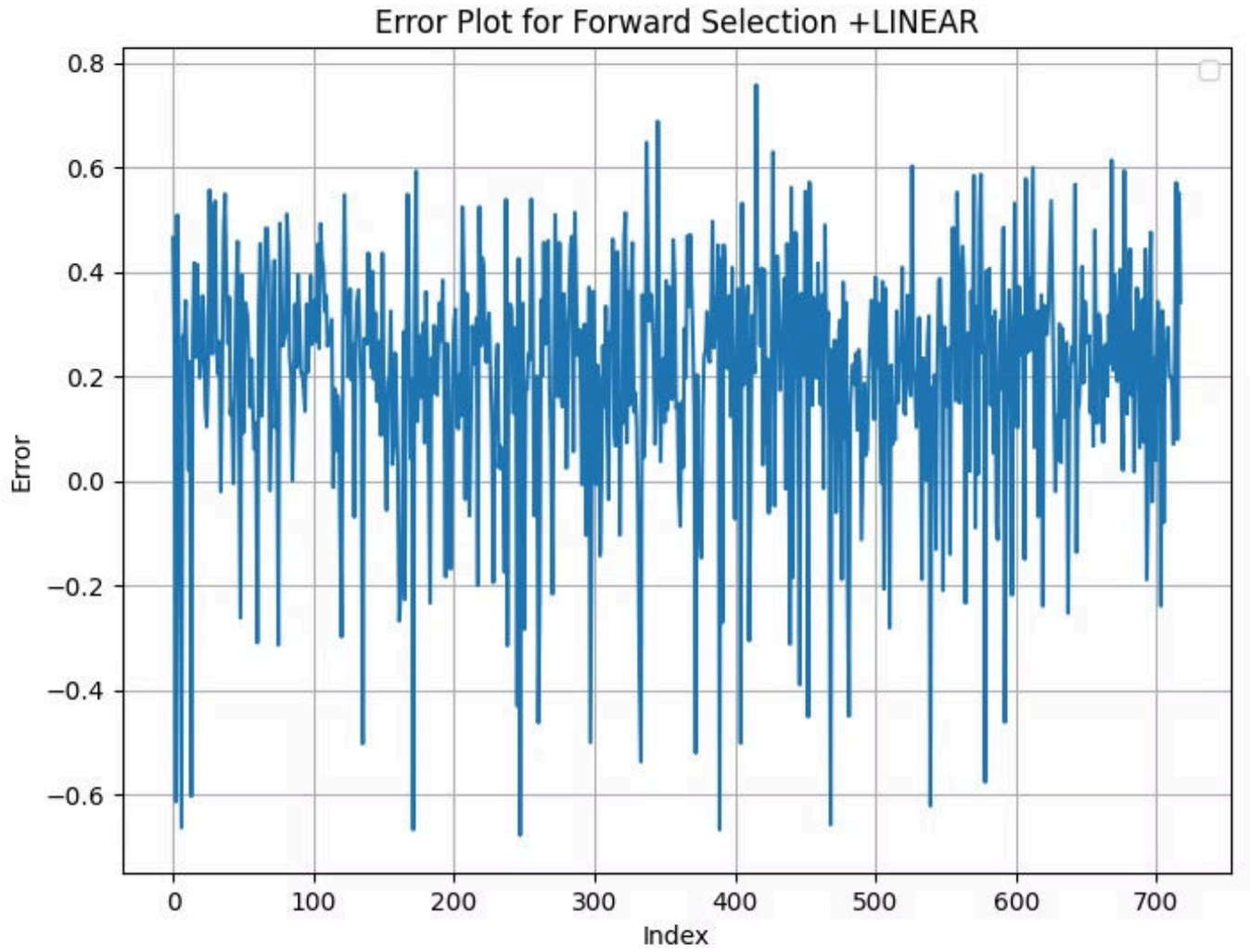


Final features u1, u2, u5

Forward Selection Method



Forward Selection Method Error

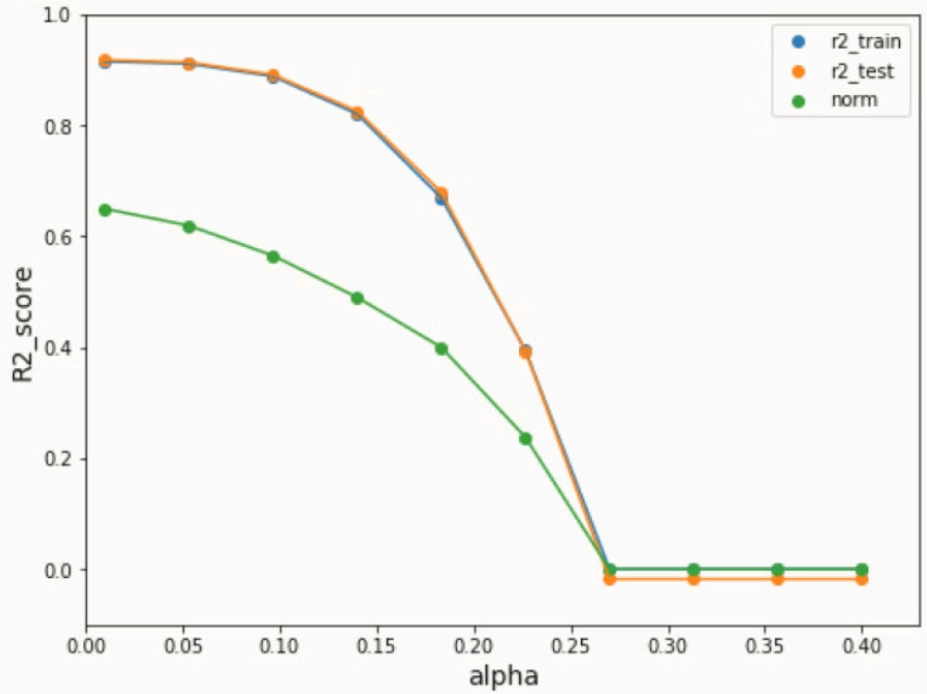


Lasso Regression Technique

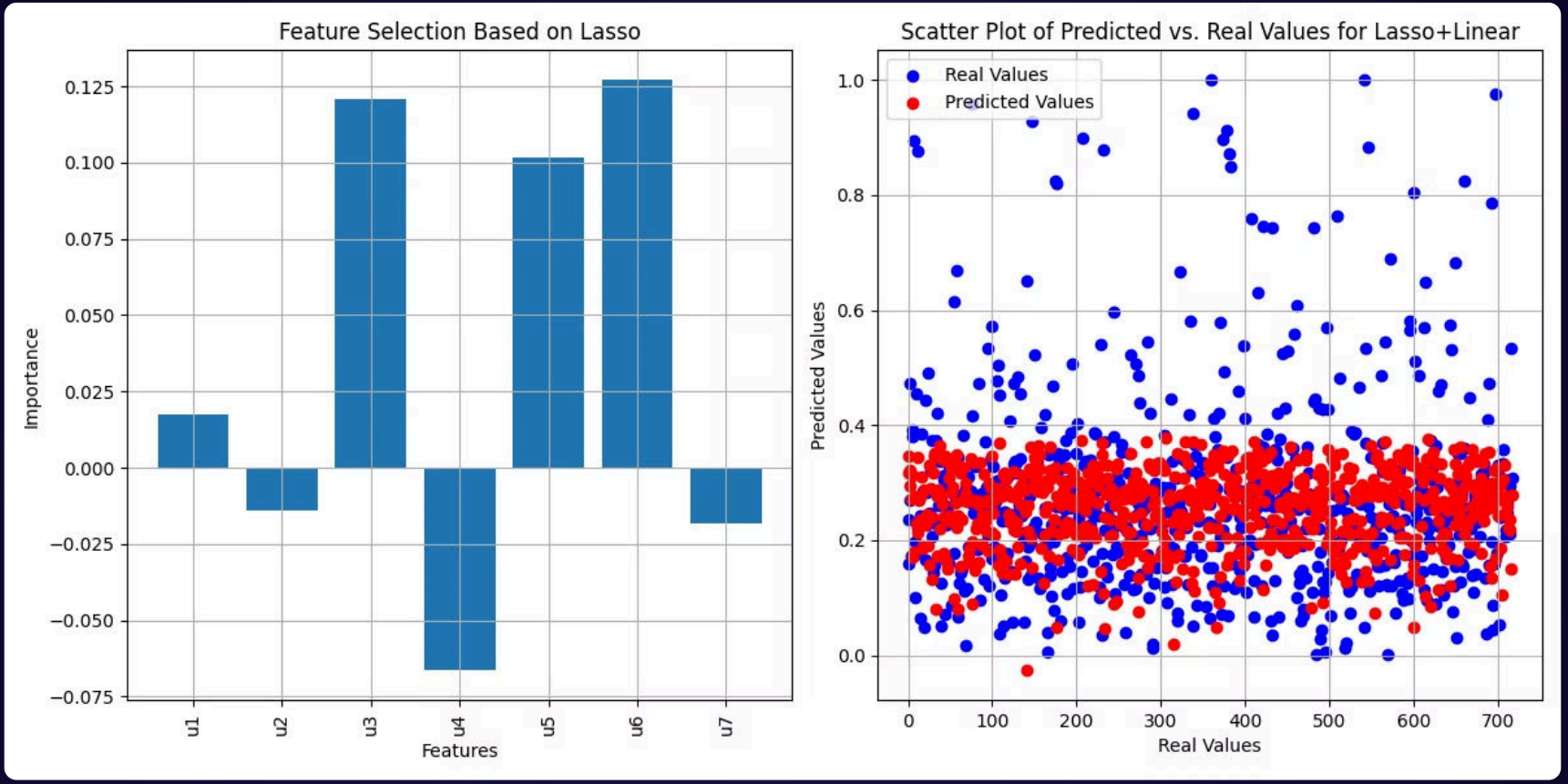
$$\hat{y}_i = w_0 + \sum_{j=1}^{m} X_{ij} w_j$$

$$J(w) = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 + \alpha \sum_{j=1}^{m} |w_j|$$

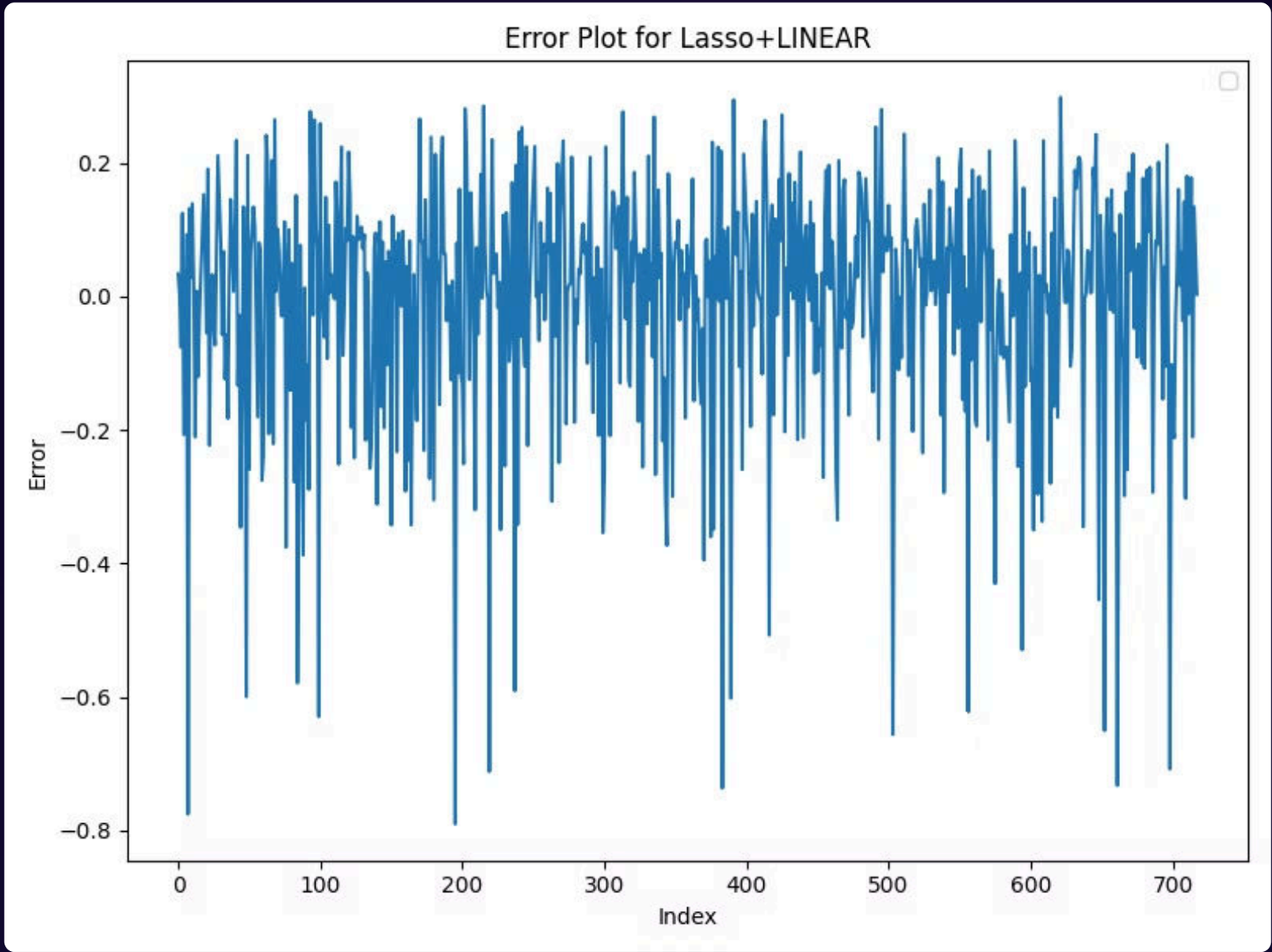
$$\|w\|^2 = \sum_{j=1}^{m} |w_j|^2$$



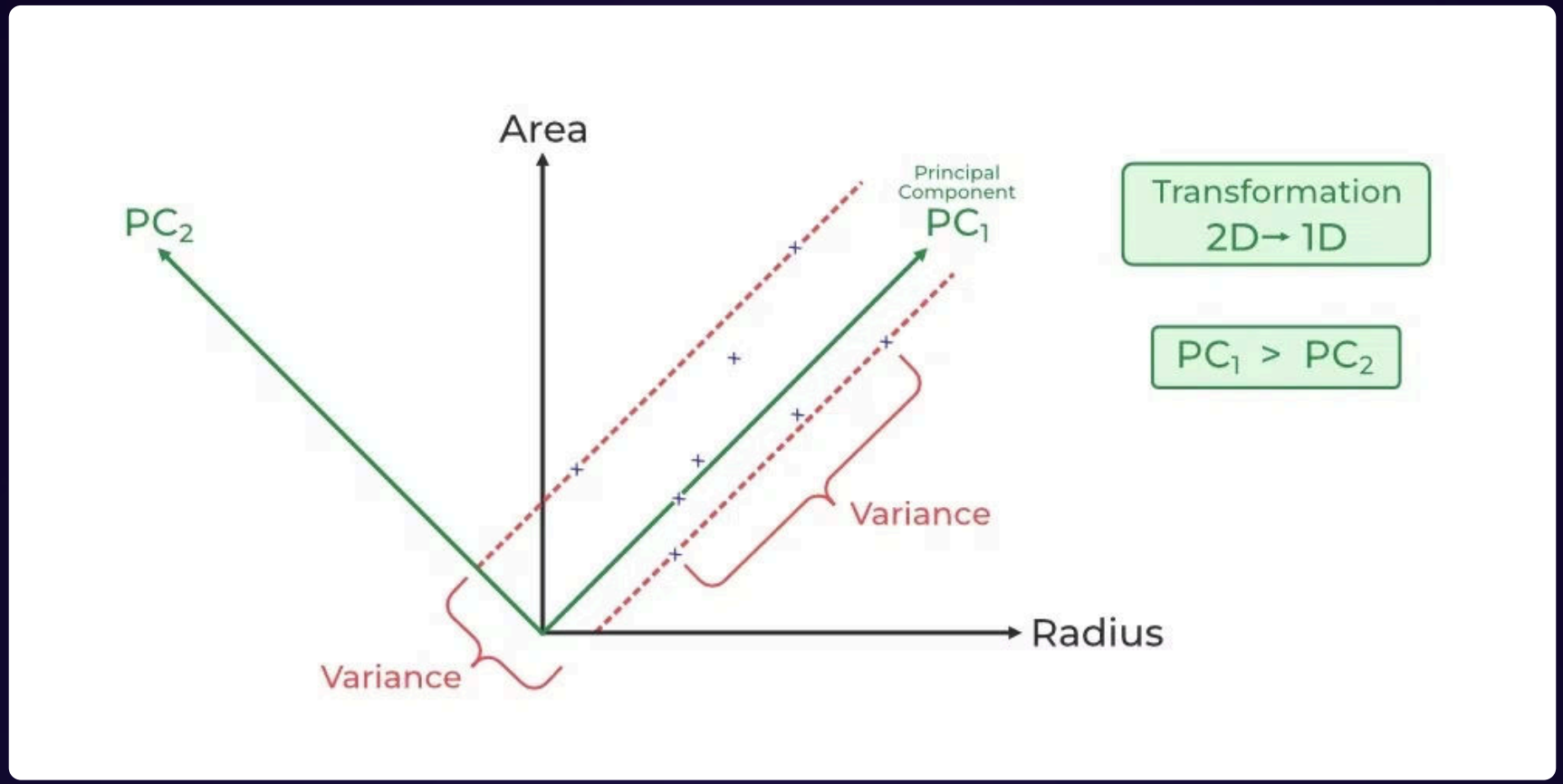
Lasso Regression Technique



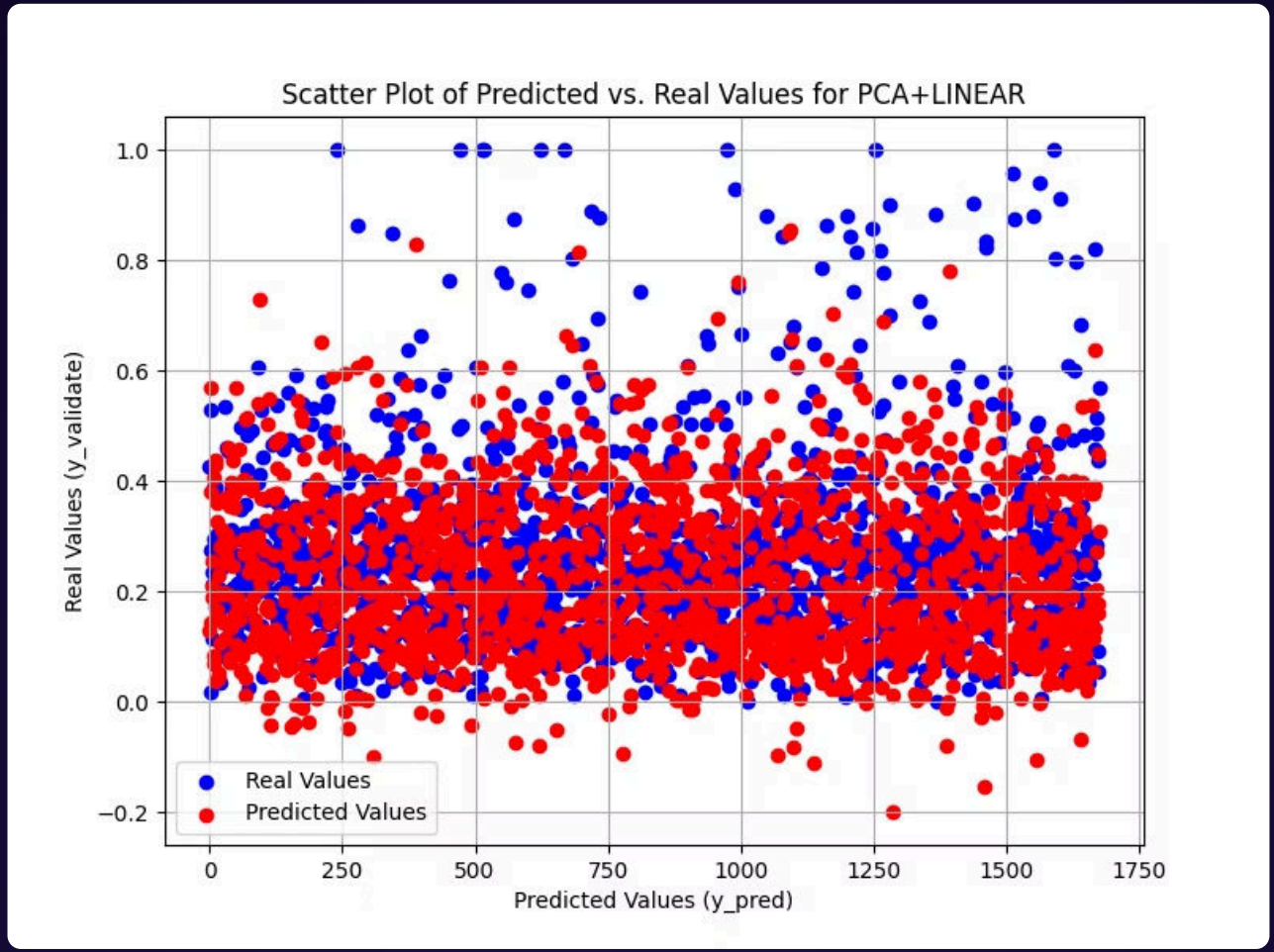
Lasso Regression Technique Error



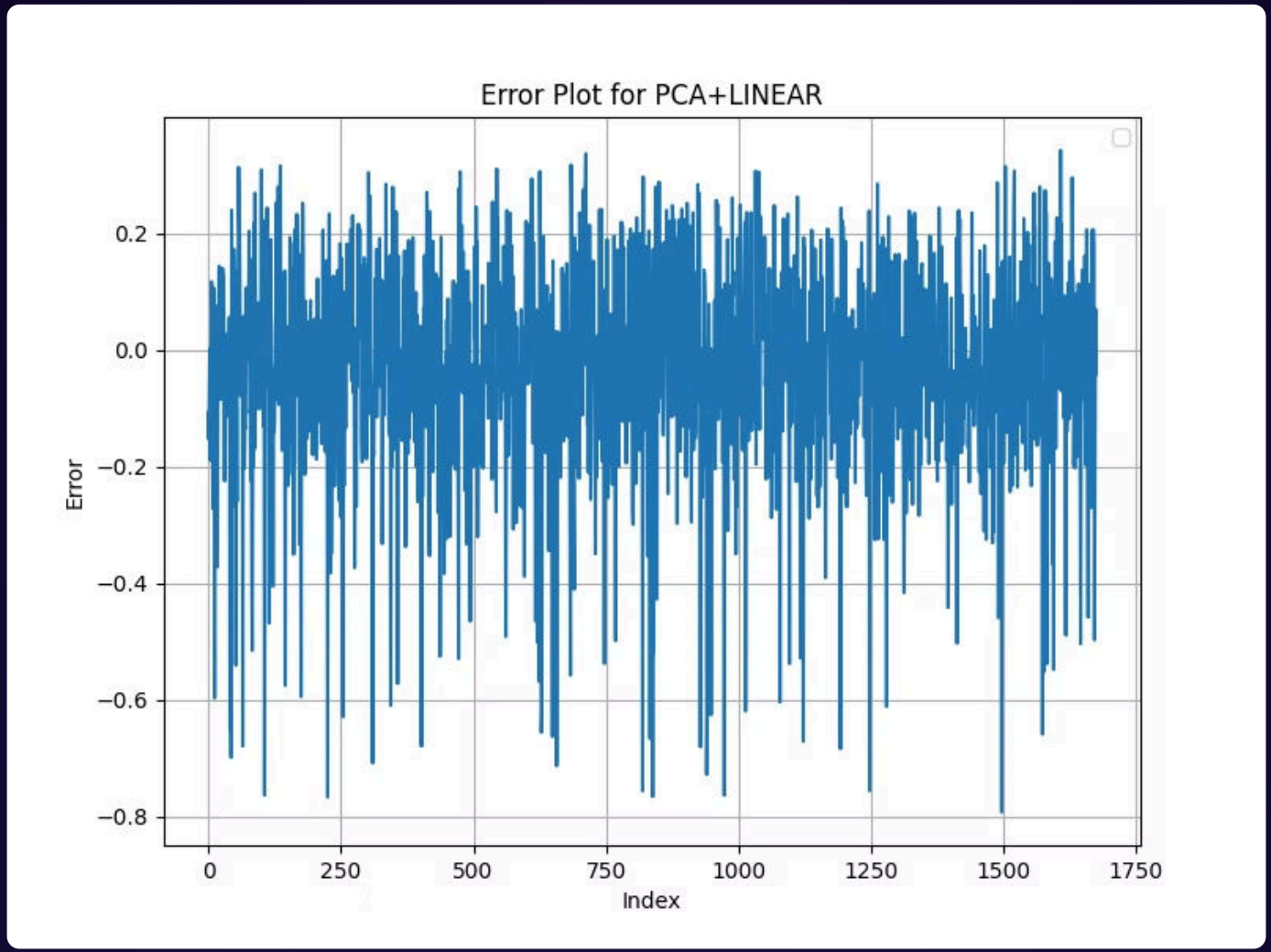
PCA based Feature Selection



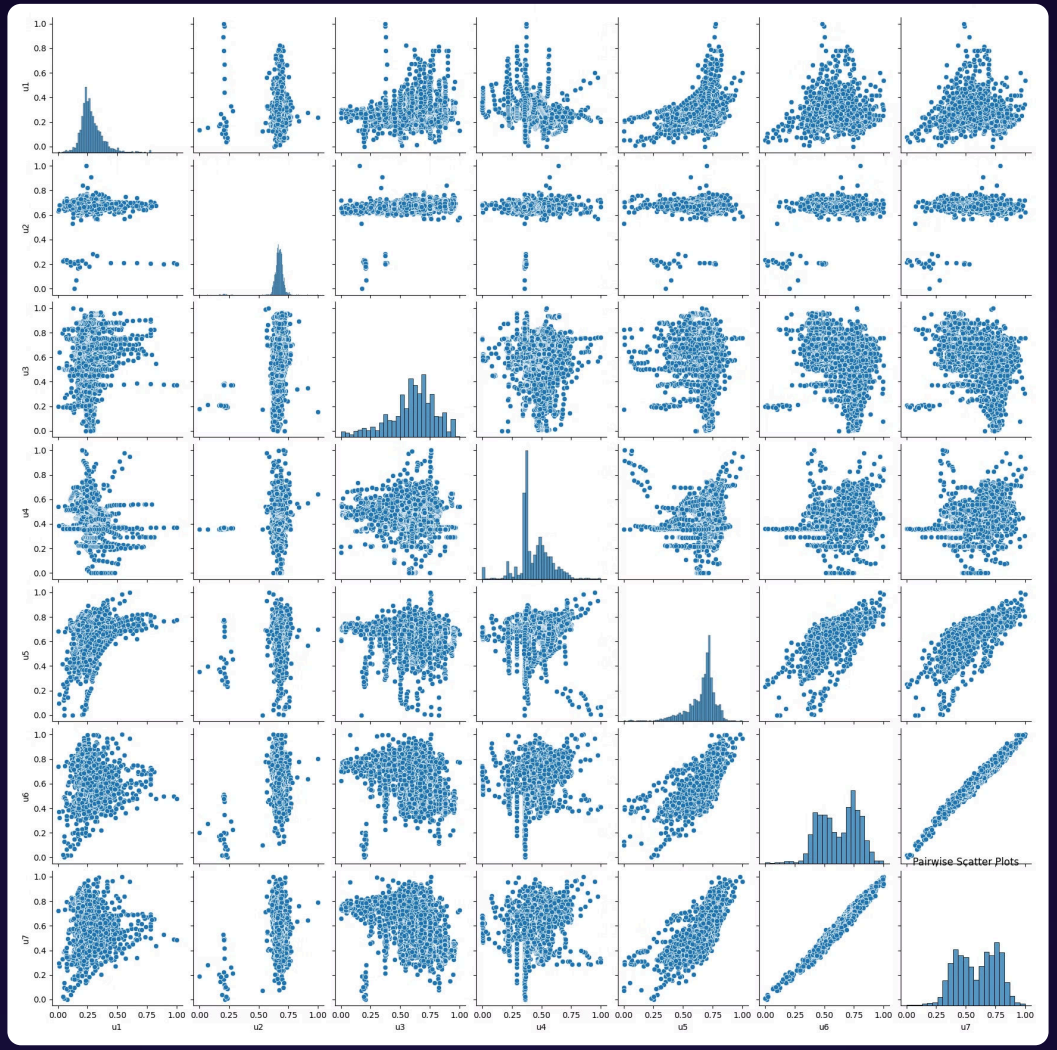
PCA based Feature Selection



PCA based Feature Selection



PCA based Feature Selection

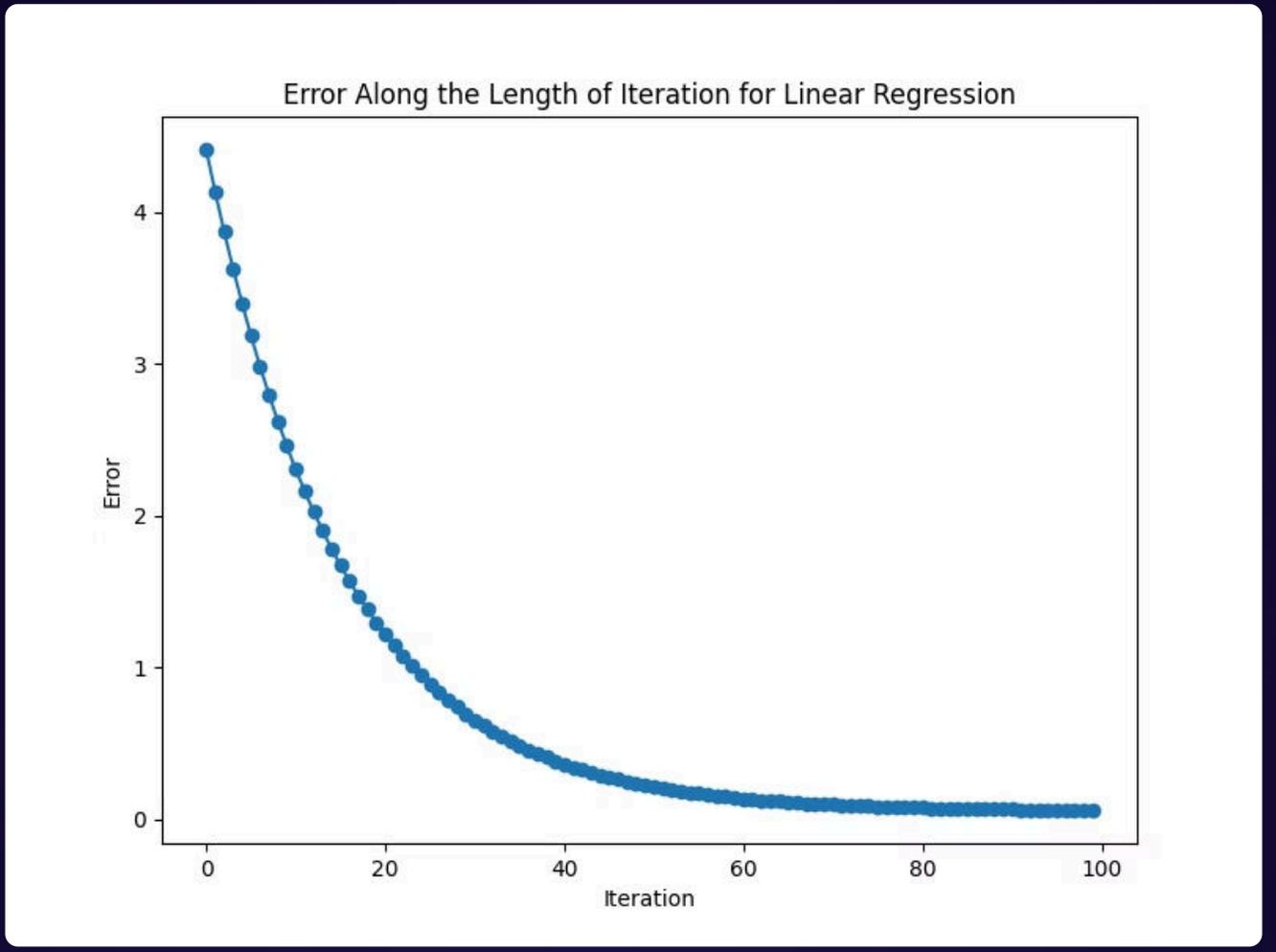


Comparing MSE LOSS for all Models

Model	Mean Squared Error	AIC
Lasso Regulation with Linear Regression	0.03241180293154075	16.858
Lasso Regulation with 2nd Order Regression	0.02481301269715393	19.392
Lasso Regulation with 3rd Order Regression	0.02244005206459875	13.423
PCA with Linear Regression	**0.044719823733125205**	**10.214**
PCA with 2nd Order Regression	0.023987154250022288	11.460
PCA with 3rd Order Regression	0.024285145721552204	11.435
Forward Feature Selection with Linear Regression	0.057633911176724555	19.809
Forward Feature Selection with 2nd Order Regression	0.030892300847618723	21.070
Forward Feature Selection with 3rd Order Regression	0.029712149840376605	20.918

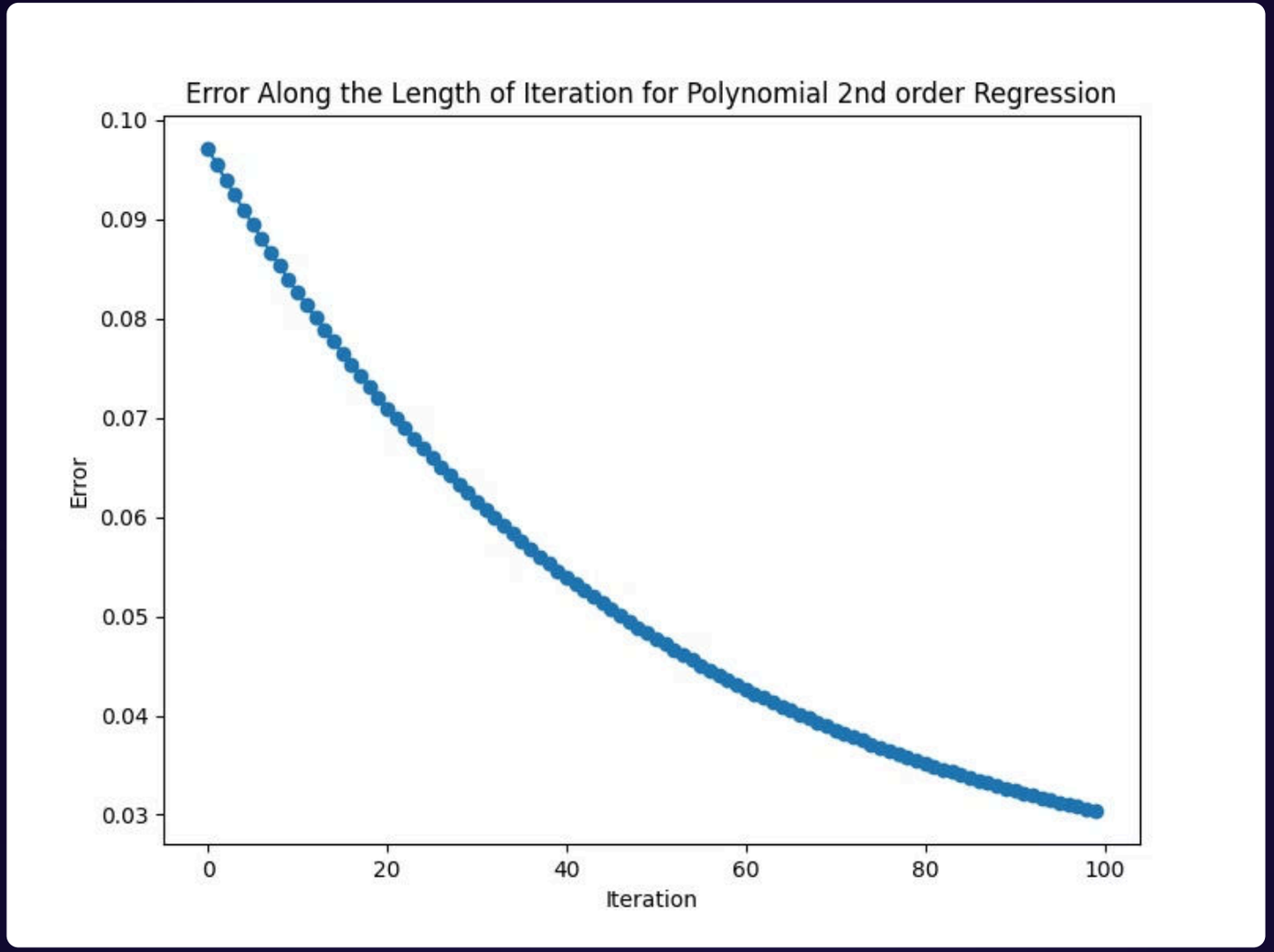
Linear Regression Model

Residuals Plot



Polynomial Regression Model

Residuals Plot



Non-Linear Function Approximations

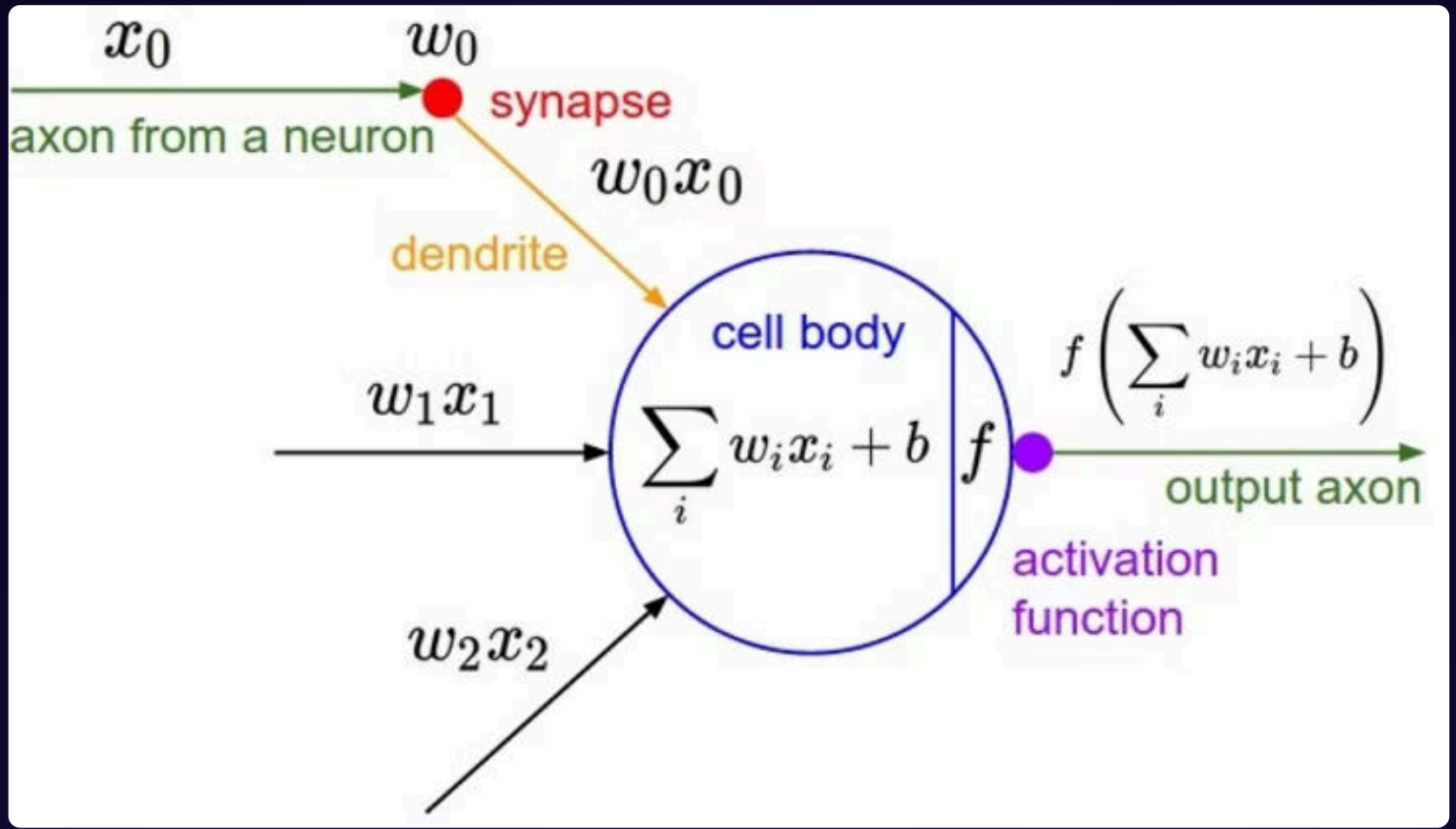
We have utilized the use of following preprocessing methods

- PCA based feature selection.

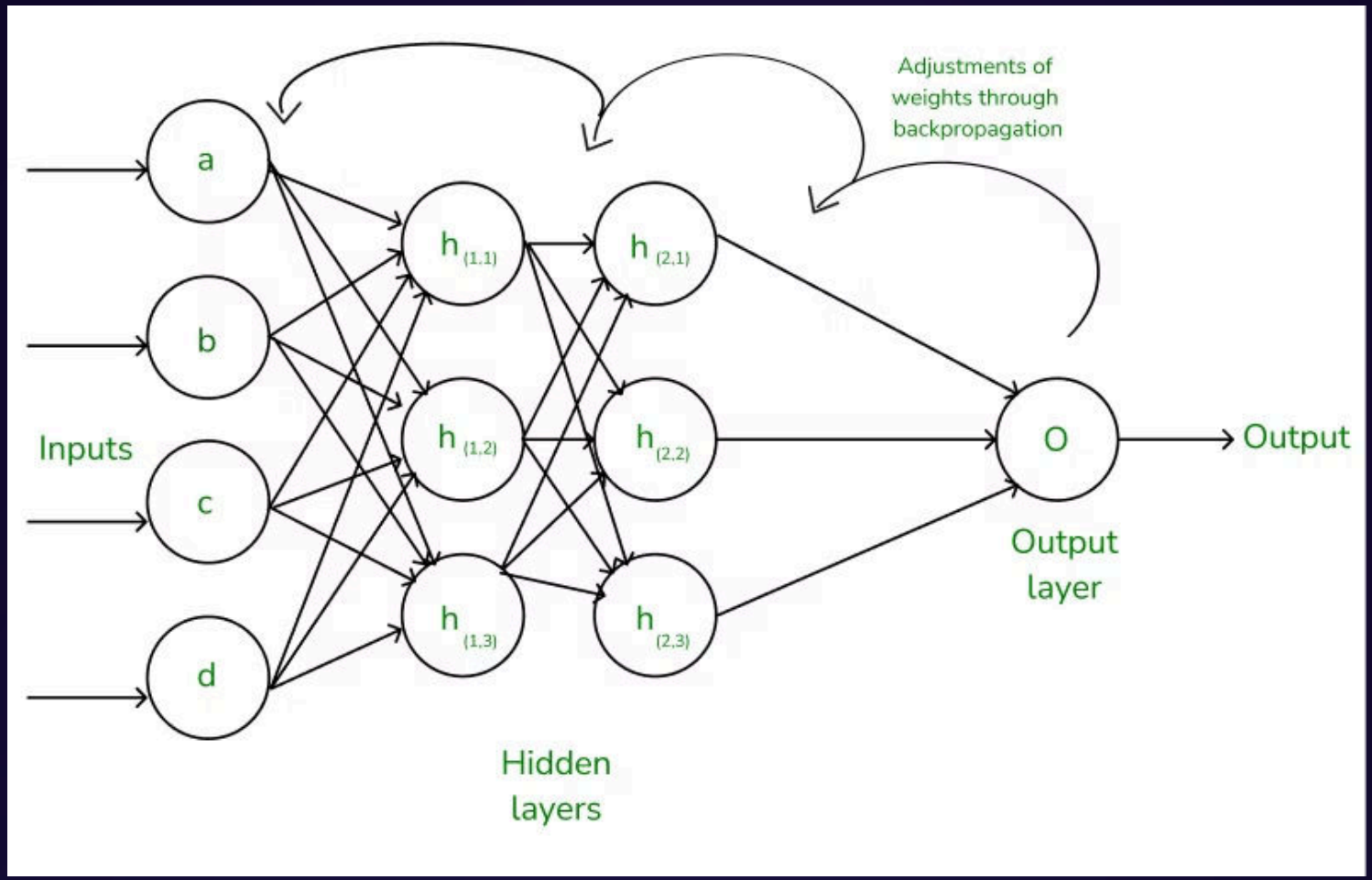
We have also built following Models to train and evaluate the model and to predict the soft sensor value

- Neural Network with Single Hidden Layer
- Neural Network with Multi Hidden Layer

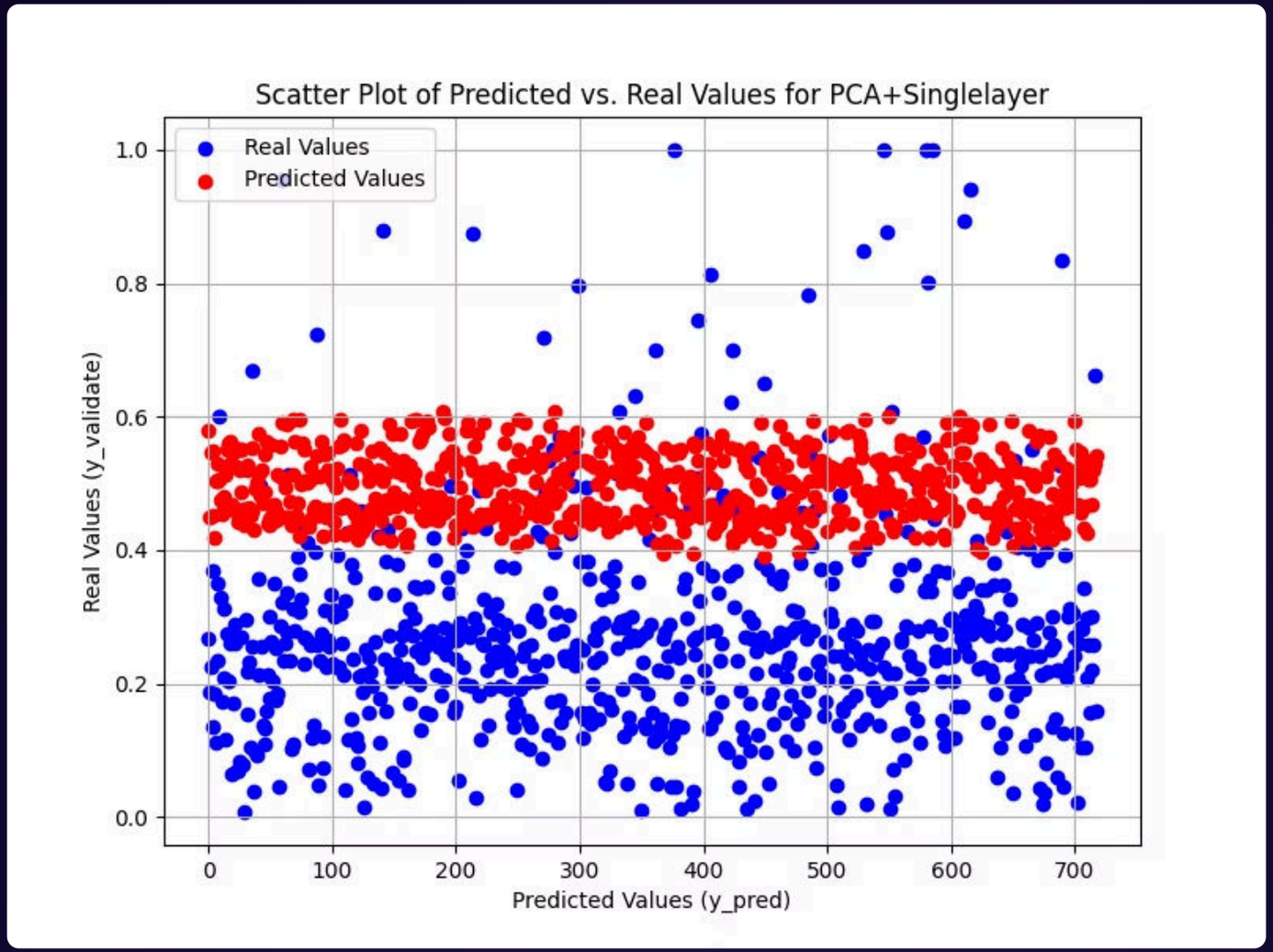
Neural Networks



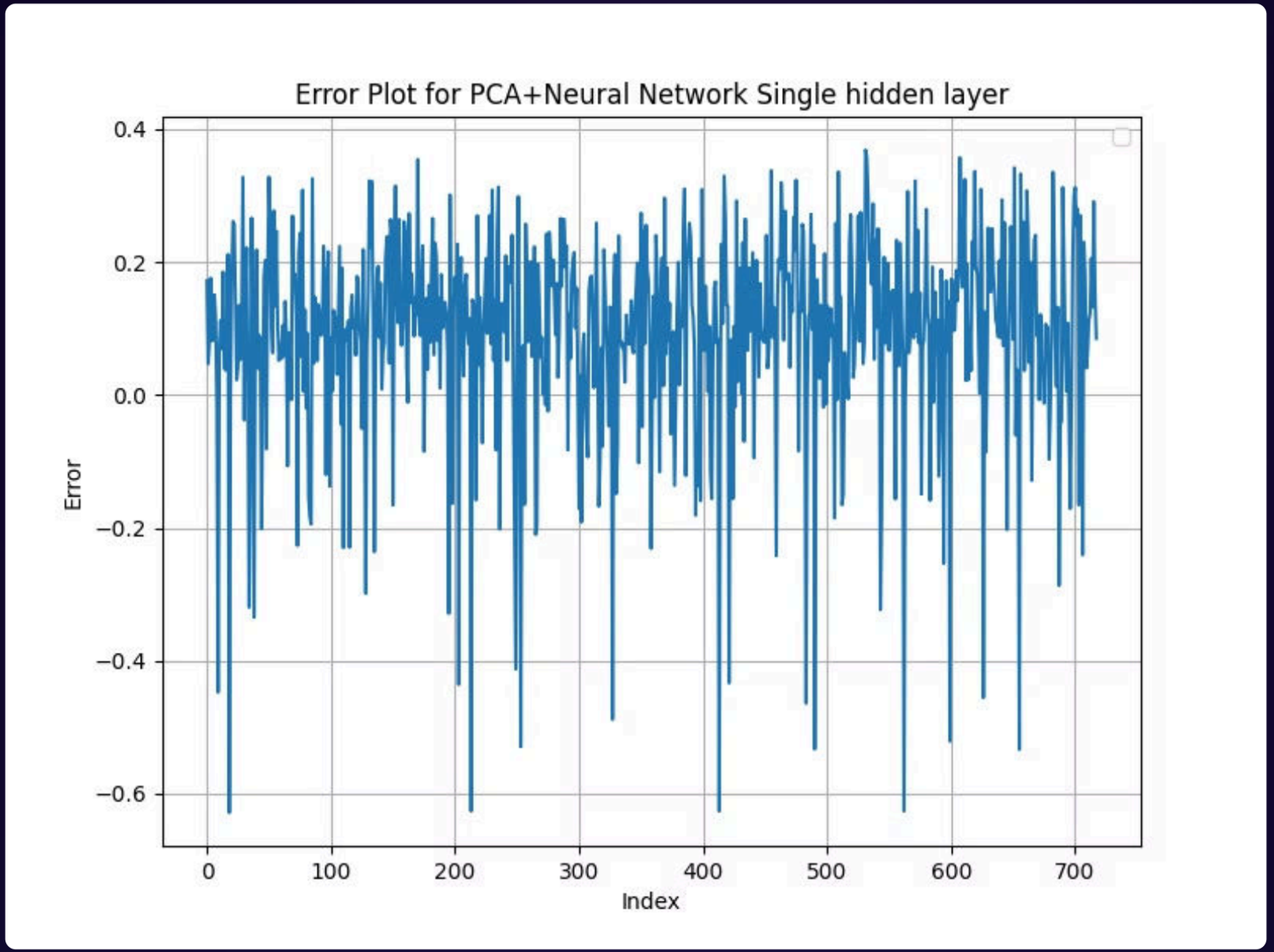
Back Propagation in Neural Networks



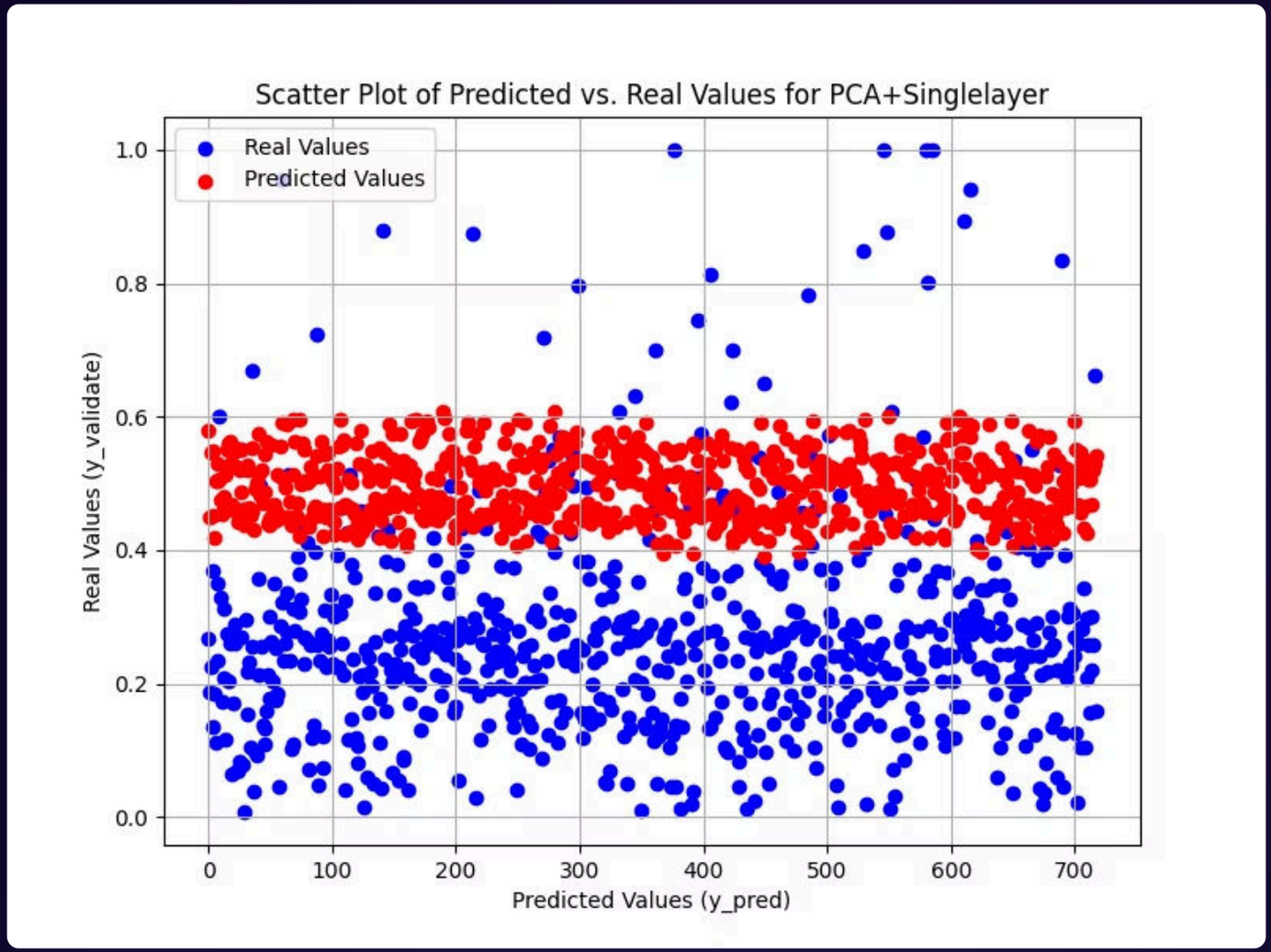
PCA with Single Hidden Layer Neural Network



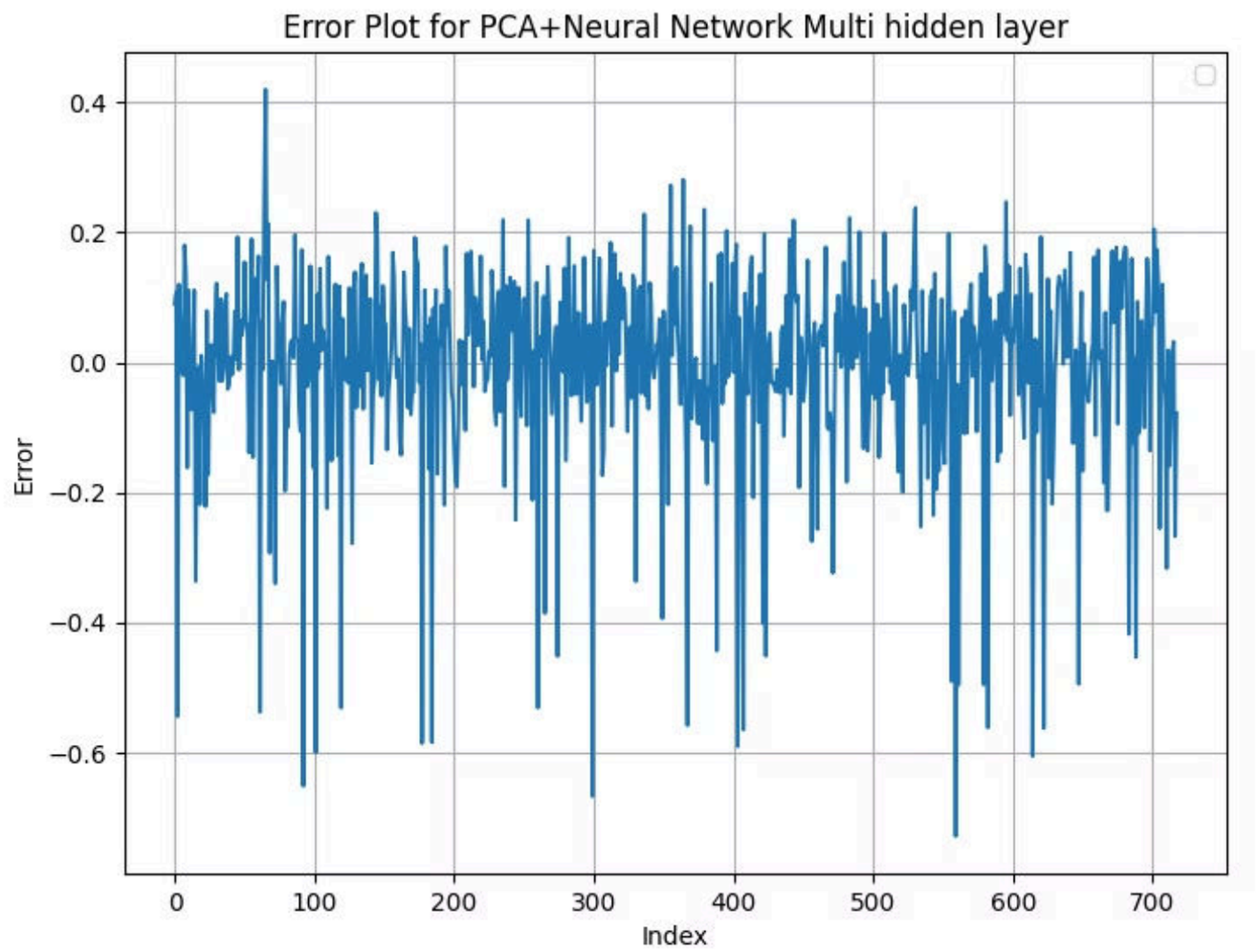
PCA with Single Hidden Layer Neural Network Error



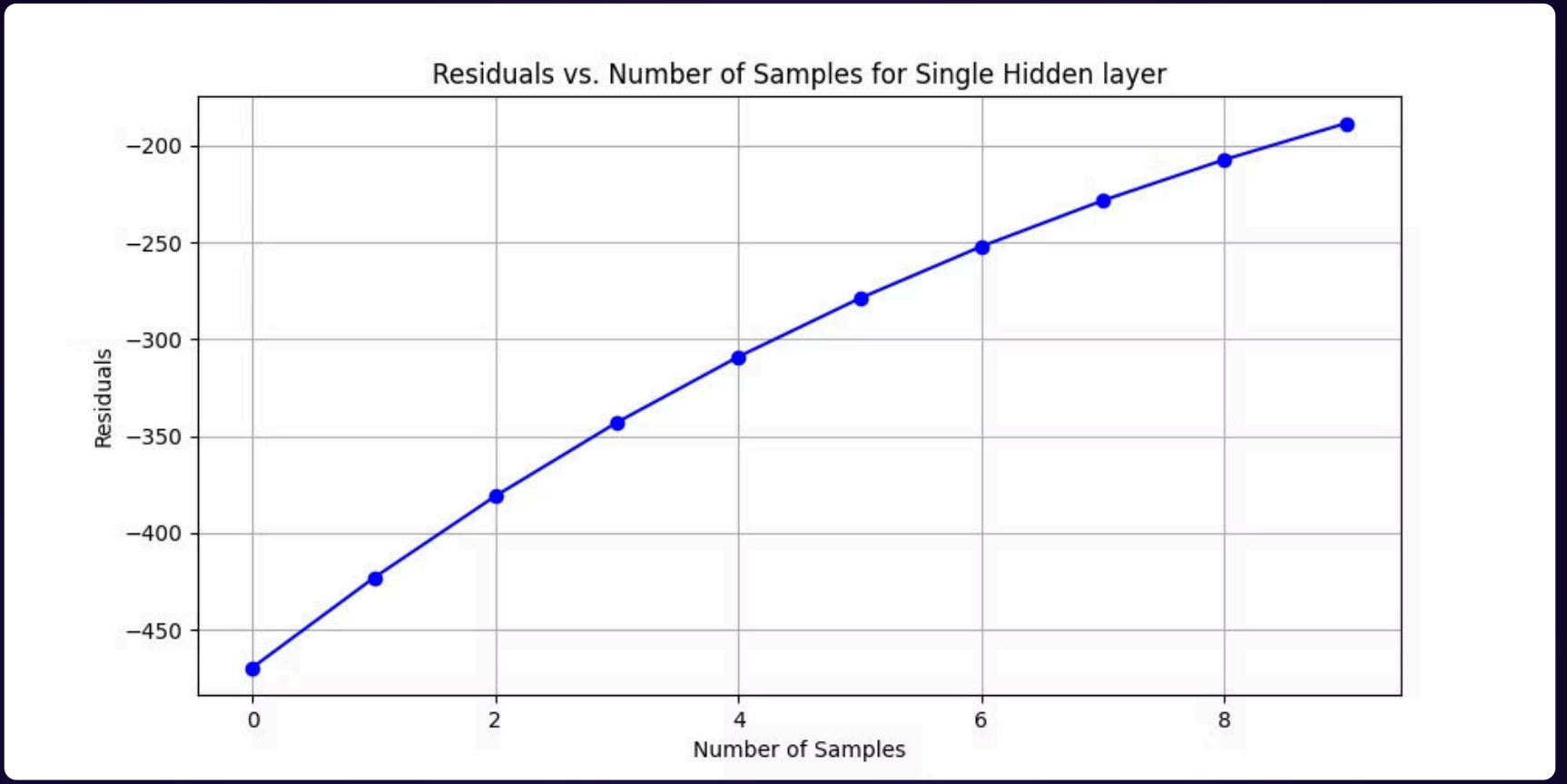
PCA with Multi Hidden Layer Neural Network



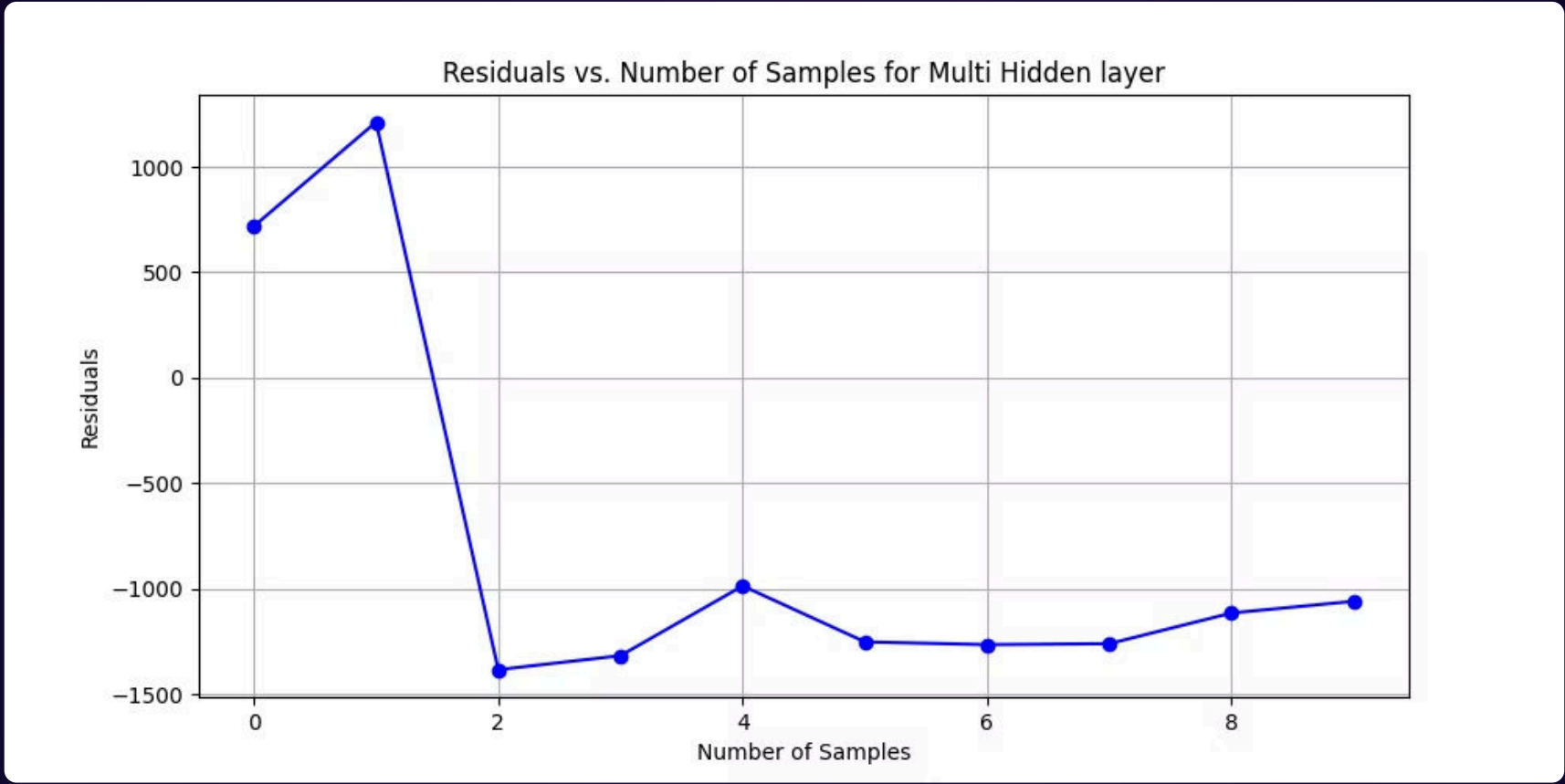
PCA with Multi Hidden Layer Neural Network Error



Residuals Neural Network Single Hidden Layer



Residuals Neural Network Multi Hidden Layer

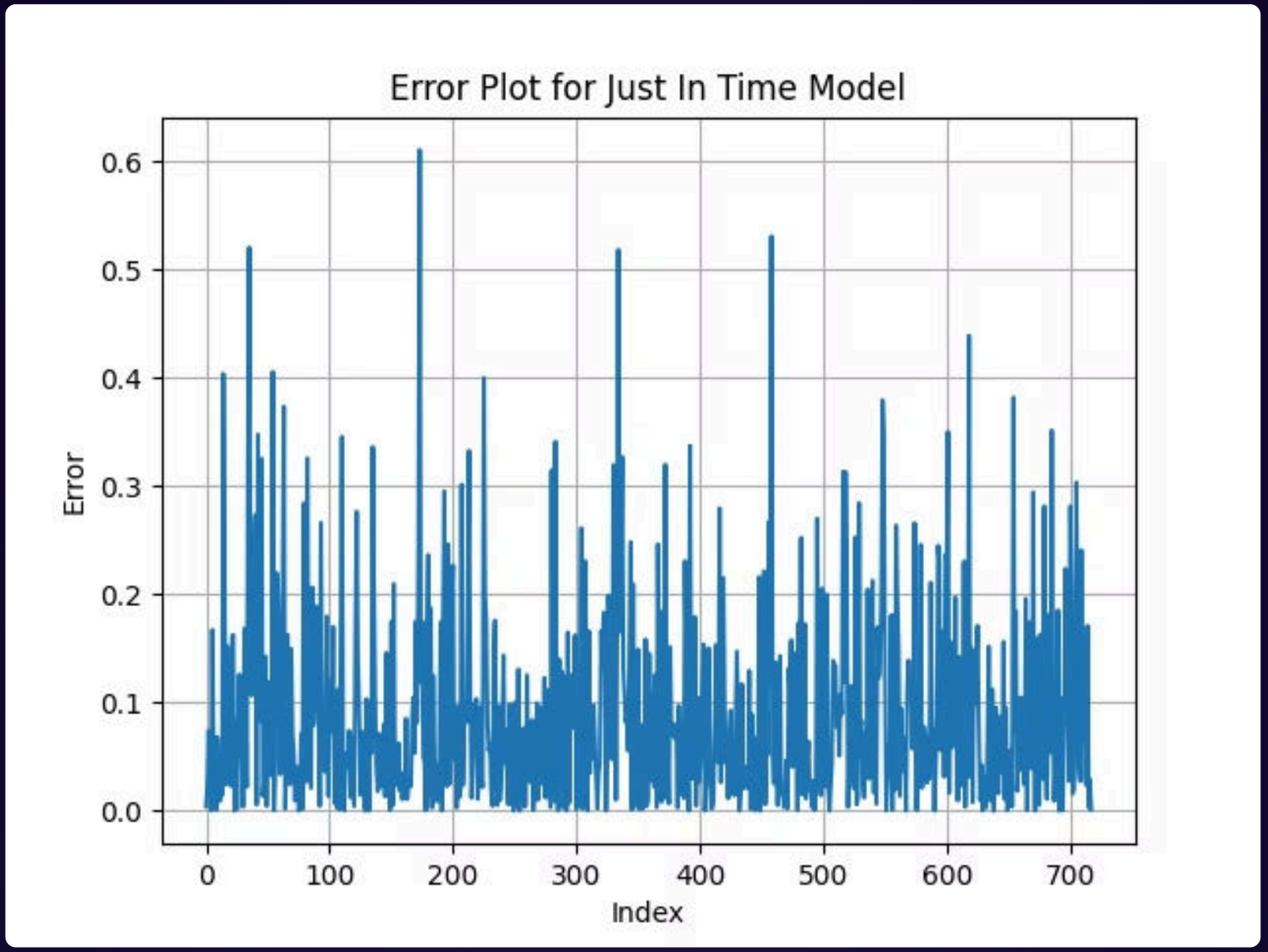


Comparing the Non Linear Model

Model	Mean Squared Error	AIC
NN with Single Hidden Layer	0.028388499570481444	11.123
NN with Mutli Hidden Layer	**0.033910758380592 21**	**10.768**

Just In Time Model

- Average MSE loss = 0.09105176840288019



Conclusion

We have successfully implemented all the preprocessing methods along with both linear and non linear models, and have validated them with metrics such as R2, MSE, AIC, BIC and compared them accordingly.

The best model came out to be lasso regression with polynomial model with 3 degree with respect to MSE metric

The best model came out to be PCA with Linear Regression with respect to AIC metric.