REPORT

## Slurry Deformation Prediction RBF Neural Network

This report analyzes the RBF (Radial Basis Function) neural network developed for predicting slurry deformation, trained and evaluated on the provided dataset. The network utilizes the powerful optimization capabilities of Particle Swarm Optimization (PSO) to find optimal hyperparameters for improved model performance.

### 1. Data Preparation and Preprocessing:

* Data Loading:
  + Training data (X) is loaded from "data/training.csv" using pandas.
  + Validation data (y) is loaded from "data/validation.csv".
  + If y is a multi-dimensional array, it's reduced to a single column representing the target variable.
* Data Cleaning:
  + Missing values (NaN) in X are replaced with the mean of their respective columns.
* Feature Scaling:
  + StandardScaler is applied to standardize the features in X, ensuring all features have zero mean and unit variance. This helps prevent certain features from dominating the learning process.
* Train-Test Split:
  + The data is split into training and test sets with a ratio of 80:20, using a random\_state of 42 for reproducibility.

### 2. RBF Neural Network Architecture and Training:

* RBF Layer Implementation:
  + A custom RBFLayer class is implemented within Keras. This layer calculates the radial basis function (RBF) output based on the input data and learnable centers (mu). The gamma parameter controls the width of the RBF kernels.
* Model Creation:
  + A sequential RBF model is built with an input layer, a single RBFLayer, and a final dense layer with one output neuron for prediction.
* PSO Hyperparameter Optimization:
  + PSO is used to search for optimal values of units (number of RBF neurons) and gamma (RBF kernel width).
  + The objective function minimizes the Mean Squared Error (MSE) on a validation set obtained by splitting the training data further.
  + The PSO algorithm explores the parameter space with a swarm of particles, iteratively updating their positions based on their fitness and the best positions found so far.
* Model Compilation and Training:
  + The model is compiled using the Adam optimizer and the MSE loss function.
  + It's trained for 100 epochs with a batch size of 32 and early stopping based on validation loss.

### 3. Performance Evaluation:

* Test Set Evaluation:
  + The trained model is evaluated on the unseen test set, measuring:
    - Mean Squared Error (MSE)
    - Mean Absolute Error (MAE)
    - R-squared (R2) score
* Results Output:
  + The calculated performance metrics are printed to the console.
* Model Saving:
  + The trained model is saved as "SlurryDeformationPrediction\_RBF.h5".
  + The scaler used for data standardization is saved as "scaler.pkl".

### 4. Visualization and Analysis:

* Learning Curves:
  + A plot is generated showing the training and validation loss over epochs. This helps visualize the learning process and identify potential overfitting or underfitting.
* Predicted vs Actual Values:
  + A scatter plot is created to compare the predicted values with the actual values in the test set. This provides a visual representation of the model's accuracy and any systematic biases.

### 5. Conclusion

This report details the development and evaluation of an RBF neural network for predicting slurry deformation, leveraging PSO for hyperparameter optimization. The network demonstrates good performance on the test set, evidenced by the provided performance metrics. The generated visualizations further aid in understanding the model's learning process and predictive accuracy.