**Milestone 3: Model Evaluation & Performance Assessment**

**Project Name:** PrognosAI: AI-Driven Predictive Maintenance System Using Time-Series Sensor Data

**Dataset:** NASA Turbofan Jet Engine Data Set

**Prepared by:** Durga Veera Prasad V

**Objective:**

Evaluate the performance of the optimized LSTM model using 5-fold cross-validation and multiple metrics, and visualize training behavior and prediction accuracy.

---

**Modules Used and Purpose:**

**numpy:** Array handling and numerical computations.

**tensorflow / keras:** Build and train the LSTM model with layers like `LSTM`, `Dense`, `Dropout`, and `BatchNormalization`.

**sklearn.preprocessing.MinMaxScaler:** Scale features and target values.

**sklearn.model\_selection.KFold:** Perform 5-fold cross-validation.

**sklearn.metrics:** Compute evaluation metrics (`r2\_score`, `mean\_squared\_error`, `mean\_absolute\_error`).

**matplotlib.pyplot:** Plot training/validation loss curves and R² scores.

**pandas:** Store and summarize cross-validation results.

**joblib:** Save scalers for future inference.

---

**Steps Implemented:**

**1. Data Preparation:**

- Used CMAPSS-style synthetic sequences (`X`) and RUL targets (`y\_raw`) for demonstration.

- Scaled features and targets using `MinMaxScaler`.

**2. Improved LSTM Model:**

- Constructed a deeper LSTM network with two LSTM layers, dropout, dense layers, and batch normalization for better generalization.

- Compiled with `Adam` optimizer and MSE loss.

**3. Cross-Validation:**

- Applied 5-fold cross-validation to evaluate model performance.

- Tracked metrics per fold: Train/Test R², RMSE, MAE.

- Plotted training and validation loss curves for each fold.

**4. Evaluation & Visualization:**

- Calculated average metrics across folds.

- Visualized R² scores per fold.

- Saved cross-validation results as `crossval\_results.csv`.

**5. Final Model Training & Saving:**

- Retrained LSTM on full dataset.

- Saved optimized model (`.keras`) and scalers (`.pkl`) for deployment or inference.

---

**Deliverables:**

- Optimized LSTM model with final weights.

- Scalers for feature and target normalization.

- Cross-validation metrics and plots.

- CSV file of fold-wise results.

**Evaluation:**

- Verified high R² scores (>95% target on training data).

- Checked convergence via loss curves.

- Confirmed generalization using cross-validation metrics.