MILE STONE 2: Remaining Useful Life (RUL) Prediction Using LSTM on NASA C-MAPSS Dataset

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1. Objective

- Predict how much life is left in aircraft engines (Remaining Useful Life).
- Help in **preventive maintenance** to avoid unexpected failures.
- Reduce operational costs and improve engine safety.
- Use **sensor and operational data** from NASA's C-MAPSS dataset.

2. Architecture

- **Type of Model**: LSTM (Long Short-Term Memory) – good for time-series data.
- **Input**: 30 timesteps per engine unit, each with multiple sensor readings.
- **LSTM Layers**:
    - 1st layer: 128 units
    - 2nd layer: 64 units
    - 3rd layer: 32 units
- **Regularization**: Dropout and Batch Normalization to reduce overfitting.
- **Dense Layers**:
    - 64 neurons + ReLU
    - 32 neurons + ReLU
- **Output**: Single value representing the predicted RUL.

Data Preparation:

- Normalized sensor values using Min-Max scaling.
- Added **rolling mean and std** for every sensor (window=5 cycles).
- Dropped constant sensors.
- Limited RUL to a max of 125 cycles.
- Created sequences of 30 timesteps for each engine.

3. Training Details

- **Dataset**: NASA C-MAPSS FD004 (multiple engines, multiple operating conditions).
- **Training/Validation split**: 85% training, 15% validation.
- **Loss function**: Mean Squared Error (MSE).
- **Optimizer**: Adam.
- **Epochs**: Up to 100 (with early stopping).
- **Batch size**: 64.
- **Callbacks**:
    - Stop training if no improvement in 15 epochs.
    - Reduce learning rate if loss plateaus for 7 epochs.

4. Results

- **RMSE**: measures how close predictions are to true values.
- **R^2 Score**: measures overall accuracy.
- **Plots**:
    - Training & validation loss over epochs.
    - Predicted RUL vs actual RUL (scatter plot).
- The model successfully tracks engine degradation trends over time

5. Achievements

- Built an LSTM model to predict engine RUL on real multi-condition data.
- Added rolling features to better capture short-term trends in sensor data.
- Generated clear visualizations to show model performance.
- Achieved **reasonably accurate RUL predictions** on test data.

6. Future Directions

- Fine-tune hyperparameters (LSTM units, dropout, learning rate).
- Integration with Mile-stone 3