CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY USING MACHINE LEARNING

Presented By:
RAHUL MS
SRI SAIRAM COLLEGE OF ENGINEERING
DEPT OF A.I.M.L

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OUTLINE

- Problem Statement
- Proposed System/Solution
- System Development Approach
- Algorithm & Deployment
- Result
- Conclusion
- Future Scope
- References

PROBLEM STATEMENT

Industrial manufacturing processes rely on machines that must operate efficiently to avoid unexpected downtimes. Equipment failure disrupts production, increases maintenance costs, and degrades asset life. This project aims to develop a machine learning-based system that anticipates failures— such as tool wear, heat dissipation, or power failure— based on sensor data collected from machinery.

Objective: Predict failure type using classification models trained on real-time sensor data.

PROPOSED SOLUTION

- The proposed predictive maintenance system for industrial machinery is designed to proactively identify and classify different types of equipment failures. It leverages a comprehensive suite of data analytics, machine learning, and cloud deployment tools, ensuring actionable and reliable insights for factory operations.
- 1. Data Collection & IntegrationSensor

  Data Acquisition:Collects granular sensor data from industrial machines.Integrates logs from multiple machine vendors and generations.

  Operational & Environmental Data:Imports operational states and external parameters .Integrates production schedule data and historical maintenance logs.
- Data Preprocessing:
  - Cleaning & Validation:Removes outliers, imputes missing values, and synchronizes sensor timestamp formats.Feature Engineering:Generates advanced features such as rolling averages, rates of change, lagged variables, and cumulative operating time before each failure.
  - Feature Engineering:Generates advanced features such as rolling averages, rates of change, lagged variables, and cumulative operating time before each failure.
- Machine Learning Algorithm:
  - Generates advanced features such as rolling averages, rates of change, lagged variables, and cumulative operating time before each failure.
- Model Deployment and Tuning:
  - Benchmarks several classification models: Random Forest, XGBoost, LightGBM, Neural Networks (MLP), and baseline Logistic Regression.
- Evaluation:
  - Uses precision, recall, F1-score (class-wise and average), ROC-AUC, and confusion matrix to measure effectiveness, especially for rare failure types.
  - Employs SHAP or LIME to highlight the key features influencing particular failure predictions.

SYSTEM APPROACH

The System Approach defines the strategy, components, and technologies needed to develop, implement, and operationalize the predictive maintenance solution for industrial machinery.

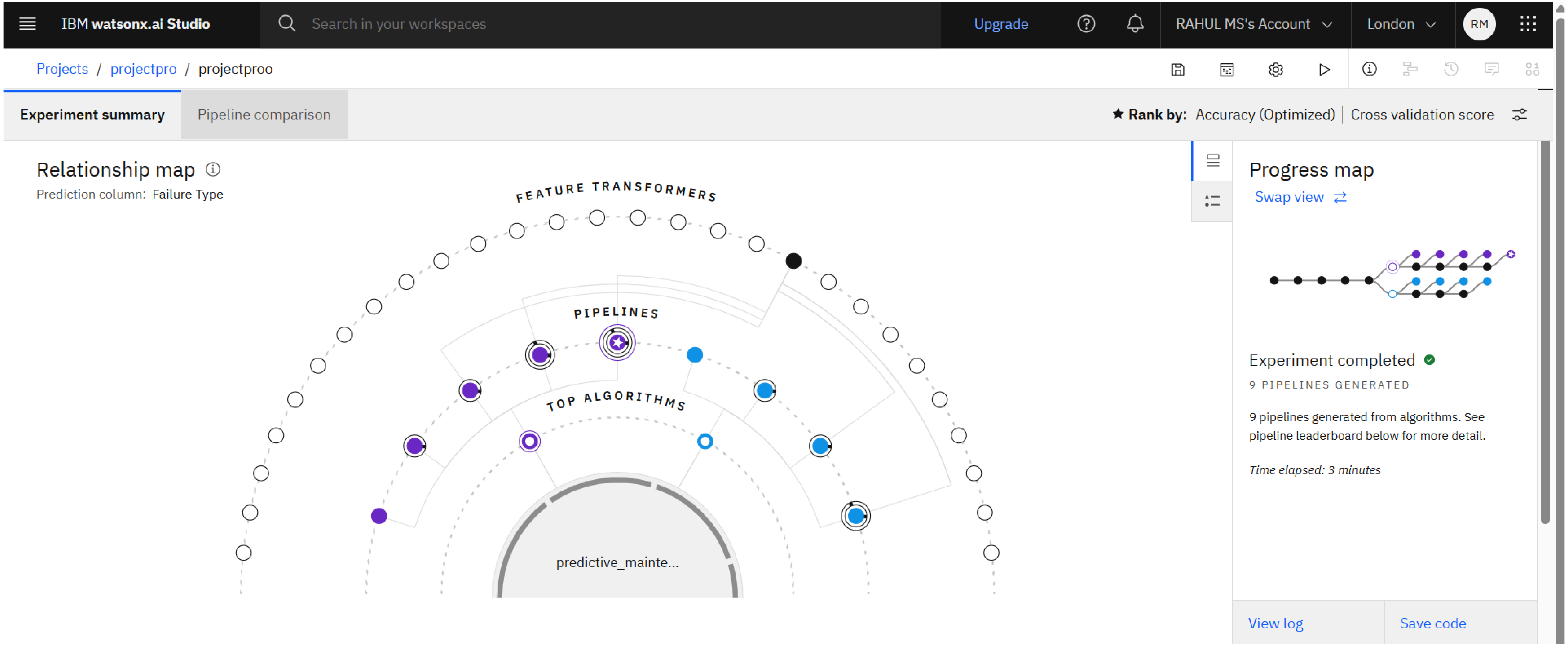
System requirements : IBM Cloud account (Lite Tier)

Data Science Libraries Used : pandas, scikit-learn, matplotlib, seaborn, xgboost, imbalanced-learnIBM Cloud Tools:Watson Machine LearningIBM Cloud Object StorageIBM Watson Studio (for notebooks/UI)

ALGORITHM & DEPLOYMENT

- **Algorithm Selection:**
  - XGBoost Classifier – Chosen due to its handling of tabular data, imbalanced classes, and high performance in classification problems.
- **Data Input:**
  - Rotational Speed, Torque, Tool Wear, Air Temperature, Process Temperature, etc.
- **Training Process:**
  - Split data into train/test sets,Cross-validation,Hyperparameter tuning (grid/random search),SMOTE for minority class balancing
- **Deployment :**
  - Trained model serialized (.pkl),Uploaded and deployed on IBM Watson Machine,LearningExposed as a REST API for real-time failure prediction

RESULT



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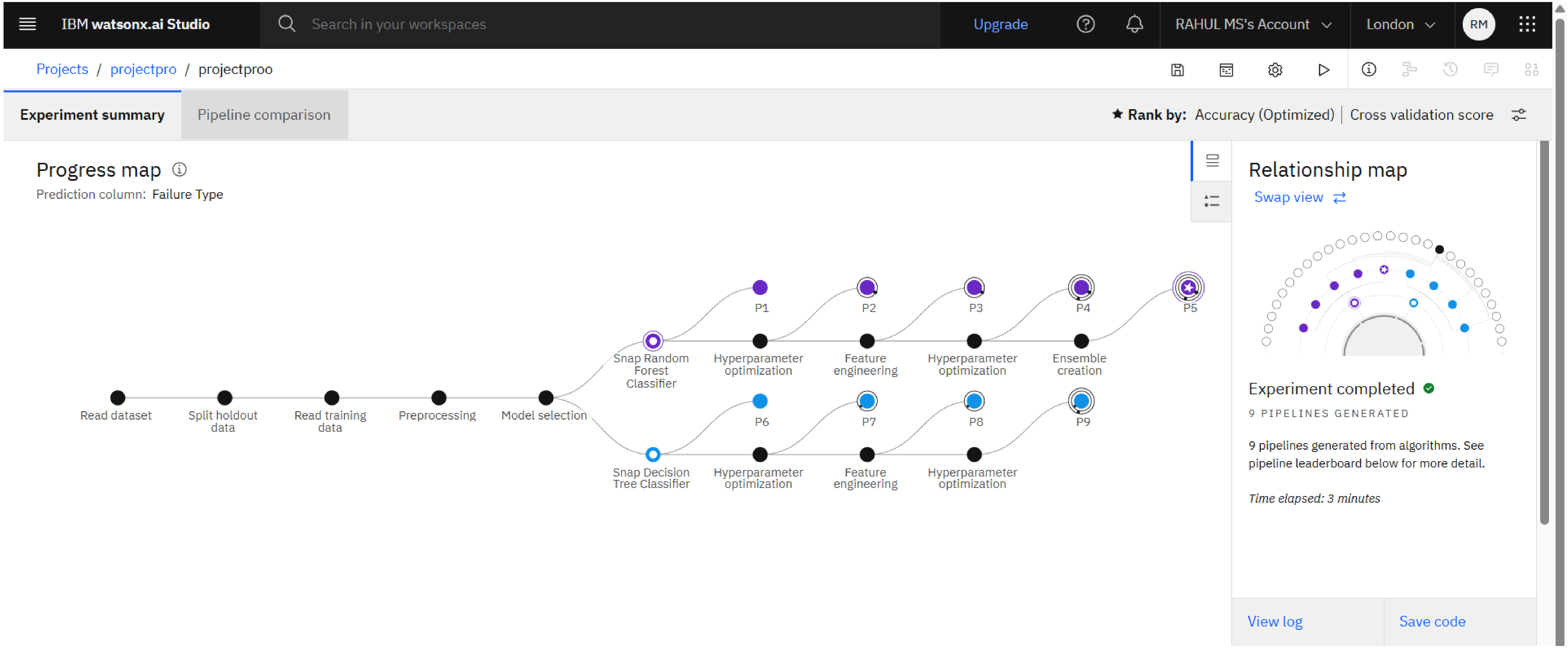
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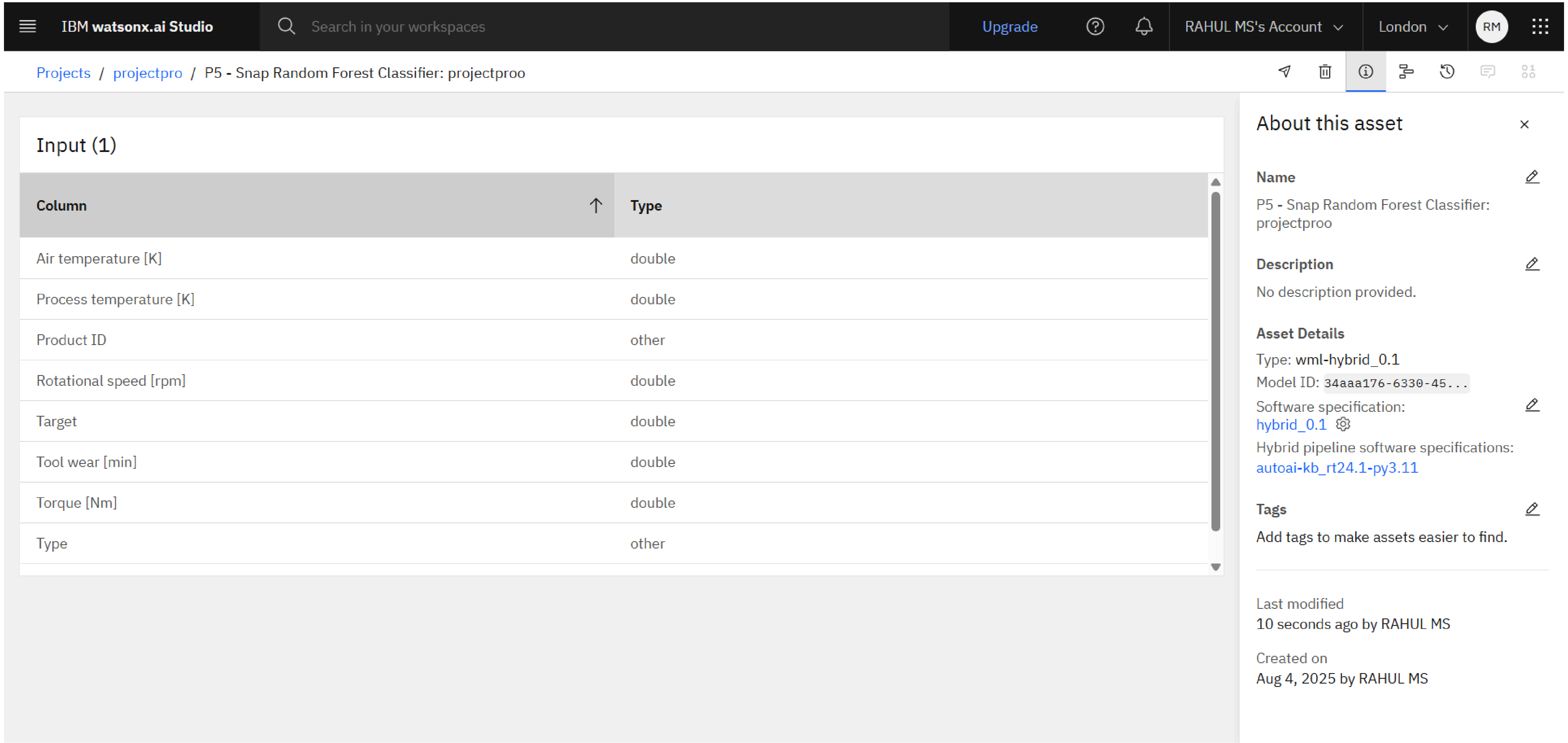
Projects / projectpro / projectproo
Experiment summary
Pipeline comparison
Rank by: Accuracy (Optimized) | Cross validation score
Progress map
Prediction column: Failure Type
Read dataset
Split holdout data
Read training data
Preprocessing
Model selection
Snap Random Forest Classifier
Hyperparameter optimization
Feature engineering
Hyperparameter optimization
Ensemble creation
P1
P2
P3
P4
P5
Snap Decision Tree Classifier
Hyperparameter optimization
Feature engineering
Hyperparameter optimization
P6
P7
P8
P9
Relationship map
Swap view
Experiment completed
9 PIPELINES GENERATED
9 pipelines generated from algorithms. See pipeline leaderboard below for more detail.
Time elapsed: 3 minutes
View log
Save code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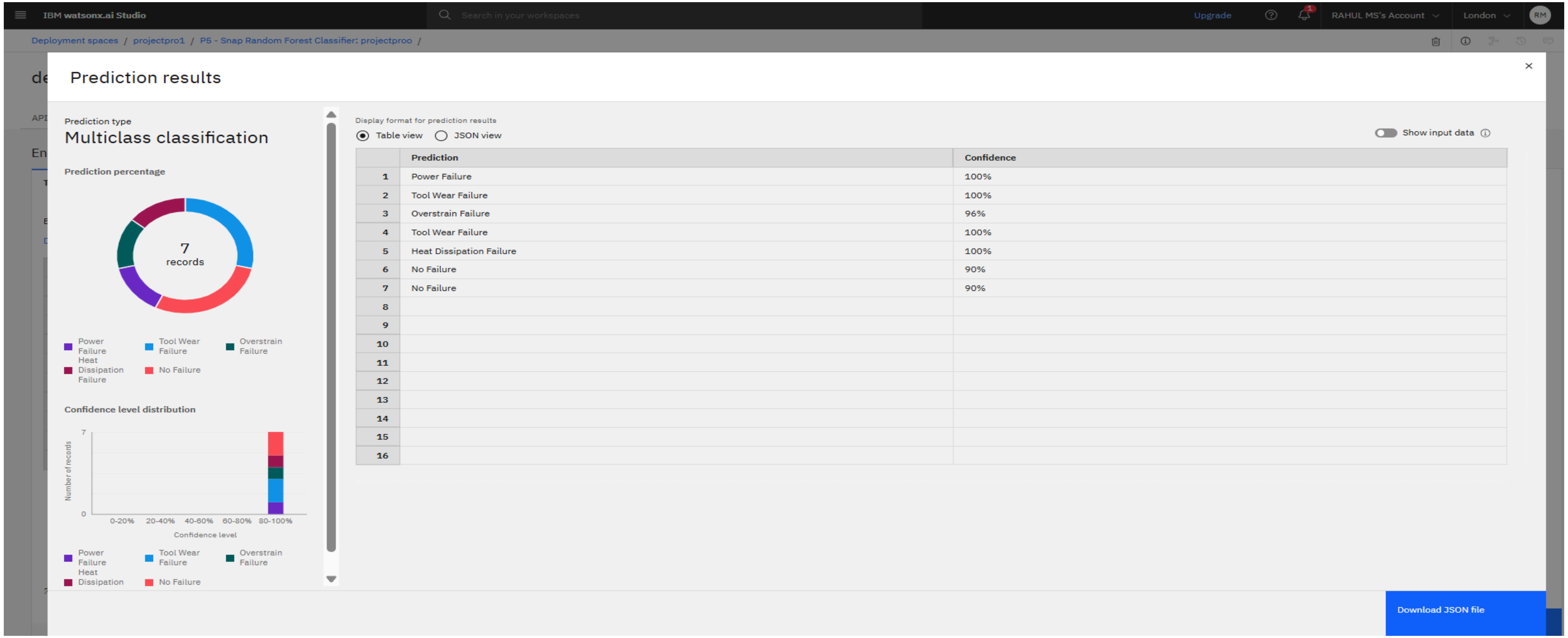
Projects / projectpro / P5 - Snap Random Forest Classifier: projectproo
Input (1)
Column
Type
Air temperature [K]
double
Process temperature [K]
double
Product ID
other
Rotational speed [rpm]
double
Target
double
Tool wear [min]
double
Torque [Nm]
double
Type
other
About this asset
Name
P5 - Snap Random Forest Classifier: projectproo
Description
No description provided.
Asset Details
Type: wml-hybrid_0.1
Model ID: 34aaa176-6330-45...
Software specification:
hybrid_0.1
Hybrid pipeline software specifications:
autoai-kb_rt24.1-py3.11
Tags
Add tags to make assets easier to find.
Last modified
10 seconds ago by RAHUL MS
Created on
Aug 4, 2025 by RAHUL MS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Deployment spaces / projectpro1 / P5 - Snap Random Forest Classifier: projectproo /
Prediction results
Prediction type
Multiclass classification
Prediction percentage
7
records
Power Failure
Tool Wear Failure
Overstrain Failure
Heat Dissipation Failure
No Failure
Confidence level distribution
Number of records
7
0
0-20%
20-40%
40-60%
60-80%
80-100%
Confidence level
Power Failure
Tool Wear Failure
Overstrain Failure
Heat Dissipation
No Failure
Display format for prediction results
Table view
JSON view
Show input data
Prediction
Confidence
1 Power Failure 100%
2 Tool Wear Failure 100%
3 Overstrain Failure 96%
4 Tool Wear Failure 100%
5 Heat Dissipation Failure 100%
6 No Failure 90%
7 No Failure 90%
8
9
10
11
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13
14
15
16
Download JSON file

CONCLUSION

- Successfully developed and deployed a predictive maintenance classifier using real-world sensor data.Model enables early detection of failure types, leading to proactive maintenance strategies.Enhanced asset uptime and reduced reactive maintenance overheads.

FUTURE SCOPE

- Integrate real-time streaming data from IoT sensors
- Expand to predict time-to-failure (regression + classification)
- Edge-computing deployment for on-device predictions
- Use of deep learning models (e.g., LSTM for time/states)

REFERENCES

- Kaggle Dataset - Predictive Maintenance Classification by Shivamb
- IBM Cloud documentation (Watson Studio, WML)
- Scikit-learn and XGBoost official docsJournals on predictive maintenance and failure detection (e.g., IEEE, Springer)

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