CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY

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OUTLINE

- Problem Statement
- Proposed System/Solution
- System Development Approach
- Algorithm & Deployment
- Result (Output Image)
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PROBLEM STATEMENT

- Develop a predictive maintenance model for a fleet of industrial machines to anticipate failures before they occur. This project will involve analyzing sensor data from machinery to identify patterns that precede a failure. The goal is to create a classification model that can predict the type of failure (e.g., tool wear, heat dissipation, power failure) based on real-time operational data. This will enable proactive maintenance, reducing downtime and operational costs.

PROPOSED SOLUTION

The proposed system is to collect and process sensor data from industrial machines to identify failure-related patterns.

Label and prepare the data based on known failure events. Use machine learning algorithms (e.g., Random Forest, XGBoost, or Neural Networks) to develop a classification model capable of predicting specific failure types (such as tool wear, power failure, or heat dissipation issues).

Deploy the model for real-time monitoring and integrate alerts to notify operators before failures occur. This approach will support timely maintenance, reduce downtime, and optimize operational efficiency.

The solution will consist of the following components:

- Data Collection:
  - Gather historical machine data, including time, sensor readings (e.g., temperature, vibration, voltage), and failure logs.
  - Utilize real-time streaming data from machine sensors to capture operational states continuously.
- Data Preprocessing:
  - Clean and preprocess the collected data to handle missing values, noise, and outliers.
  - Perform feature engineering to extract critical features like rolling averages, peak values, and rate of change.
- Machine learning Algorithm:
  - Implement a supervised classification algorithm, such as Random Forest, XGBoost, or a Deep Neural Network, to predict machine failure types.
  - Optionally, experiment with LSTM or other time-series models if sequential patterns improve prediction accuracy.

- Deployment:
  - Develop a dashboard or application that provides real-time failure predictions and alerts to maintenance personnel.
  - Develop a user-friendly web interface or dashboard using IBM Cloud services like IBM Cloud Foundry or IBM Code Engine to display real-time machine failure predictions and alerts.
  - Integrate the deployed model with IBM IoT Platform to stream real-time sensor data from industrial machines into the cloud environment for prediction.
- Evaluation:
  - Evaluate model performance using classification metrics such as Precision, Recall, F1-Score, and Confusion Matrix.
  - Continuously monitor prediction accuracy and retrain the model periodically using fresh sensor data.
  - Fine-tune the model based on operator feedback and evolving machine behavior.

SYSTEM APPROACH

The "System Approach" section outlines the overall strategy and methodology for developing and implementing the predictive maintenance system for industrial machines.

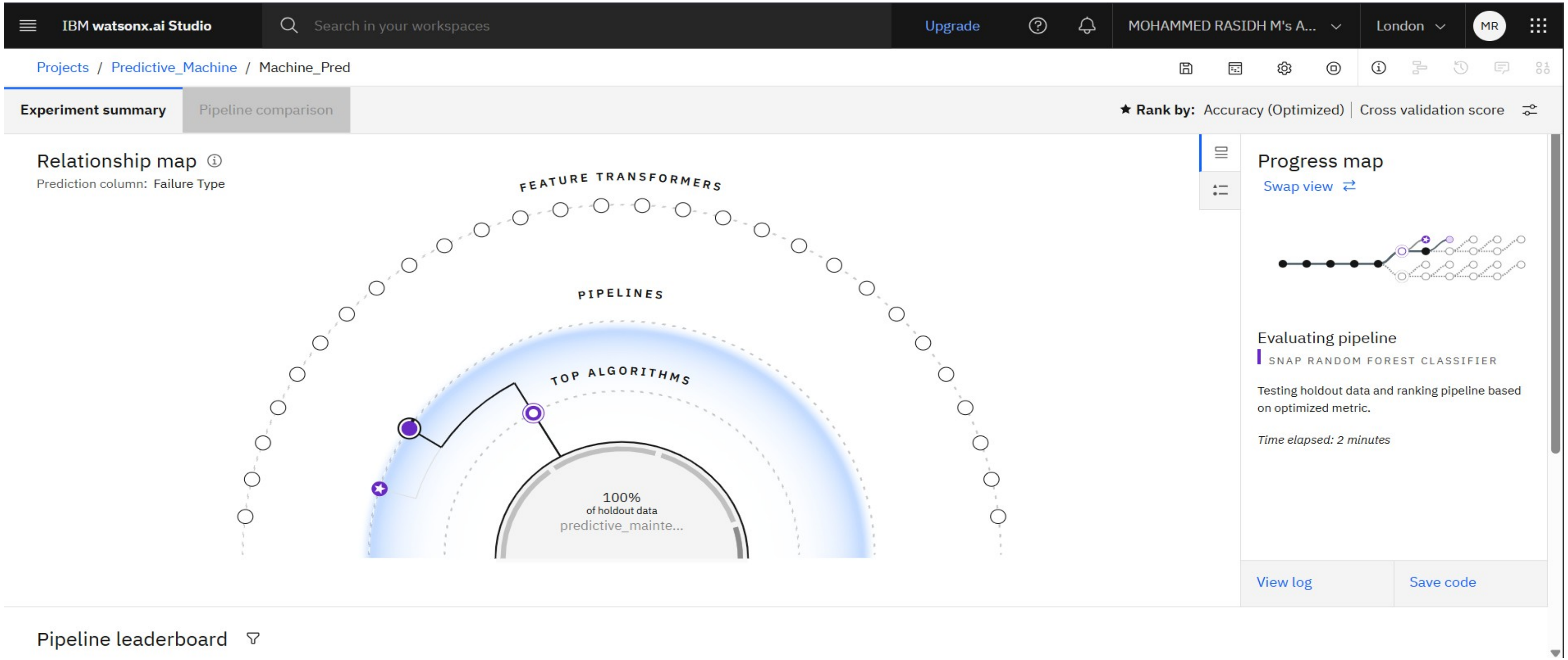
- System Requirements:
  - IBM Cloud – Cloud platform for data storage, scalable computing, and deployment of AI services.
  - Watsonx.ai Studio – For building, training, and evaluating machine learning models in a collaborative environment.
  - Watsonx Runtime Environment – To host the deployed machine learning model and enable real-time inference.
  - IBM Cloud Object Storage – For storing historical machine data and failure logs.
- Library Required to build the Model:
  - Scikit-learn – For implementing machine learning algorithms like Random Forest, model evaluation, and preprocessing.
  - Pandas – For structured data handling and preprocessing.
  - NumPy – For numerical operations and matrix handling.
  - IBM Watson Machine Learning SDK – For model deployment and interaction with Watsonx services.

ALGORITHM & DEPLOYMENT

- Algorithm Selection:
  - A Random Forest classifier was selected due to its robustness, ability to handle high-dimensional sensor data, and suitability for multi-class classification problems.
  - It performs well even with noisy or partially missing data, which is common in industrial environments.
  - The model’s interpretability and ability to rank feature importance make it ideal for maintenance decision-making.
- Data Input:
  - The model uses a wide range of input features derived from real-time and historical data, including:
    - UDI
    - Product ID
    - Product type
    - Air temperature
    - Process temperature
    - Rational Speed
    - Torque
    - Tool wear

- Training Process:
  - The algorithm is trained on labeled historical data using Scikit-learn within Watsonx.ai Studio.
  - Data preprocessing includes missing value handling, outlier removal, and feature scaling.
  - Feature engineering is applied to create meaningful statistics like rolling averages and rate of change.
  - Model performance is optimized using cross-validation and grid search for hyperparameter tuning.
- Prediction Process:
  - The trained model predicts the type of failure (or no failure) based on real-time streaming data from the machine's sensors.
  - Deployed on IBM Watsonx Runtime, it acts as an API endpoint that receives sensor inputs and returns predictions instantly.
  - The output is integrated into a dashboard or alert system, which notifies operators when a specific failure is imminent, enabling proactive maintenance actions.

RESULT



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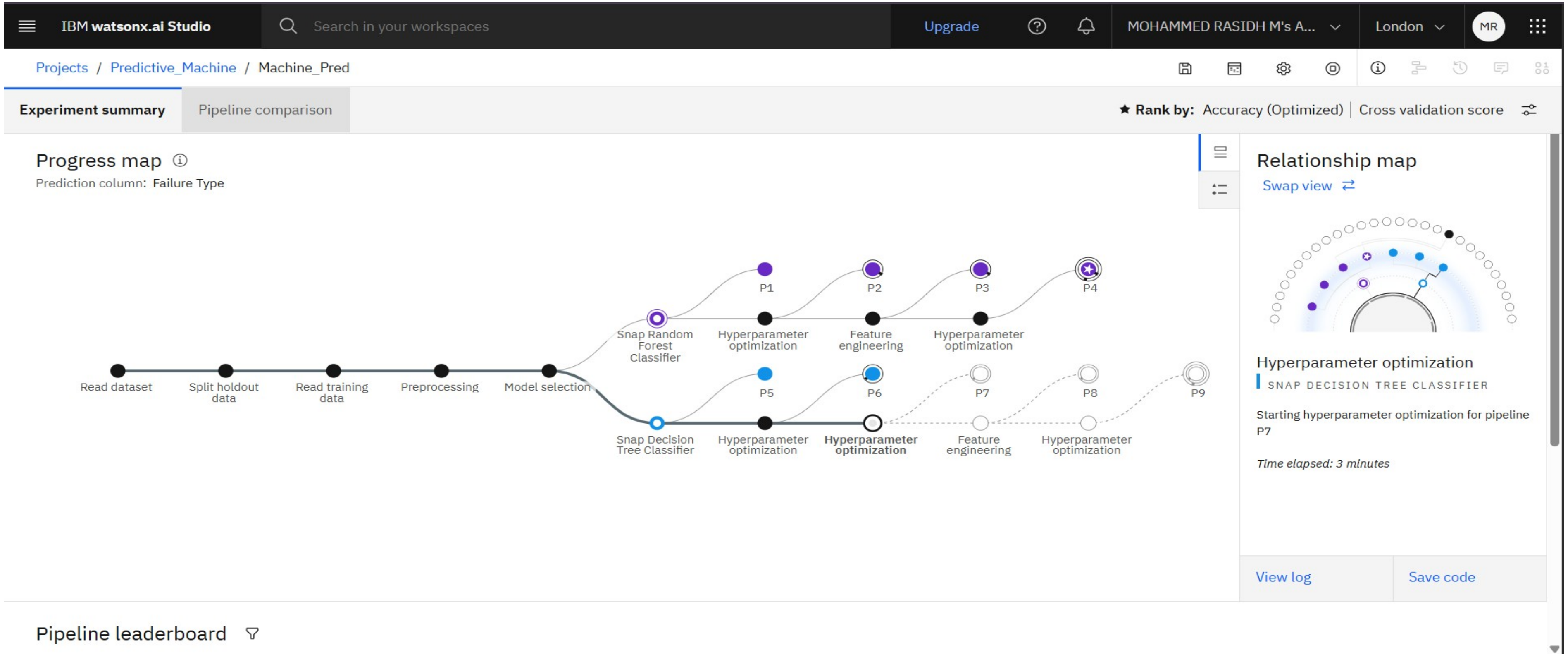

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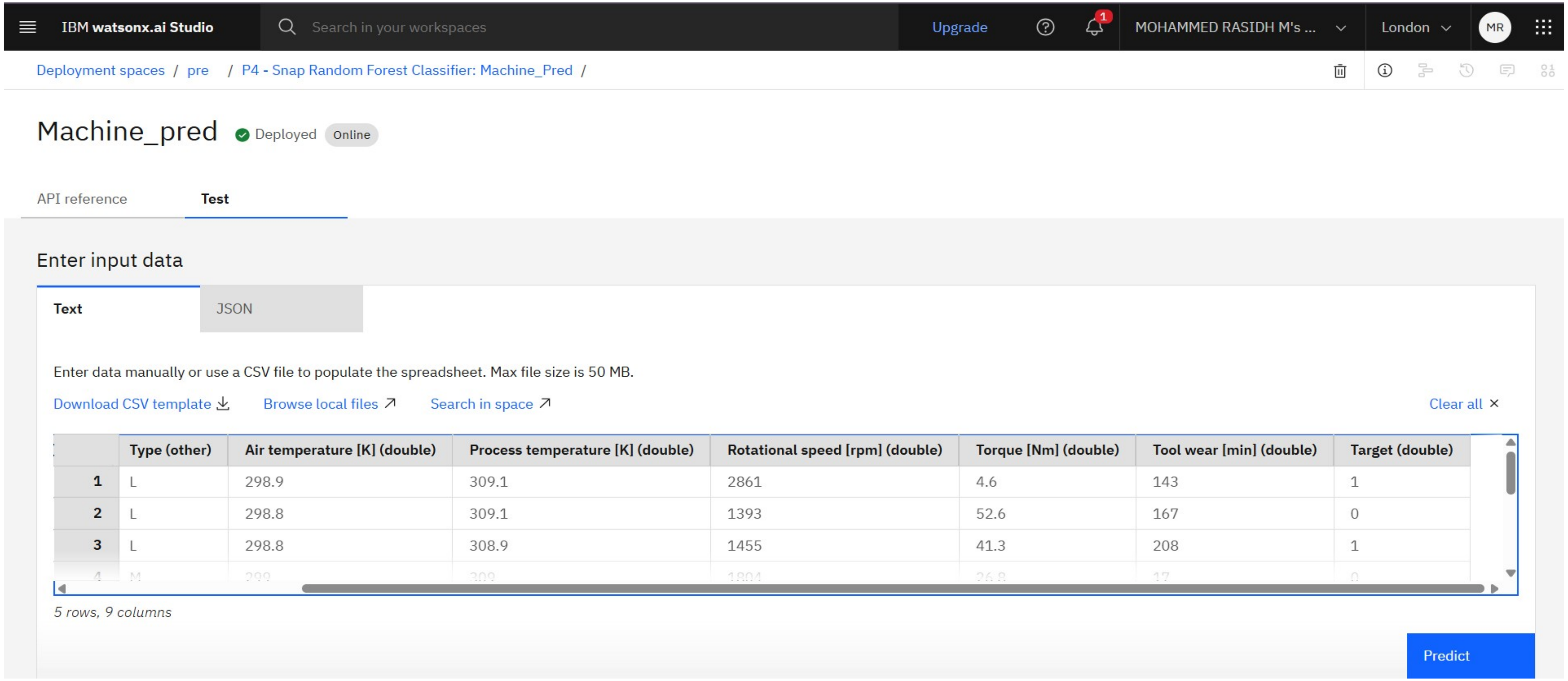
IBM watsonx.ai Studio
Search in your workspaces
Upgrade
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Deployment spaces / pre / P4 - Snap Random Forest Classifier: Machine_Pred /
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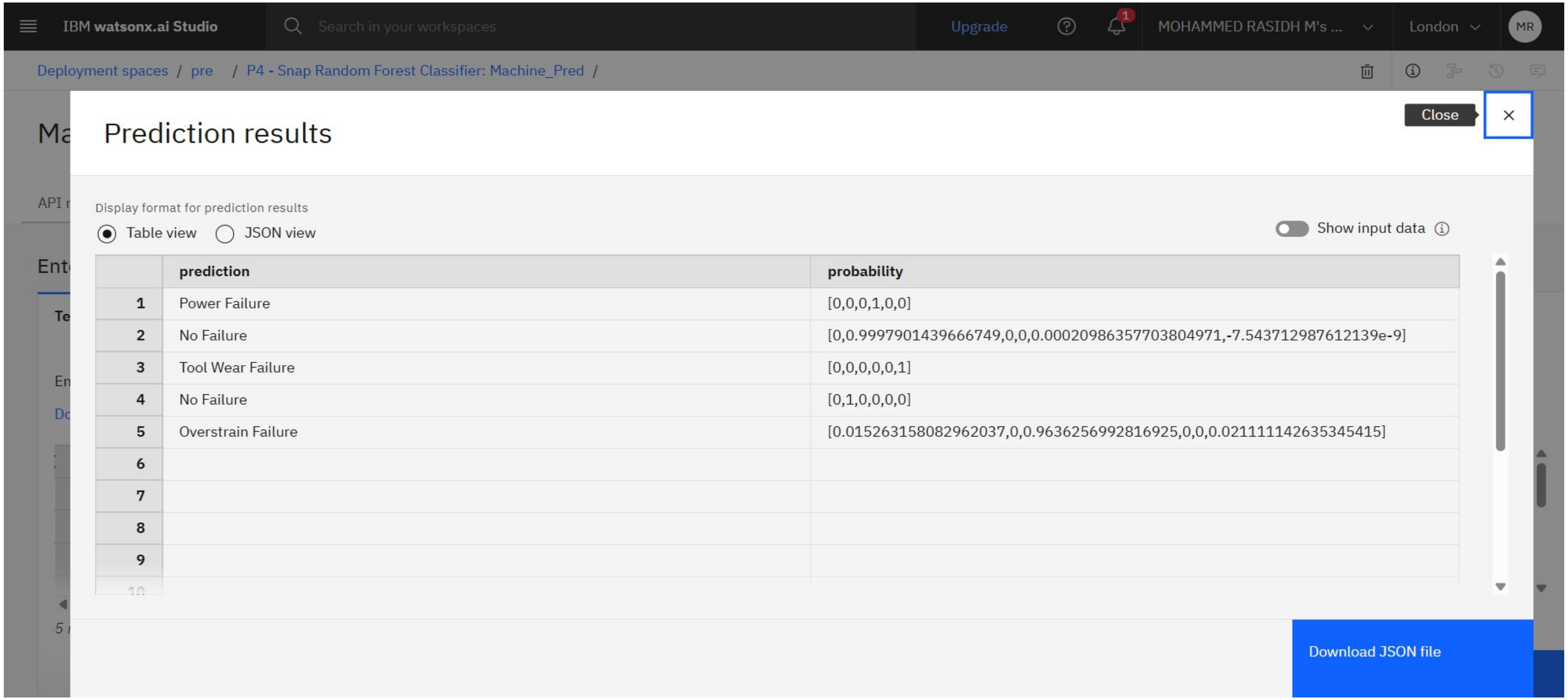
Deployed
Online
API reference
Test
Enter input data
Text
JSON
Enter data manually or use a CSV file to populate the spreadsheet. Max file size is 50 MB.
Download CSV template
Browse local files
Search in space
Clear all
Type (other)
Air temperature [K] (double)
Process temperature [K] (double)
Rotational speed [rpm] (double)
Torque [Nm] (double)
Tool wear [min] (double)
Target (double)
1 L 298.9 309.1 2861 4.6 143 1
2 L 298.8 309.1 1393 52.6 167 0
3 L 298.8 308.9 1455 41.3 208 1
5 rows, 9 columns
Predict



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CONCLUSION

- The predictive maintenance model developed in this project effectively anticipates machine failures using sensor data and machine learning. By applying the Random Forest algorithm, the system classifies failure types like tool wear, heat issues, and power failure with high accuracy. Data was preprocessed and trained using Watsonx.ai Studio, and the model was deployed on IBM Cloud for real-time monitoring. This solution helps reduce unexpected breakdowns, maintenance costs, and downtime. The use of IBM's scalable cloud services ensures reliability and fast response. Overall, the project demonstrates how AI can make industrial systems smarter and more efficient.

FUTURE SCOPE

- Advanced Algorithms: Implement deep learning models like LSTM or CNN to better capture time-series patterns and complex sensor interactions.
- Edge Computing: Integrate edge AI to process sensor data locally on industrial machines for faster, low-latency failure predictions.
- Expanded Failure Types: Include additional failure categories (e.g., mechanical wear, lubrication issues) to increase diagnostic coverage.
- Automated Maintenance Scheduling: Connect the prediction system with automated maintenance ticketing systems to streamline repair workflows.
- Explainable AI (XAI): Integrate explainability tools (e.g., SHAP, LIME) to help technicians understand why a specific failure was predicted.
- Integration with ERP/SCADA Systems: Enhance the system by integrating it with enterprise resource planning and SCADA platforms for better coordination and planning.
- Continuous Learning: Enable the system to self-improve over time using continuous data collection and periodic model retraining.

REFERENCES

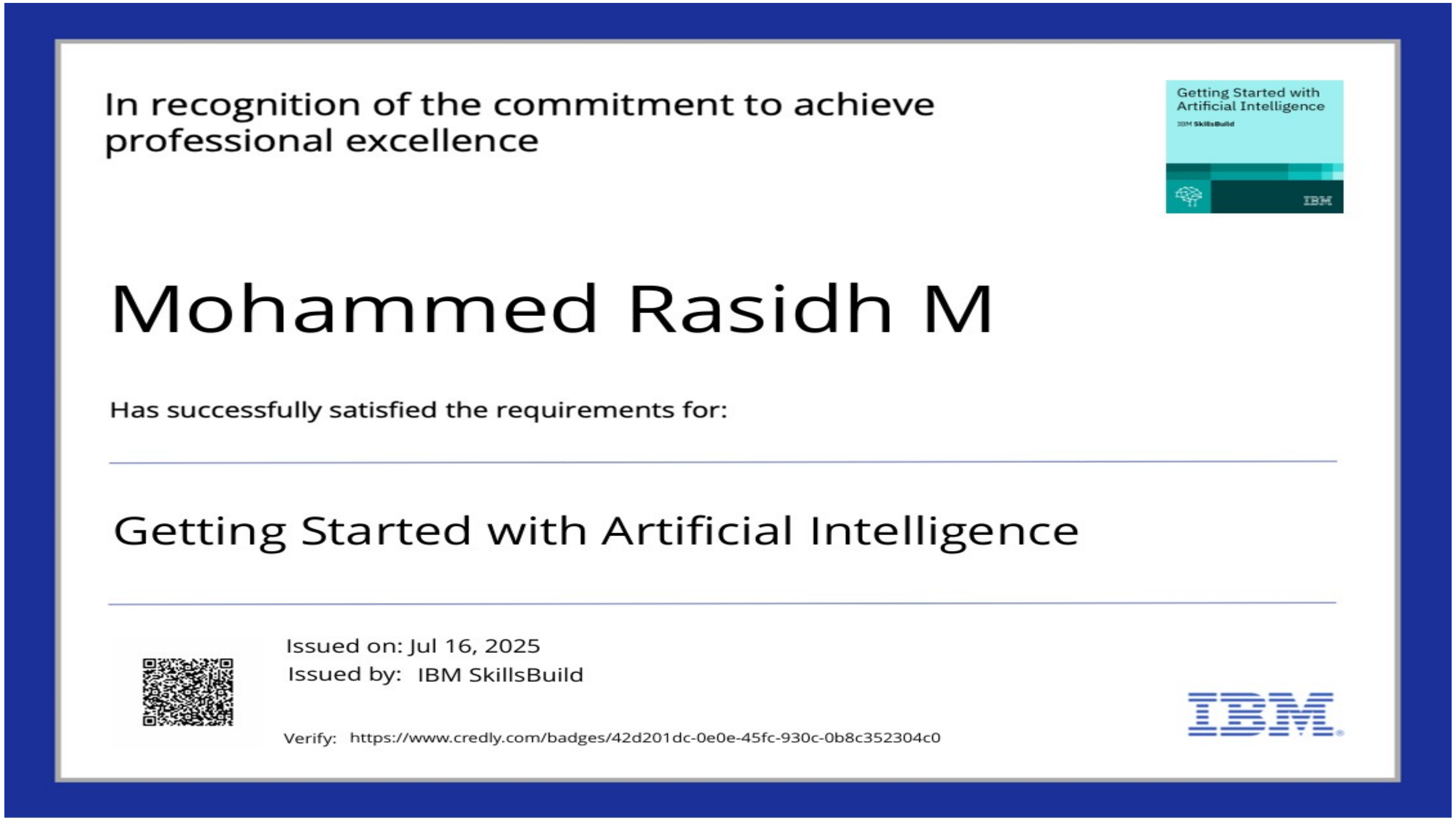
- Dataset:

Shivamb. (2018). Machine Predictive Maintenance Classification [Dataset]. Kaggle.

Available at: https://www.kaggle.com/datasets/shivamb/machine-predictive-maintenance-classification

IBM CERTIFICATIONS

1.GETTING STARTED WITH ARTIFICIAL INTELLIGENCE CERTIFIACTE



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IBM **SkillsBuild** Completion Certificate

This certificate is presented to

Mohammed Rasidh M

for the completion of

Lab: Retrieval Augmented Generation with LangChain

(ALM-COURSE_3824998)

According to the Adobe Learning Manager system of record

Completion date: 23 Jul 2025 (GMT) **Learning hours:** 20 mins

- Github Link:-----https://github.com/mohd-Rasidh

THANK YOU