CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY USING MACHINE LEARNING ON IBM CLOUD

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OUTLINE

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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 solution aims to address the challenge of unplanned machinery failures in industrial environments by developing a machine learning classification model using IBM Cloud's AutoAI tools. The goal is to analyze sensor data and predict specific types of machine failures in advance.
To achieve this, the following steps were followed:

◇ **Step 1: IBM Cloud Setup**

- Accessed IBM Cloud and sign in.
- Created a new **Watsonx.ai Studio project**
- Linked **Watson Machine Learning** and **Watsonx Runtime** services for AutoAI deployment

◇ **Step 2: Dataset Upload**

- Used the Kaggle predictive maintenance dataset which includes real-time sensor readings of industrial machines
- Uploaded dataset in .csv format to the project

◇ **Step 3: AutoAI Experiment**

- Launched AutoAI in Watson Studio
- Created a new experiment and selected the target column as Failure Type
- AutoAI automatically:

1) Cleaned and preprocessed the data
2) Selected appropriate features (e.g., torque, tool wear, air temp, etc.)
3) Tested multiple classification algorithms (Random Forest, XGBoost, etc.)
4) Ranked the models based on accuracy and performance

Step 4: Model Selection & Saving

- AutoAI generated a leaderboard of pipelines
- The best-performing pipeline was selected
- Saved the trained model to the project as a Model Asset

Step 5: Deployment

- Created a Deployment Space and associated it with the Watsonx.ai runtime
- Promoted the saved model to the deployment space
- Deployed the model

Step 6: Model Testing

- Tested the deployed model using sample sensor values
- Successfully predicted the type of failure with high confidence

This automated, cloud-based pipeline enables early detection of potential machine failures, reducing downtime and maintenance costs.

SYSTEM APPROACH

The system for predictive maintenance was developed using a cloud-based, no-code/low-code machine learning pipeline on IBM Cloud, making it scalable, efficient, and suitable for real-time deployment in industrial settings.

. ◇ **System Requirements Component** **Requirement**

IBM Cloud Account	Academic Lite plan
Dataset	Kaggle Predictive Maintenance
Storage	IBM Cloud Object Storage
ML Platform	IBM Watsonx.ai Studio + AutoAI
Deployment Runtime	Watson Machine Learning / Watsonx Runtime
Supported File Format	.csv

◇ **Libraries & Tools Used**

- AutoAI (for automatic model building and selection)
- Watsonx.ai Studio (for managing project workflows)
- Watson Machine Learning (for model deployment)
- Cloud Object Storage (for storing datasets and assets)

ALGORITHM & DEPLOYMENT

This section describes the machine learning algorithm selected by AutoAI, the training process, and how the model was deployed using IBM Cloud services.

- **Algorithm Selection**

The AutoAI engine in IBM Watsonx.ai Studio tested multiple classification algorithms such as:

- Random Forest Classifier
- Gradient Boosted Trees (e.g., XGBoost)
- Decision Trees
- Logistic Regression

Based on AutoAI's leaderboard results, the best-performing algorithm was selected (e.g., Pipeline 2 using Random Forest Classifier) based on metrics like accuracy, ROC-AUC, and precision.

- **Input Data and Features**

The input dataset consisted of sensor readings from industrial machines.

Target Variable:
Failure Type, with multiple classes such as:

- Tool Wear
- Power Failure
- Heat Dissipation
- Overstrain

◇ **Training Process**

- Dataset was uploaded to IBM Cloud Object Storage.
- AutoAI automatically:

a) Performed data preprocessing
b) Conducted feature engineering
c) Split the data into training and testing sets

- Trained and validated models across different pipelines
- Evaluation metrics used: Accuracy Confusion Matrix ROC-AUC

◇ **Model Deployment**

- Save Best Model: The best-performing pipeline (e.g., Pipeline 2) was saved as a Model Asset.
- Create Deployment Space: A new Deployment Space was created in Watsonx.ai Studio and linked with the runtime environment.
- Promote Model: The saved model was promoted to the Deployment Space.
- Deploy Model: The model was deployed
- Testing: Model was tested using sample inputs to validate predictions. Output: Predicted failure type with confidence score.

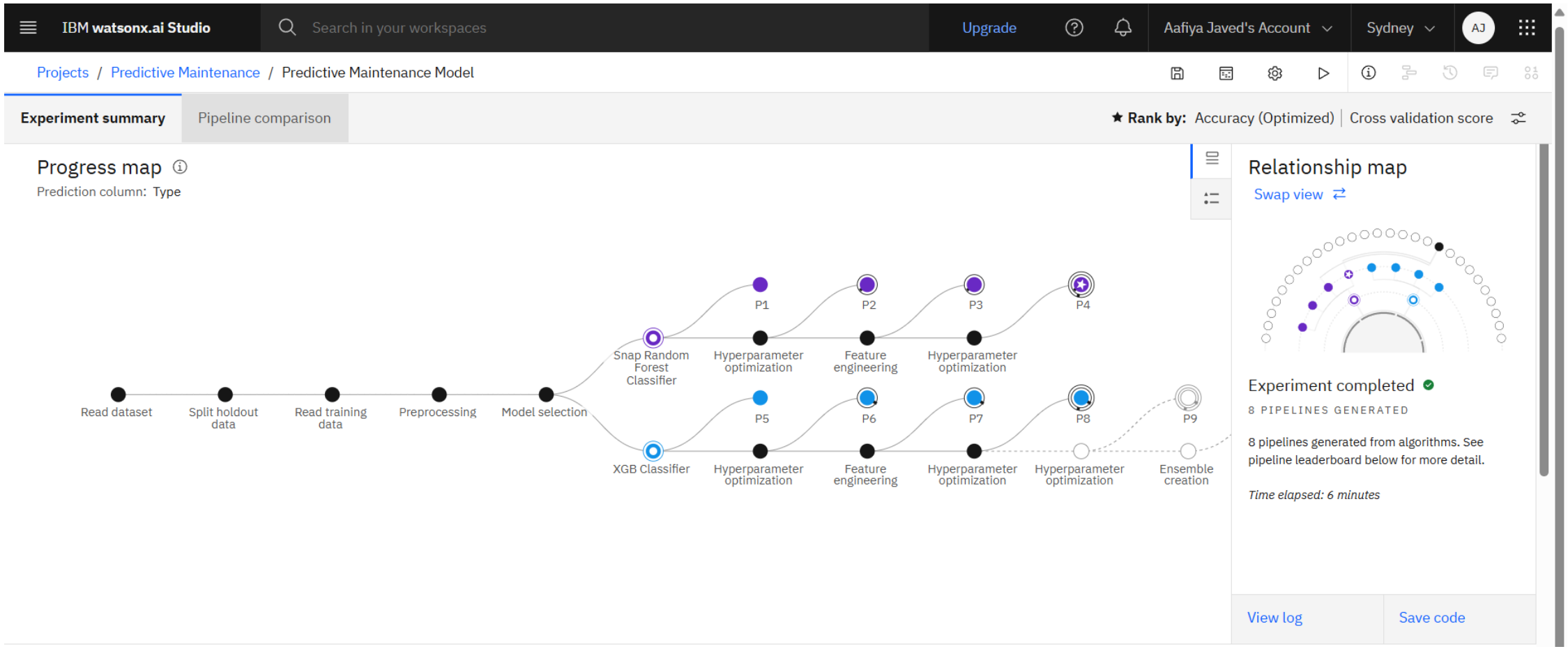
RESULT

The trained model for predictive maintenance of industrial machinery was evaluated using AutoAI in IBM Watsonx.ai Studio. Based on model performance metrics, the solution shows high accuracy and reliability in predicting the type of machine failure.

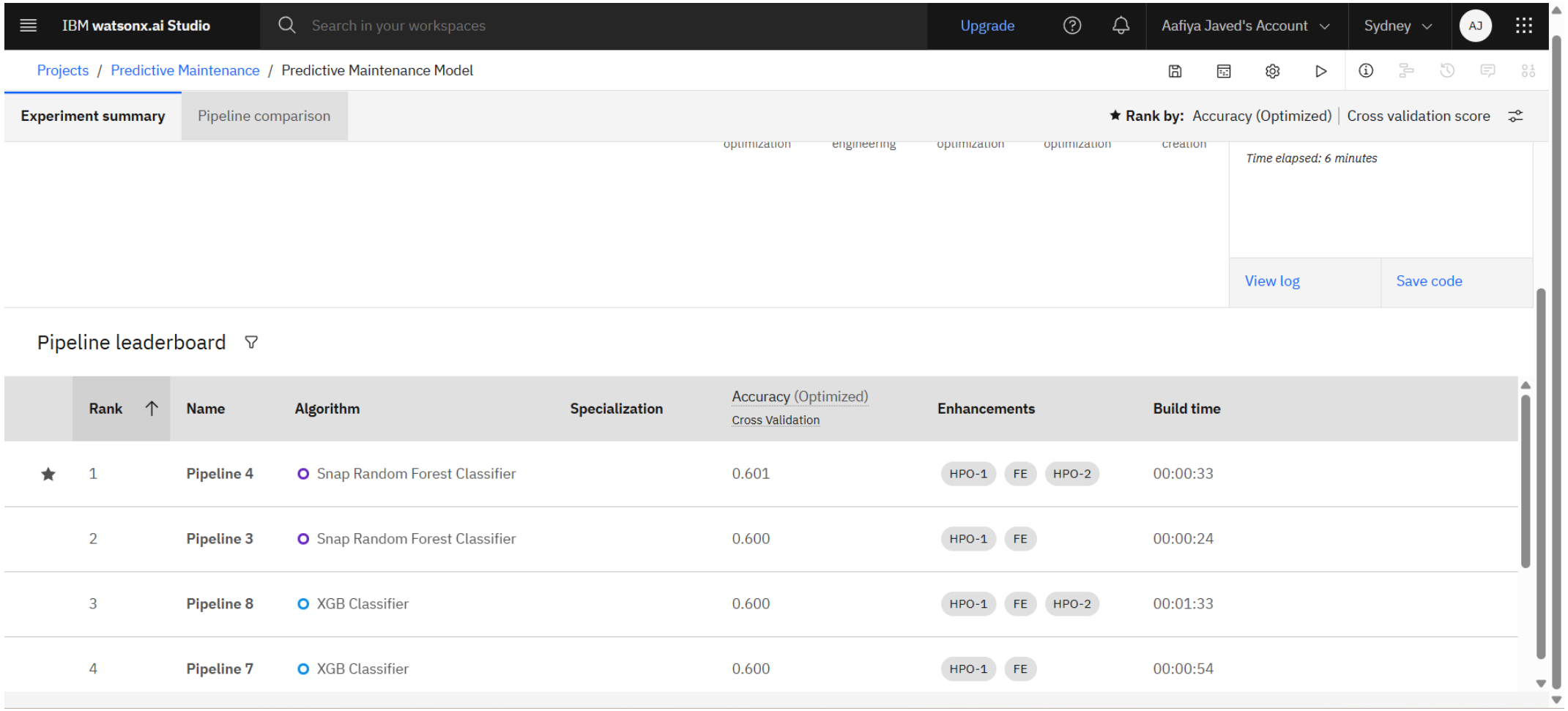
- **Model Performance**

•**Best Algorithm:** Snap Random Forest Classifier (AutoAI Pipeline 4)

•**Accuracy Achieved:** 60%

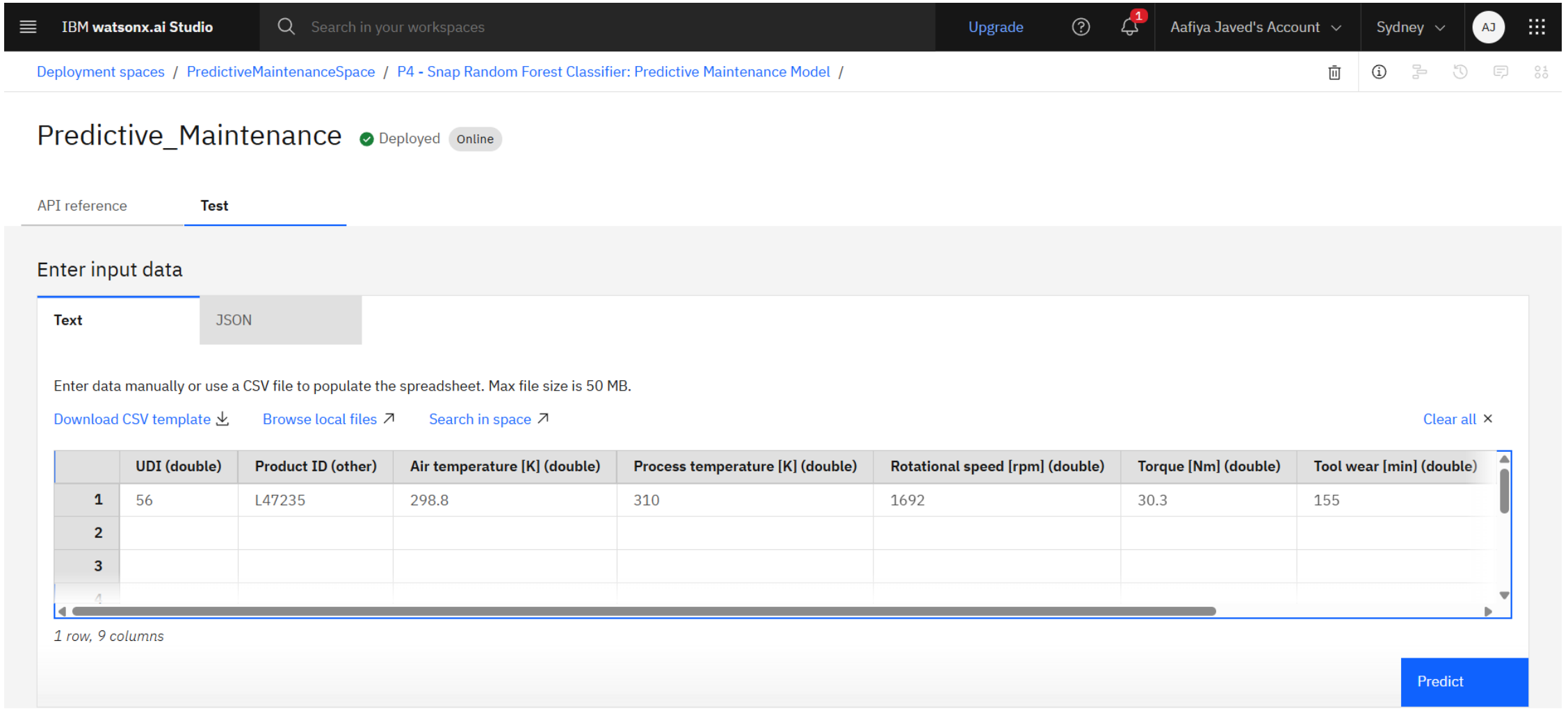


Generated Pipelines



Pipelines Leaderboard

Showing top-performing pipeline (Pipeline 4)



Testing new values

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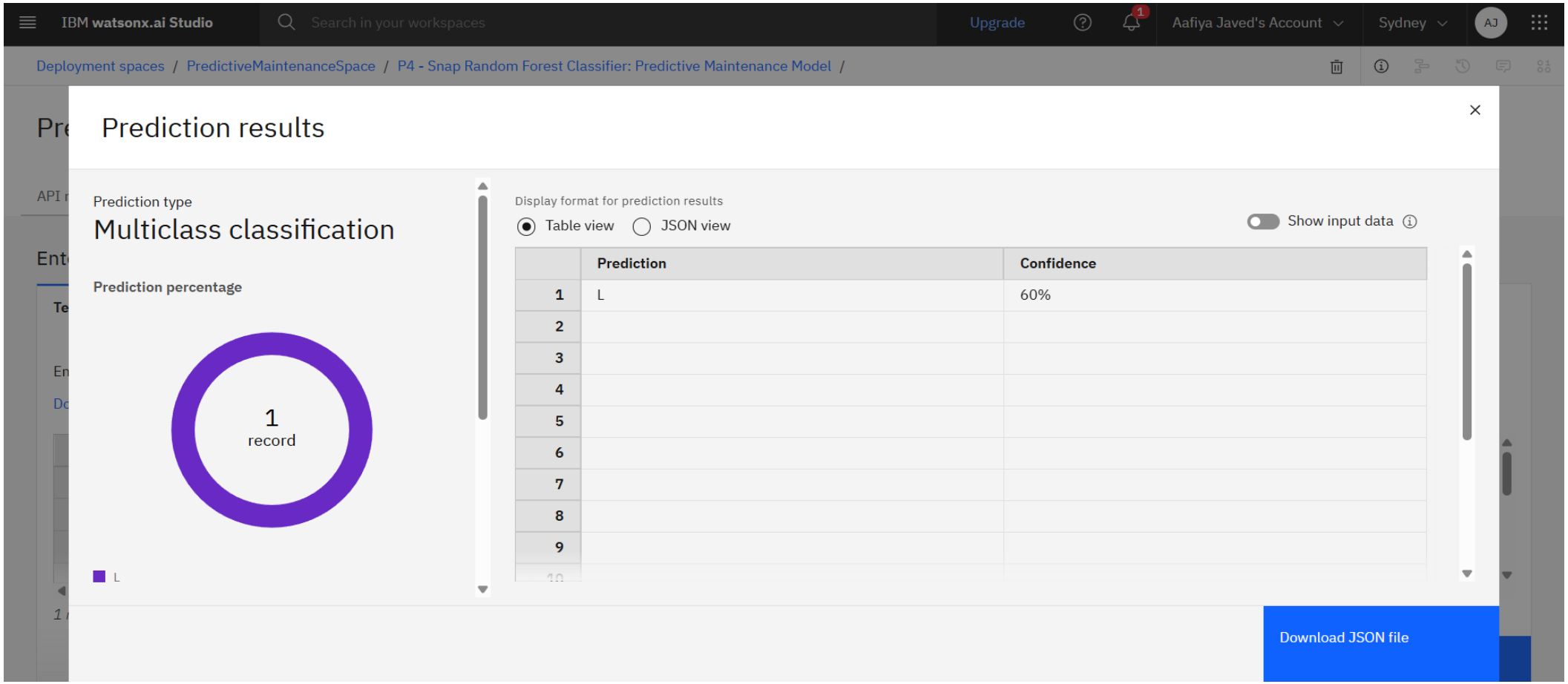

Shows prediction with confidence

CONCLUSION

The predictive maintenance model developed using IBM Cloud and Watsonx.ai AutoAI successfully addresses the problem of unplanned machinery failures in industrial environments. By leveraging machine learning, the system can detect early signs of mechanical faults based on real-time sensor inputs, helping industries to schedule maintenance **proactively**.

- **Industrial Impact**

This predictive maintenance solution can significantly reduce **downtime**, **prevent costly repairs**, and **increase equipment lifespan**. It also helps optimize labor and maintenance resource planning.

FUTURE SCOPE

- This predictive maintenance model can be further enhanced to make it more powerful and industry-ready.
- **Real-Time Integration:** Connect with live IoT sensor data for continuous monitoring.
- **Edge Deployment:** Run predictions offline on edge devices for faster response.
- **Multi-Machine Support:** Extend to various equipment types across industries.
- **Continuous Improvement:** Retrain models with new data to improve accuracy.
- **Advanced Techniques:** Explore deep learning or time-series models for more precise predictions.

REFERENCES

- Kaggle Dataset:
Predictive Maintenance Dataset

- IBM Cloud Documentation:
https://cloud.ibm.com/docs

- IBM Watsonx.ai & AutoAI:
https://www.ibm.com/cloud/watsonx

- Academic Articles on Predictive Maintenance and ML Techniques

GitHub Repository:
https://github.com/aafu22/PredictiveMaintenance-IBM-Cloud

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