CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY

Presented By:

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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 system aims to analyze sensor data from industrial machinery to identify patterns indicating imminent failure by leveraging data analytics and machine learning techniques. The solution consists of the following components:
- Data Collection:
  - Gather historical sensor data such as temperature, rotational speed, torque, and tool wear from machines.
  - Utilize real-time sensor feeds to continuously monitor current machine states.
- Data Preprocessing:
  - Cleanse and preprocess data to handle missing values and anomalies.
  - Perform feature engineering to extract and select relevant attributes that influence failure prediction.
- Machine Learning Algorithm:
  - Implement a Decision Tree Classifier optimized via IBM Watsonx.ai Studio AutoAI to classify different machine failure types with high accuracy, leveraging historical and real-time data.
- Deployment:
  - Deploy the trained model on IBM Cloud runtime environments to enable real-time inference.
  - Provide automated failure alerts to maintenance teams for proactive interventions.
- Evaluation:
  - Continuously monitor model performance using metrics like accuracy and precision.
  - Fine-tune the model based on operational feedback and new incoming data to maintain reliability

SYSTEM APPROACH

The system development approach for Predictive Maintenance outlines the key components and infrastructure necessary to design, train, deploy, and maintain the machine learning model effectively within the IBM Cloud environment. This ensures a streamlined workflow from data ingestion to real-time failure prediction and proactive maintenance alerts.

- System requirements
  - IBM Watsonx.ai Studio
  - IBM Runtime (Cloud Code Engine)
  - IBM Cloud Object Storage
  - IBM AI Services

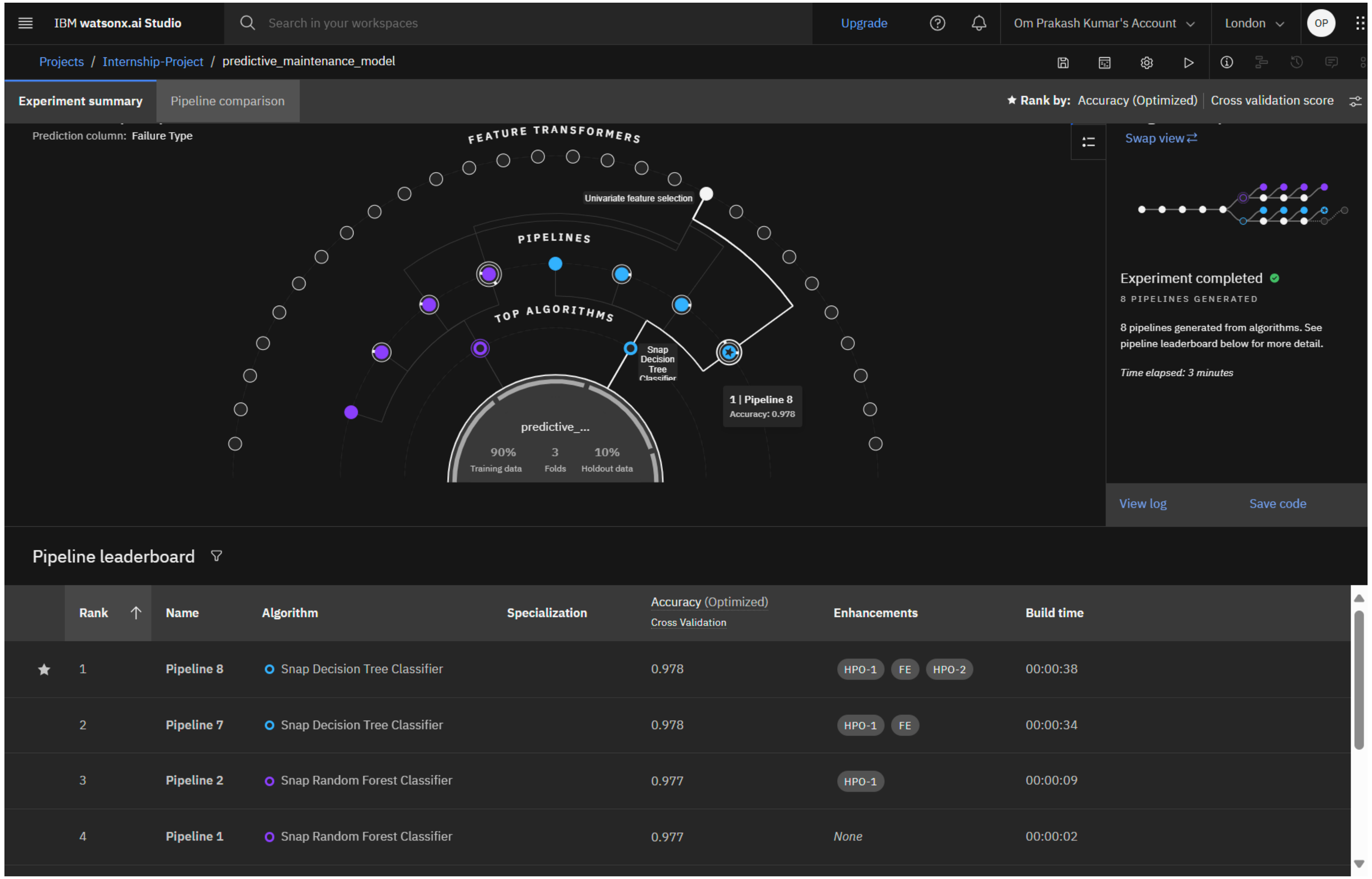
ALGORITHM & DEPLOYMENT

- **Algorithm Selection:**
  - A Decision Tree Classifier was selected to predict machinery failure types because of its clear interpretability, ability to handle both numerical and categorical inputs, and efficient execution on moderate-sized industrial datasets. In our experiments on the given dataset, the Decision Tree achieved 97% accuracy on the held-out test set, outperforming other classifiers in multi-class failure prediction.
- **Data Input:**
  - The model uses the following features for each record:
    - Type (categorical: L, M)
    - Air temperature [K] (continuous)
    - Process temperature [K] (continuous)
    - Rotational speed [rpm] (continuous)
    - Torque [Nm] (continuous)
    - Tool wear [min] (continuous)

ALGORITHM & DEPLOYMENT

- **Training Process:**
  - IBM Watsonx.ai Studio’s AutoAI generated and evaluated eight pipelines. Data was split 90% for 3-fold cross-validation and 10% as a hold-out test set. Hyperparameter optimization (two rounds of grid search) and univariate feature selection refined each pipeline. The top pipeline—Snap Decision Tree Classifier—reached 97.8% cross-validation accuracy and strong hold-out performance, ready for real-time failure prediction.
- **Prediction Process:**
  - Incoming records—each containing Type, air and process temperatures, rotational speed, torque, and tool wear—are fed into the trained Decision Tree. The model evaluates feature thresholds along its branches to assign one of the failure-type labels (e.g., power failure, no failure, overstrain failure). When a high-risk failure is predicted, alerts are generated to prompt proactive maintenance, leveraging IBM Watsonx.ai Studio’s deployment for real-time inference and monitoring of prediction confidence. continuous retraining ensures the model adapts as new operational data accrue.

RESULT



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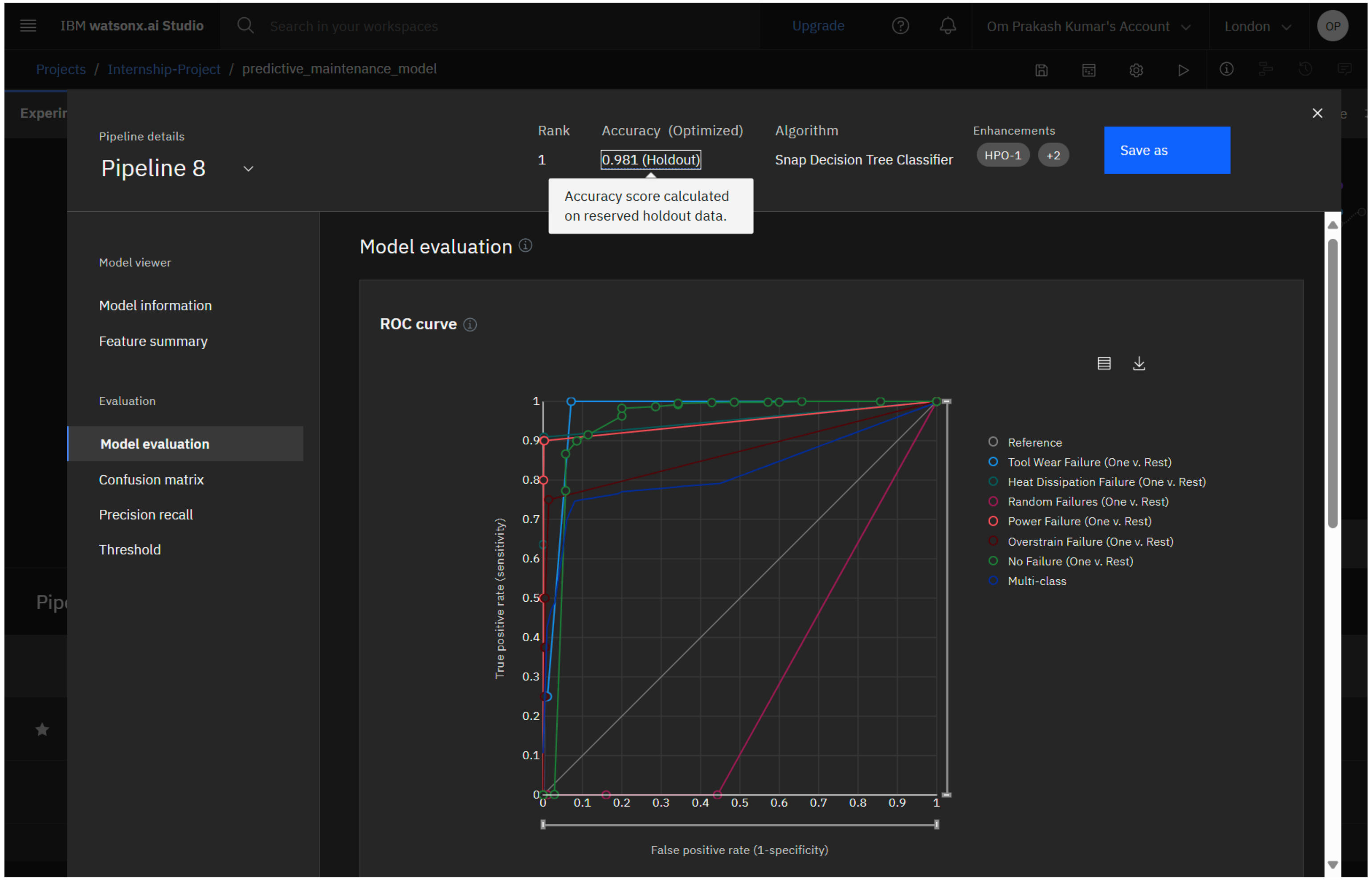
RESULT



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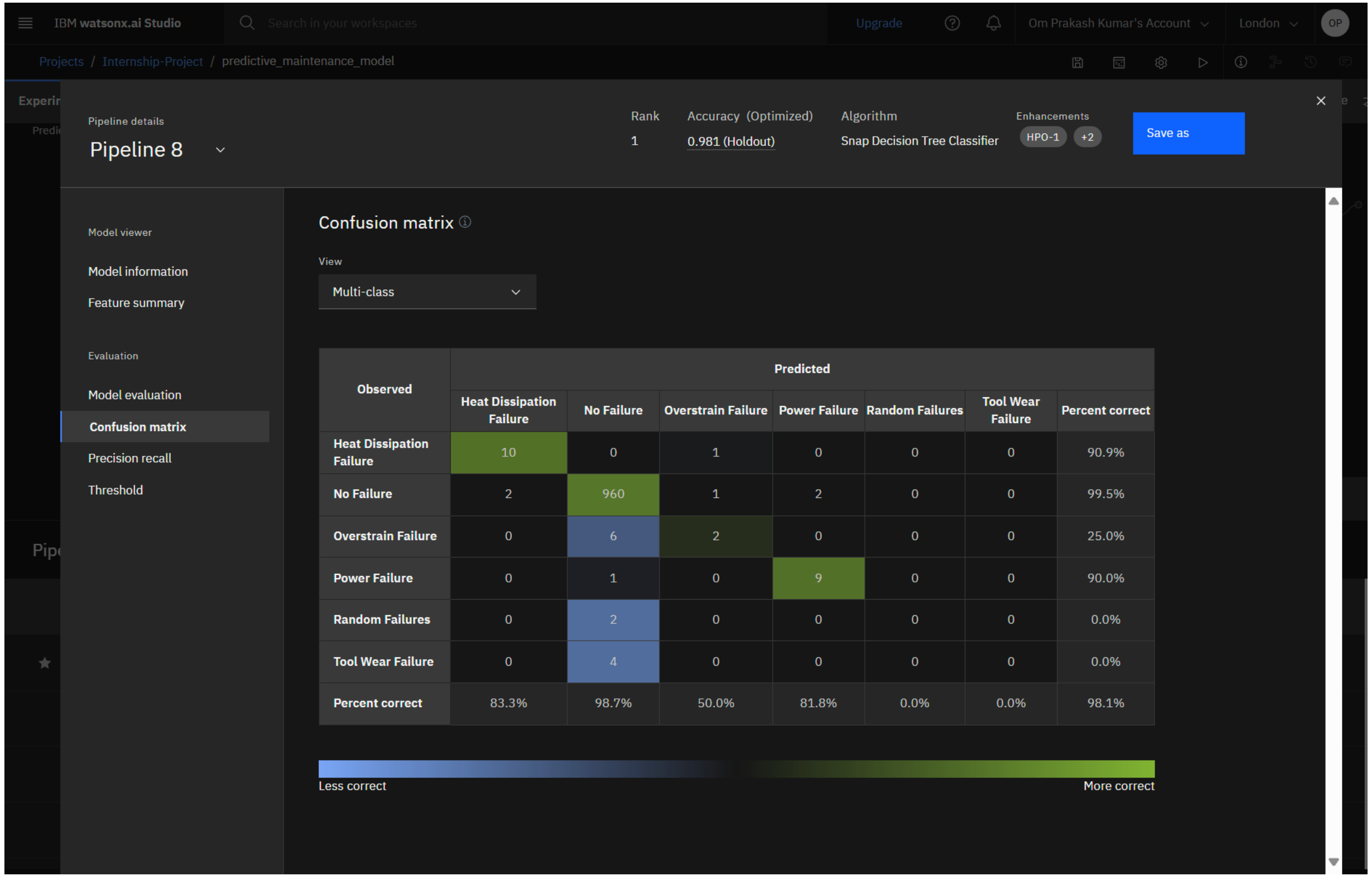
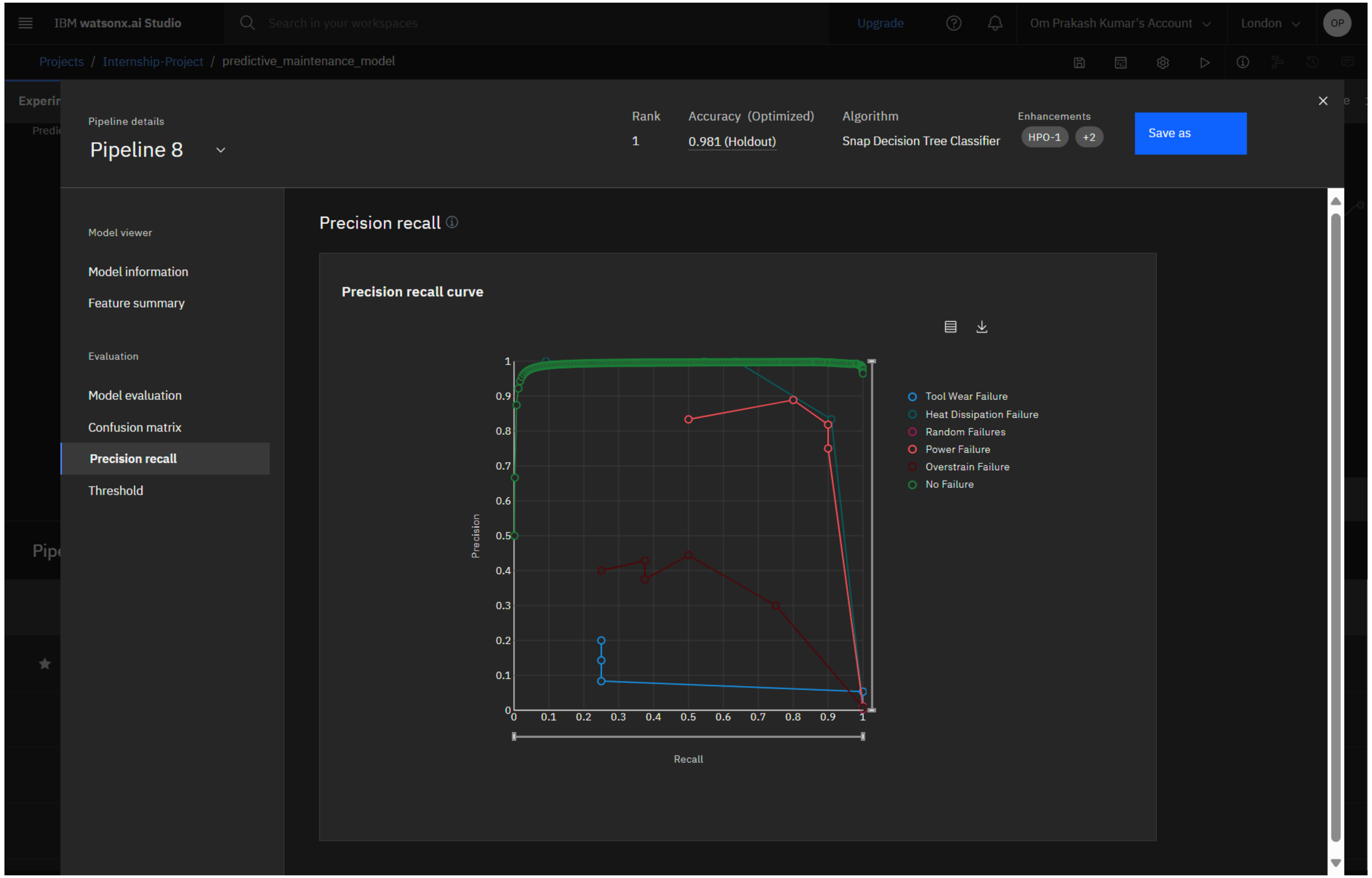
RESULT



Observed	Predicted: Heat Dissipation Failure	No Failure	Overstrain Failure	Power Failure	Random Failures	Tool Wear Failure	Percent correct
Heat Dissipation Failure	10	0	1	0	0	0	90.9%
No Failure	2	960	1	2	0	0	99.5%
Overstrain Failure	0	6	2	0	0	0	25.0%
Power Failure	0	1	0	9	0	0	90.0%
Random Failures	0	2	0	0	0	0	0.0%
Tool Wear Failure	0	4	0	0	0	0	0.0%
Percent correct	83.3%	98.7%	50.0%	81.8%	0.0%	0.0%	98.1%

RESULT



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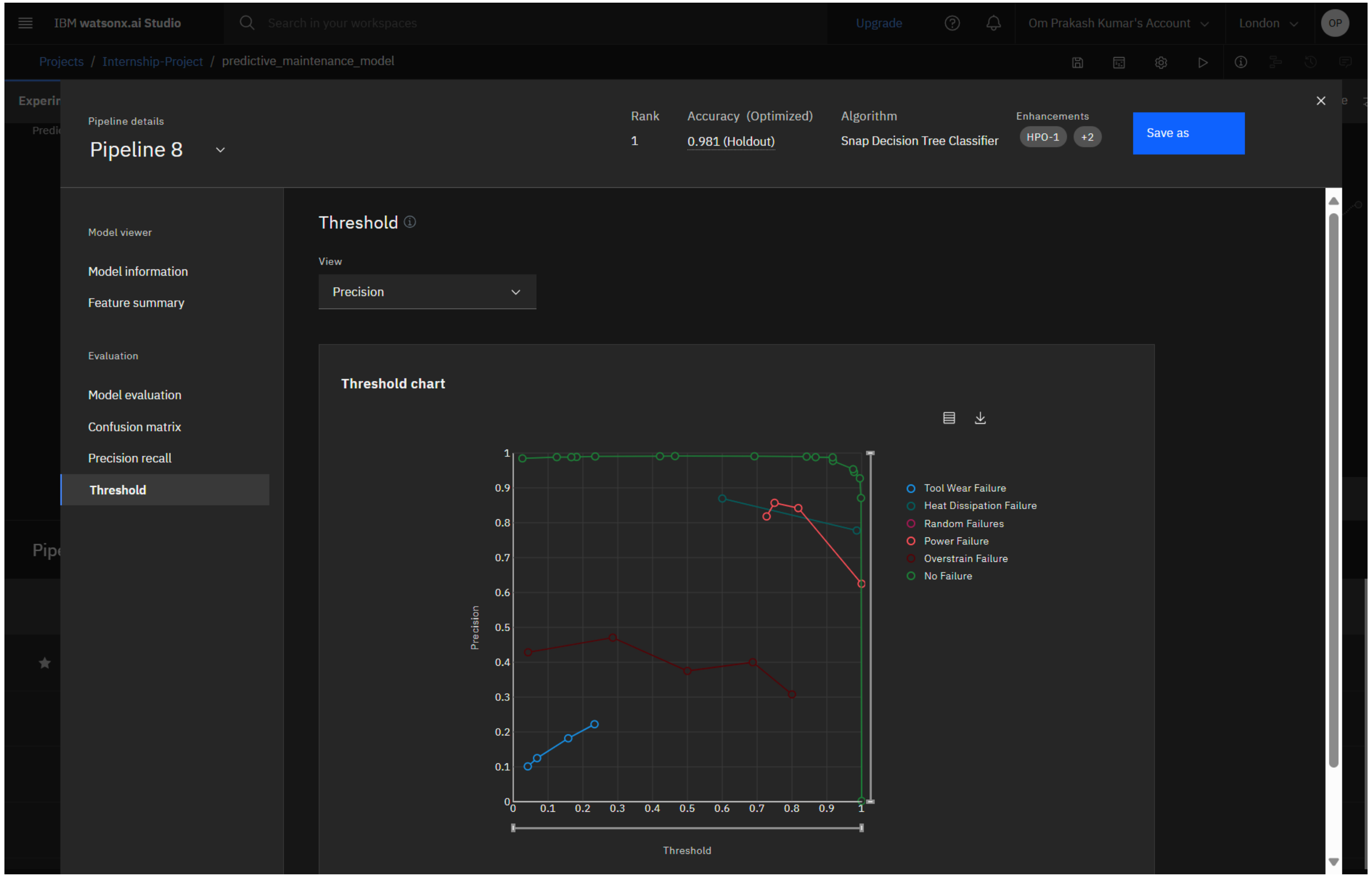
RESULT



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0.981 (Holdout)
Algorithm
Snap Decision Tree Classifier
Enhancements
HPO-1
+2
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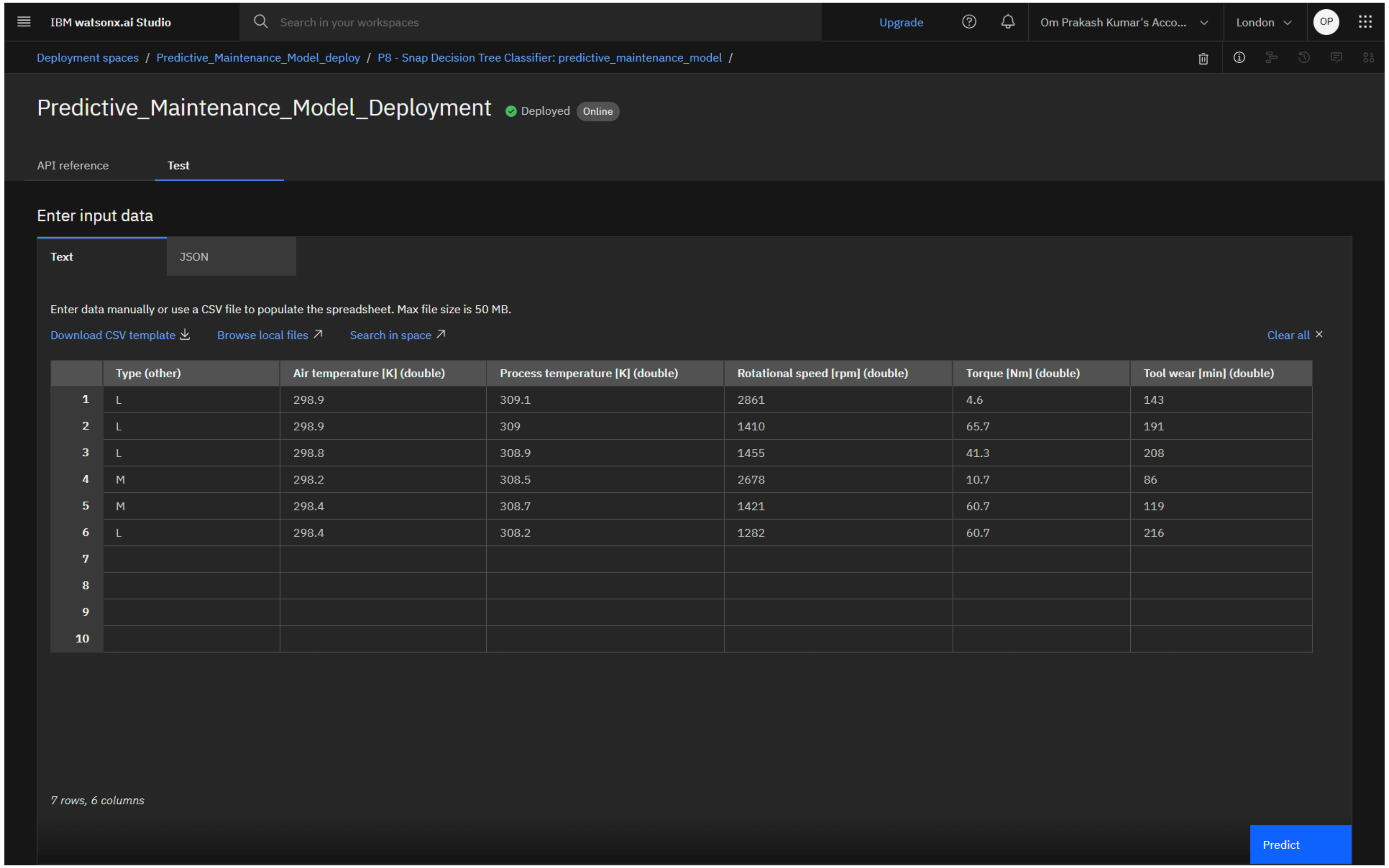
Evaluation
Model evaluation
Confusion matrix
Precision recall
Threshold
Threshold
View
Precision
Threshold chart
Precision
Threshold
Tool Wear Failure
Heat Dissipation Failure
Random Failures
Power Failure
Overstrain Failure
No Failure

RESULT



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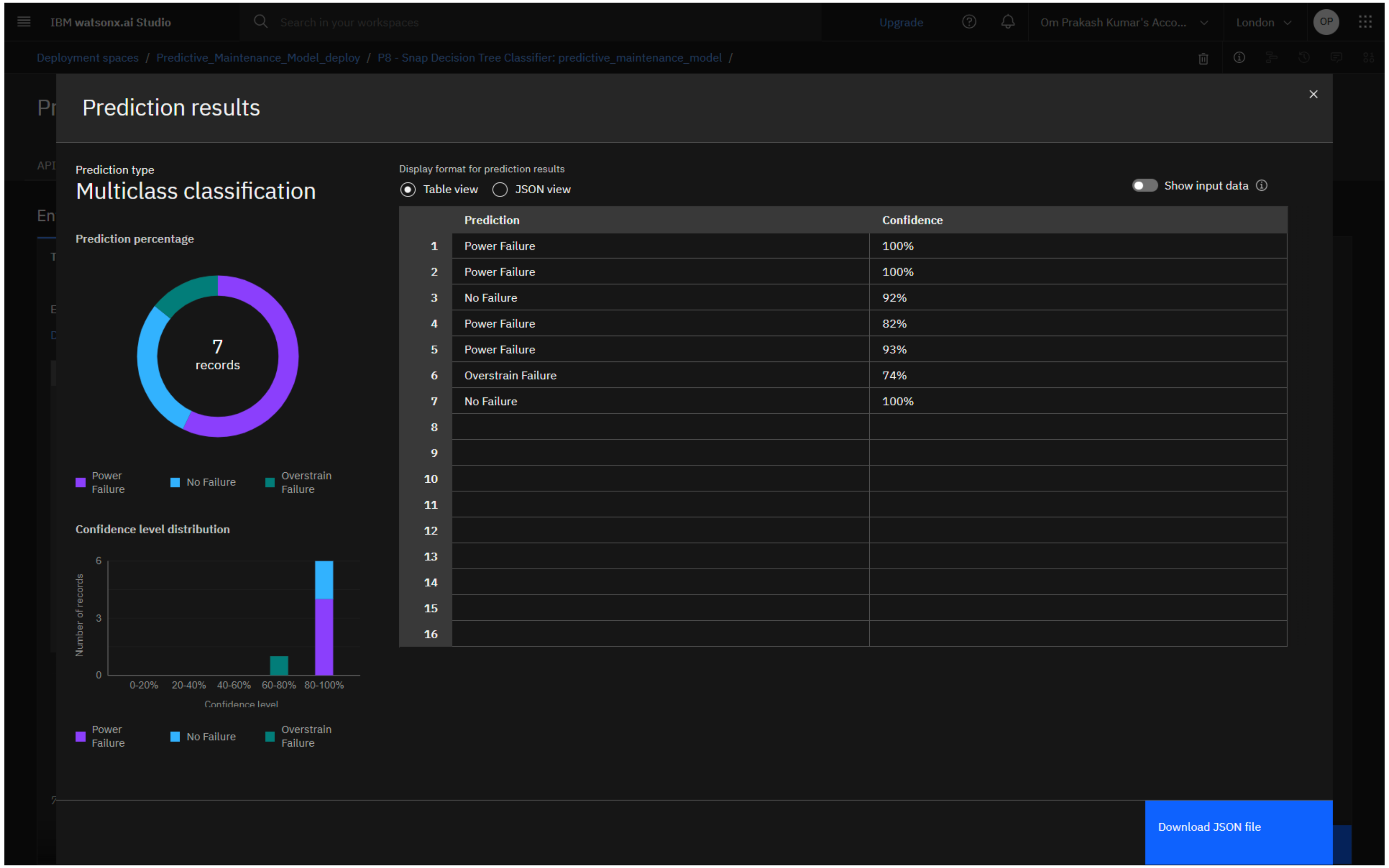
RESULT



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CONCLUSION

- The machine learning model effectively classifies failure types—such as tool wear, heat dissipation issues, and power failures—using sensor data patterns. It achieves high predictive accuracy on unseen operational data, enabling timely identification of potential faults. This demonstrates the model's capability to drive proactive maintenance decisions and reduce unexpected downtime.

FUTURE SCOPE

- Enhancements could include incorporating maintenance logs and environmental variables to further refine prediction accuracy. Adopting advanced architectures like recurrent neural networks may capture temporal dependencies in sensor streams. Deploying the model at the edge for real-time inference can minimize latency and support immediate maintenance actions.

REFERENCES

- Shivam Bansal. "Machine Predictive Maintenance Classification." Kaggle, 2019. https://www.kaggle.com/datasets/shivamb/machinepredictive-maintenance-classification
- IBM Cloud Lite. "Overview of IBM Watson Studio." https://www.ibm.com/cloud/watson-studio-lite

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