PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY

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OUTLINE

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PROBLEM STATEMENT

Modern industries rely on machinery that may unexpectedly fail, causing production downtime, increased costs, and significant disruptions to production lines. Traditional reactive maintenance strategies are often insufficient, leading to longer repair times and unplanned shutdowns. This project aims to predict various types of failures (e.g., tool wear, heat dissipation, power failure) before they happen using real-time sensor data from machines. Early identification of faults can reduce maintenance costs, improve equipment life and efficiency, and enable industries to implement condition-based maintenance strategies. By leveraging predictive analytics, industries can shift from reactive to proactive maintenance, enhancing productivity and operational reliability.

PROPOSED SOLUTION

The proposed system addresses the challenge of predicting industrial machinery failures by leveraging machine learning and IBM Cloud technologies. The solution is built and deployed using IBM Watson Studio with the help of AutoAI for automated pipeline generation and optimization.

- Data Collection:
  - Utilize the Kaggle dataset with sensor readings such as rotational speed, torque, temperature, and tool wear. Collect real-time operational data from machines.
- Data Preprocessing:
  - Handle missing values, normalize data, and encode categorical features. Perform feature selection to improve model performance.Machine Learning Algorithm:
- Model Selection and Training:
  - Snap Random Forest Classifier was selected as the best-performing model. Achieved 99.7% accuracy on the holdout dataset with high precision and recall scores across all classes.
- Deployment:
  - Deploy the model on IBM Watson Studio using IBM Cloud Lite services. Use AutoAI for model optimization and performance tuning.
- Evaluation:
  - Model performance was validated using metrics like ROC curves, confusion matrix, and precision-recall curves. The finalized model was deployed on IBM Cloud as a REST API for real-time predictions.
  - Result: Model Accuracy is 99.7% (Holdout score)

SYSTEM APPROACH

To address the challenge of predicting machinery failures, a cloud-based automated machine learning workflow was implemented. The solution leverages IBM Cloud services to handle data processing, model building, evaluation, and deployment, ensuring scalability, automation, and real-time monitoring for industrial use.

- **System Requirements:**
  - IBM Cloud Lite account with Watson Studio enabled
  - AutoAI for automated model generation and evaluation
  - IBM Cloud Object Storage for dataset hosting and retrieval
  - Deployment space for publishing and testing REST APIs
- **Libraries & Tools Used:**
  - IBM Watson Studio's AutoAI (built-in models like Snap Random Forest, Decision Tree)
  - Python (for additional metrics, visualization, and preprocessing using Pandas, Scikit-learn, Matplotlib)
  - REST API interface for integration with industrial systems and dashboards.

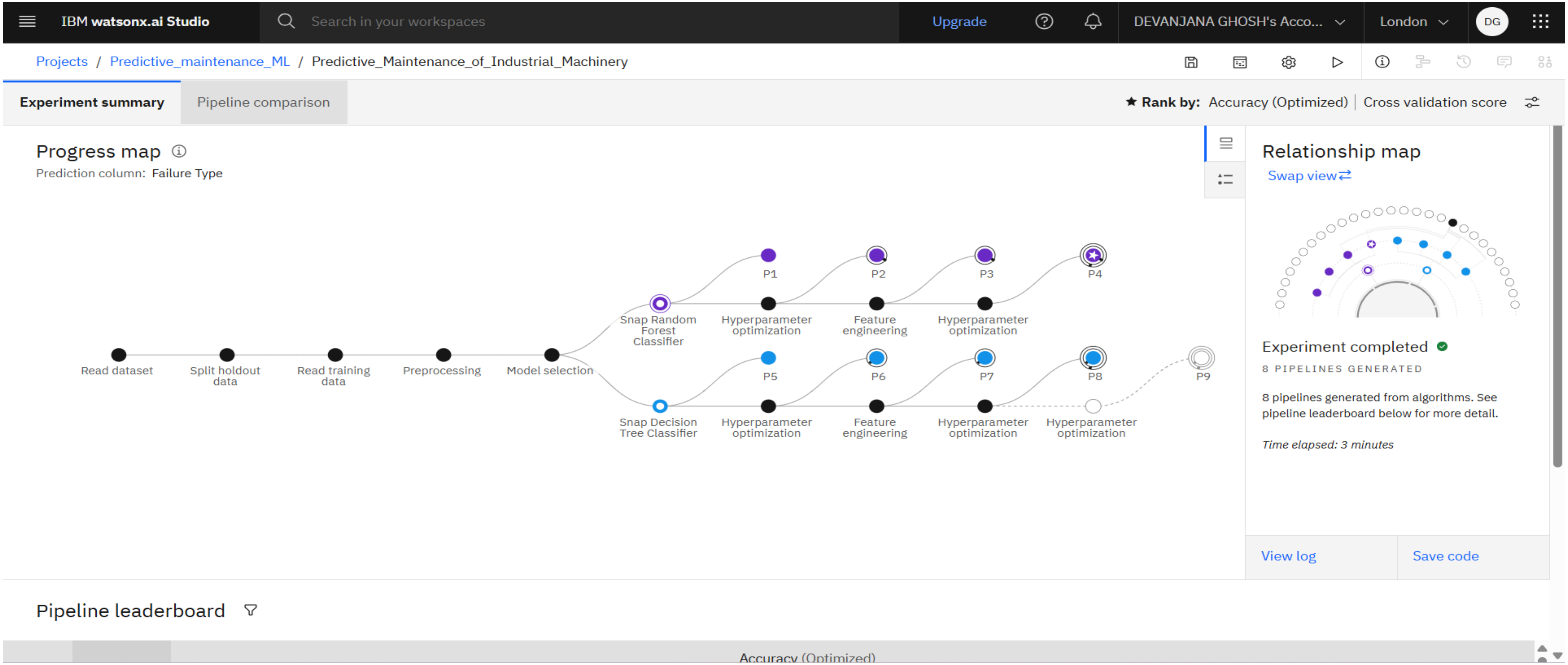
This approach enables predictive maintenance by automating the entire ML lifecycle — from data ingestion to real-time failure prediction, helping industries reduce downtime and maintenance costs.

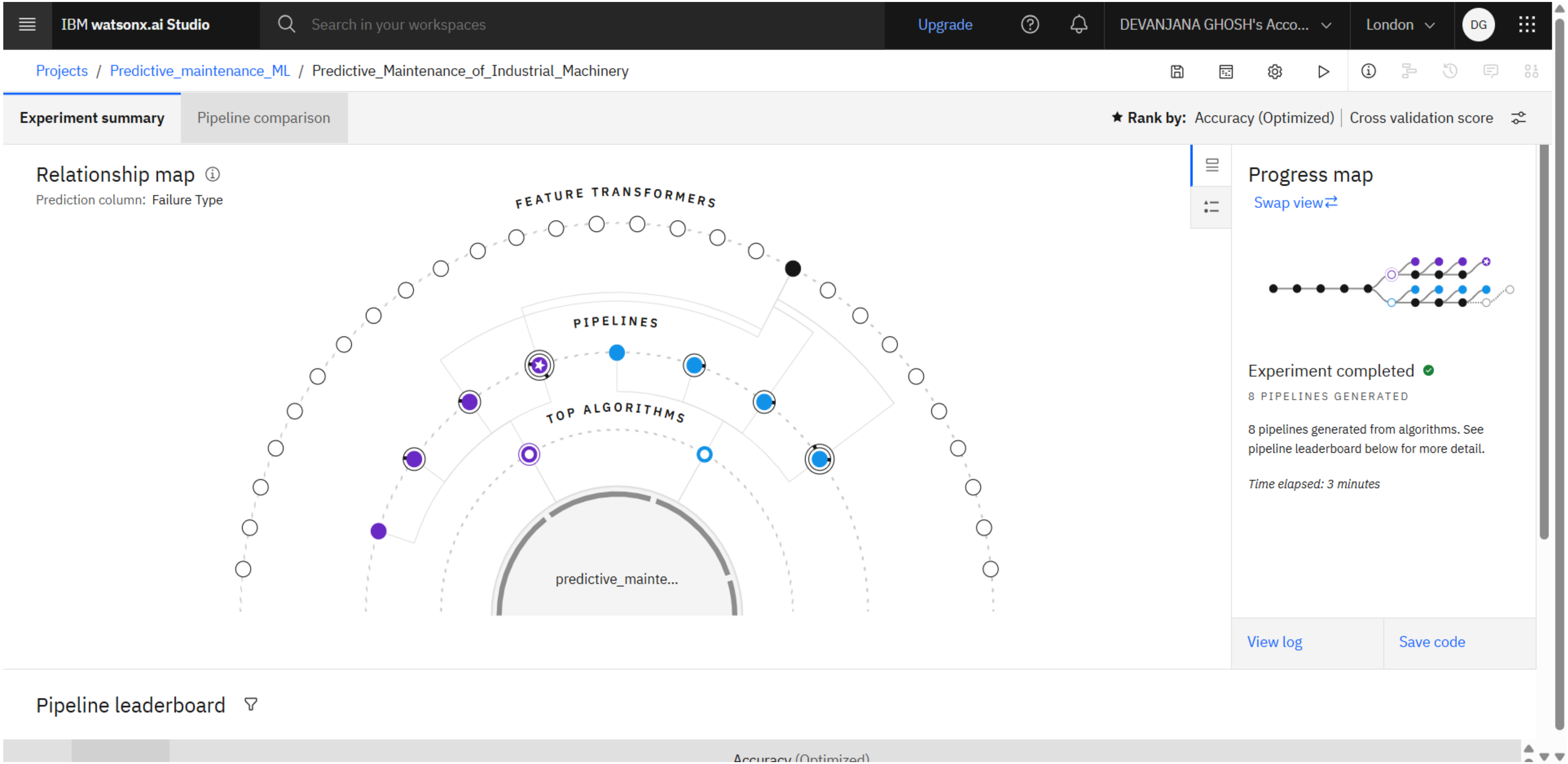
ALGORITHM & DEPLOYMENT

- Algorithm Selection:
  - Snap Random Forest Classifier was chosen as the primary algorithm for its ability to handle complex and nonlinear patterns effectively in multi-class classification problems. It was the top-performing model among several tested using AutoAI, including SVM, Logistic Regression, and Decision Tree.
- Data Input:
  - The model was trained using the attributes such as Air Temperature,
  - Process Temperature, Type (categorical) etc which extracted from the dataset.
- Training Process:
  - Data preprocessing included handling null values and normalizing numerical features.
  - AutoAI handled model selection and hyperparameter tuning across multiple pipelines.
- Prediction Process:
  - The deployed model accepts real-time machine input data in JSON or CSV format. It predicts the most likely failure type (e.g., tool wear, power failure) with a corresponding confidence score.
  - The results are visualized and can be used for alerting and triggering maintenance tasks.

RESULT

- **Model Accuracy:** 99.7% (Holdout score)

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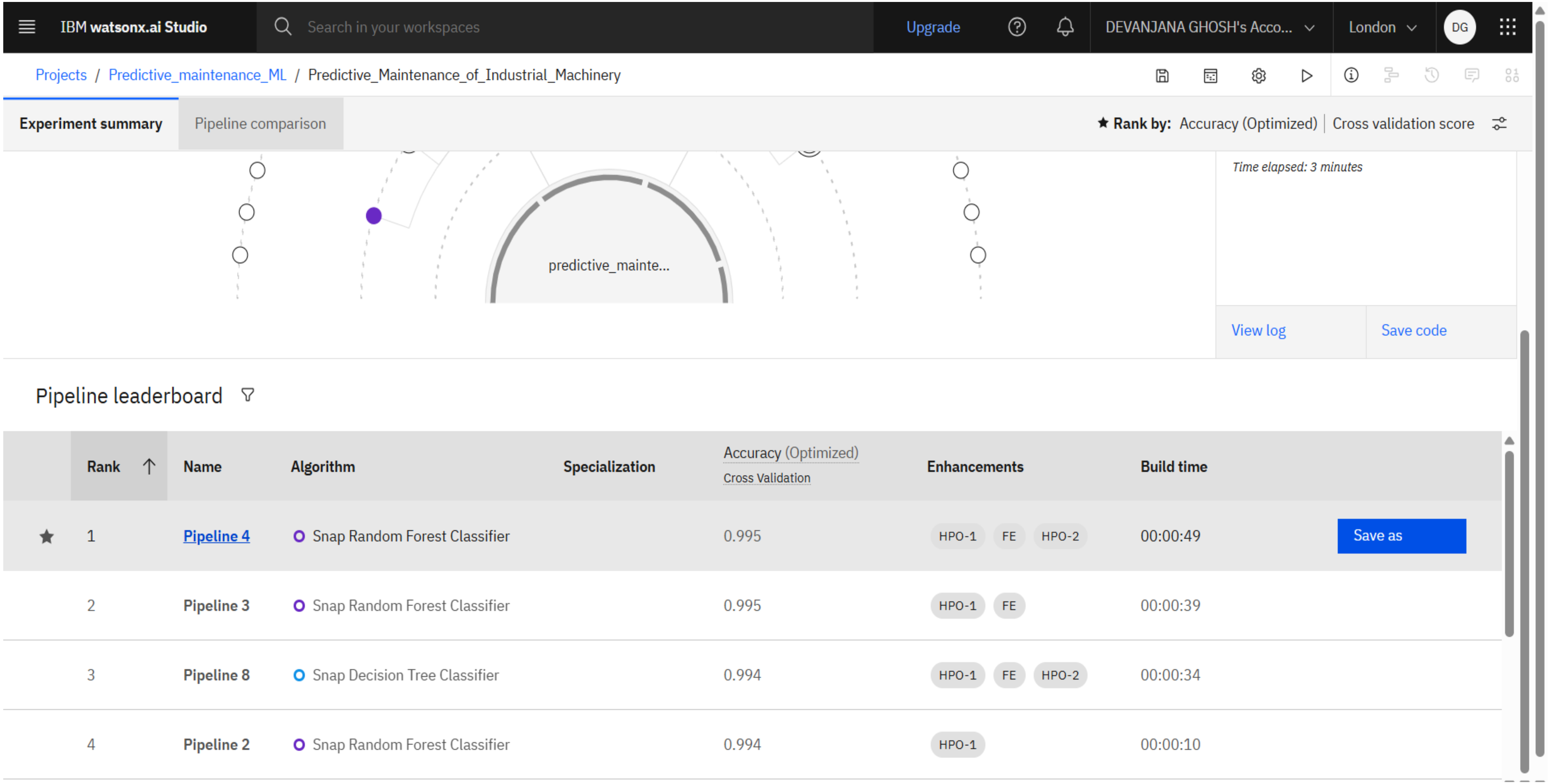
Experiment summary
Pipeline comparison
Rank by: Accuracy (Optimized) | Cross validation score
Relationship map
Prediction column: Failure Type
FEATURE TRANSFORMERS
PIPELINES
TOP ALGORITHMS
predictive_mainte...
Progress map
Swap view
Experiment completed
8 PIPELINES GENERATED
8 pipelines generated from algorithms. See pipeline leaderboard below for more detail.
Time elapsed: 3 minutes
View log
Save code
Pipeline leaderboard
Accuracy (Optimized)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Experiment summary
Pipeline comparison
Rank by: Accuracy (Optimized) | Cross validation score
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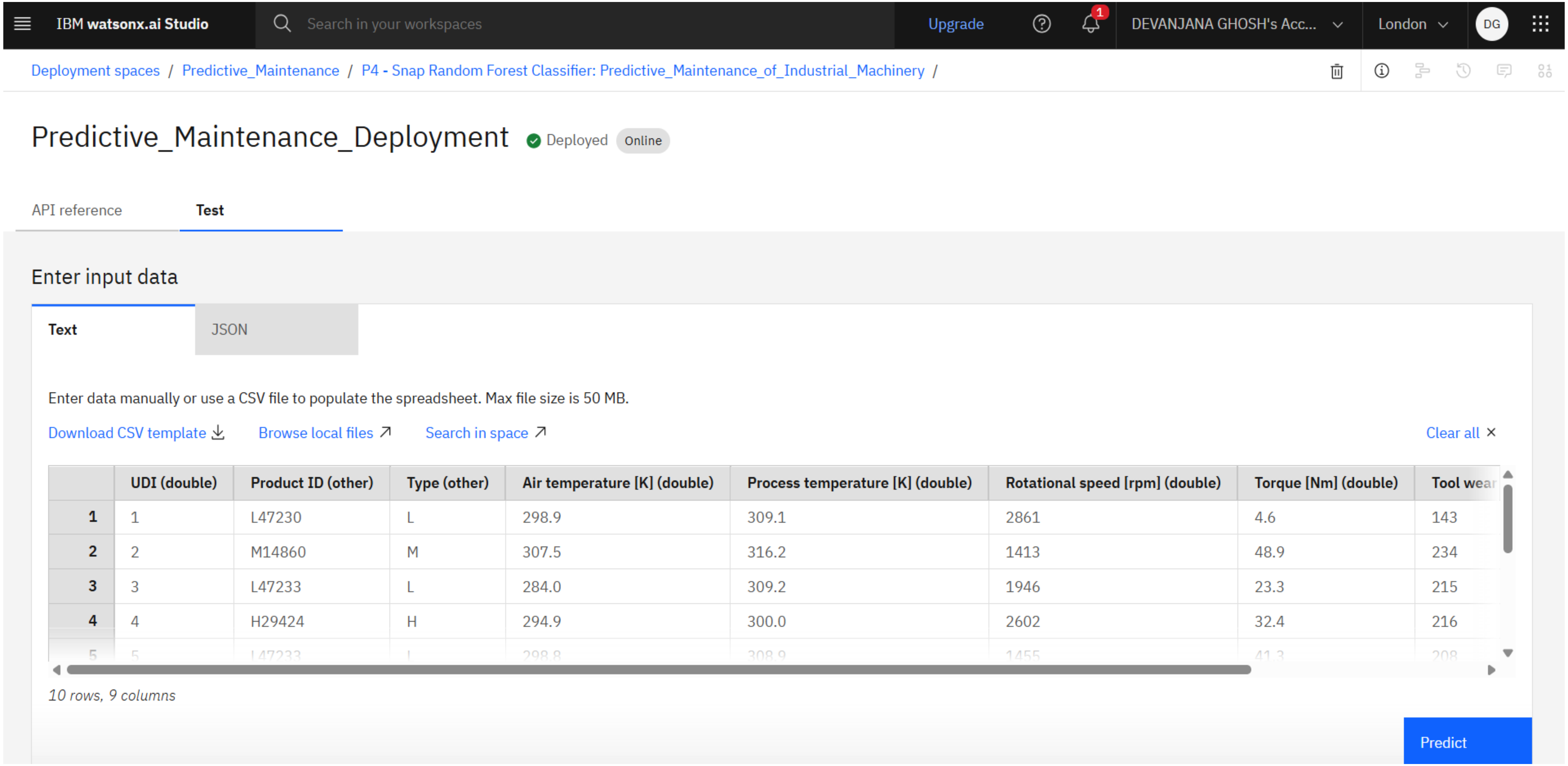
Time elapsed: 3 minutes
View log
Save code
Pipeline leaderboard
Rank
Name
Algorithm
Specialization
Accuracy (Optimized)
Cross Validation
Enhancements
Build time
1 Pipeline 4 Snap Random Forest Classifier 0.995 HPO-1 FE HPO-2 00:00:49
Save as
2 Pipeline 3 Snap Random Forest Classifier 0.995 HPO-1 FE 00:00:39
3 Pipeline 8 Snap Decision Tree Classifier 0.994 HPO-1 FE HPO-2 00:00:34
4 Pipeline 2 Snap Random Forest Classifier 0.994 HPO-1 00:00:10



	UDI (double)	Product ID (other)	Type (other)	Air temperature [K] (double)	Process temperature [K] (double)	Rotational speed [rpm] (double)	Torque [Nm] (double)	Tool wear
1	1	L47230	L	298.9	309.1	2861	4.6	143
2	2	M14860	M	307.5	316.2	1413	48.9	234
3	3	L47233	L	284.0	309.2	1946	23.3	215
4	4	H29424	H	294.9	300.0	2602	32.4	216
5	5	L47233	L	298.8	308.9	1455	41.3	208

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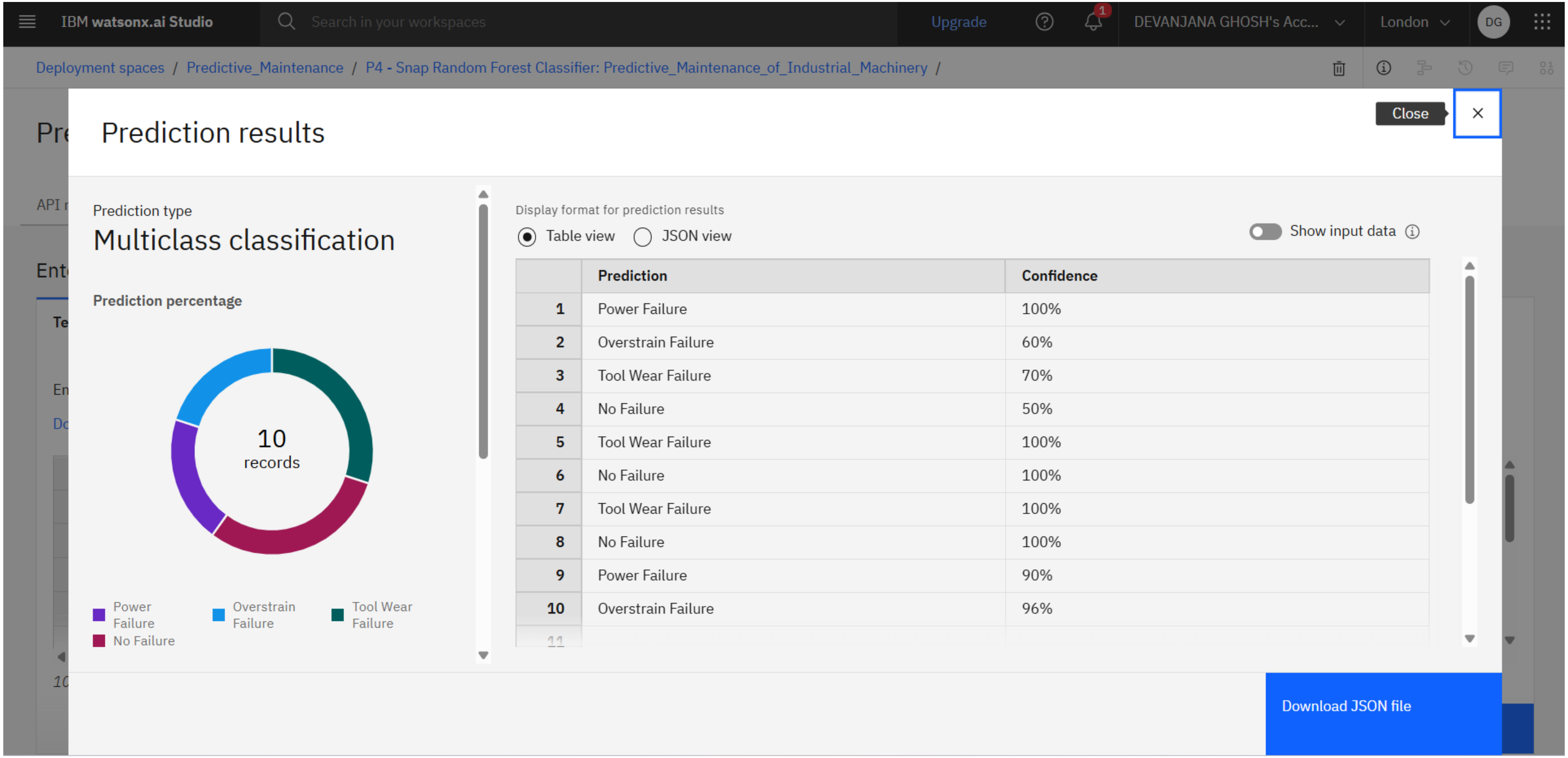
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Prediction results
Close
Prediction type
Multiclass classification
Prediction percentage
10
records
Power Failure
Overstrain Failure
Tool Wear Failure
No Failure
Display format for prediction results
Table view
JSON view
Show input data
Prediction
Confidence
1 Power Failure 100%
2 Overstrain Failure 60%
3 Tool Wear Failure 70%
4 No Failure 50%
5 Tool Wear Failure 100%
6 No Failure 100%
7 Tool Wear Failure 100%
8 No Failure 100%
9 Power Failure 90%
10 Overstrain Failure 96%
Download JSON file

CONCLUSION

The project successfully developed and deployed a predictive maintenance system using IBM Watson Studio and AutoAI on IBM Cloud Lite. The Snap Random Forest Classifier demonstrated exceptional performance in classifying multiple machine failure types with a holdout accuracy of 99.7%. This solution not only minimizes machine downtime and operational costs but also enhances equipment reliability and extends machinery lifespan. The seamless integration of REST APIs further enables real-time predictions and alerts for industrial teams, fostering smarter and more responsive maintenance strategies.

FUTURE SCOPE

The current system forms a solid base for predictive maintenance and can be enhanced further. Future improvements include using LSTM/GRU models for better time-series predictions, deploying models on edge devices for faster response, and integrating multimodal data like images or sound for deeper insights. The solution can be extended across industries and linked with smart schedulers for automated maintenance. A real-time IBM Cloud dashboard can also improve monitoring and decision-making.

REFERENCES

- Kaggle Dataset – Predictive Maintenance Dataset
- IBM Watson Studio Documentation
- AutoAI Overview in Watson Studio

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