CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY

Presented By:
Shruti Suresh Gaikwad – Vivekanand Arts, Sardar Dalipsingh Commerce and Science College – Computer Science

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OUTLINE

- **Problem Statement**
- **Proposed System/Solution**
- **System Development Approach** (Technology Used)
- **Algorithm & Deployment**
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- **Conclusion**
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- **References**

PROBLEM STATEMENT

- In modern manufacturing industries, machinery breakdowns lead to significant production losses, increased maintenance costs, and unexpected downtime.
- Traditionally, maintenance is either reactive (after a failure) or scheduled (based on usage), both of which are inefficient.
- The challenge is to develop a system that can predict potential machine failures in advance using real-time sensor data such as temperature, torque, speed, and tool wear.
- Accurately predicting the **type of failure** before it occurs can enable industries to shift toward **predictive maintenance**, improving operational efficiency and reducing unplanned outages.

PROPOSED SOLUTION

- The proposed system aims to address the challenge of predicting the type of failure in industrial machines before it occurs. This enables industries to move from reactive or scheduled maintenance to **predictive maintenance**, reducing unplanned downtime and optimizing operational efficiency. The solution will consist of the following components:
- **Data Collection :**
  - Gather historical sensor data from industrial machinery, including : Air temperature, Process temperature, Rotational speed, Torque, Tool wear, Product type
  - The target column is the Failure Type, which includes various failure categories (e.g., Tool Wear, Overstrain, Power Failure, etc.).
- **Data Preprocessing :**
  - Clean and preprocess the dataset by :
    - Removing irrelevant columns (UID, Product ID)
    - Handling missing values
    - Ensuring categorical data like Type is encoded properly
  - Analyze class imbalance and prepare data for model training.
- **Machine Learning Algorithm :**
  - Implement a Supervised Machine Learning algorithm using Watsonx.ai AutoAI, which automatically:
    - Selects the best classification algorithm
    - Trains the model on historical sensor data
    - Evaluates multiple pipelines based on accuracy
  - Multi-class classification is used to predict the specific type of failure

PROPOSED SOLUTION

- **Deployment :**
  - The best model from Auto AI is:
    - Promoted to a **Deployment Space**
    - Deployed as an **online prediction** service using IBM Watsonx.ai
  - This enables real-time prediction of failure types from new input data.
- **Evaluation :**
  - Model performance is evaluated using metrics like:
    - Accuracy
    - Precision
    - Recall
    - Confusion Matrix
  - Predictions are tested using sample machine data to verify accuracy

SYSTEM APPROACH

The "System Approach" section outlines the overall strategy and tools used to develop and implement the predictive maintenance system using machine learning on IBM Cloud. Here's a suggested structure for this section:

- **System requirements :**
  - Minimum 4 GB RAM
  - Intel i3 Processor or above
  - Stable Internet Connection
  - Web browser (Chrome/Edge) to access IBM Cloud
- **Library required to build the model :**
  - IBM Cloud Lite Account
  - Watsonx.ai Studio
  - Cloud Object Storage (Free plan)

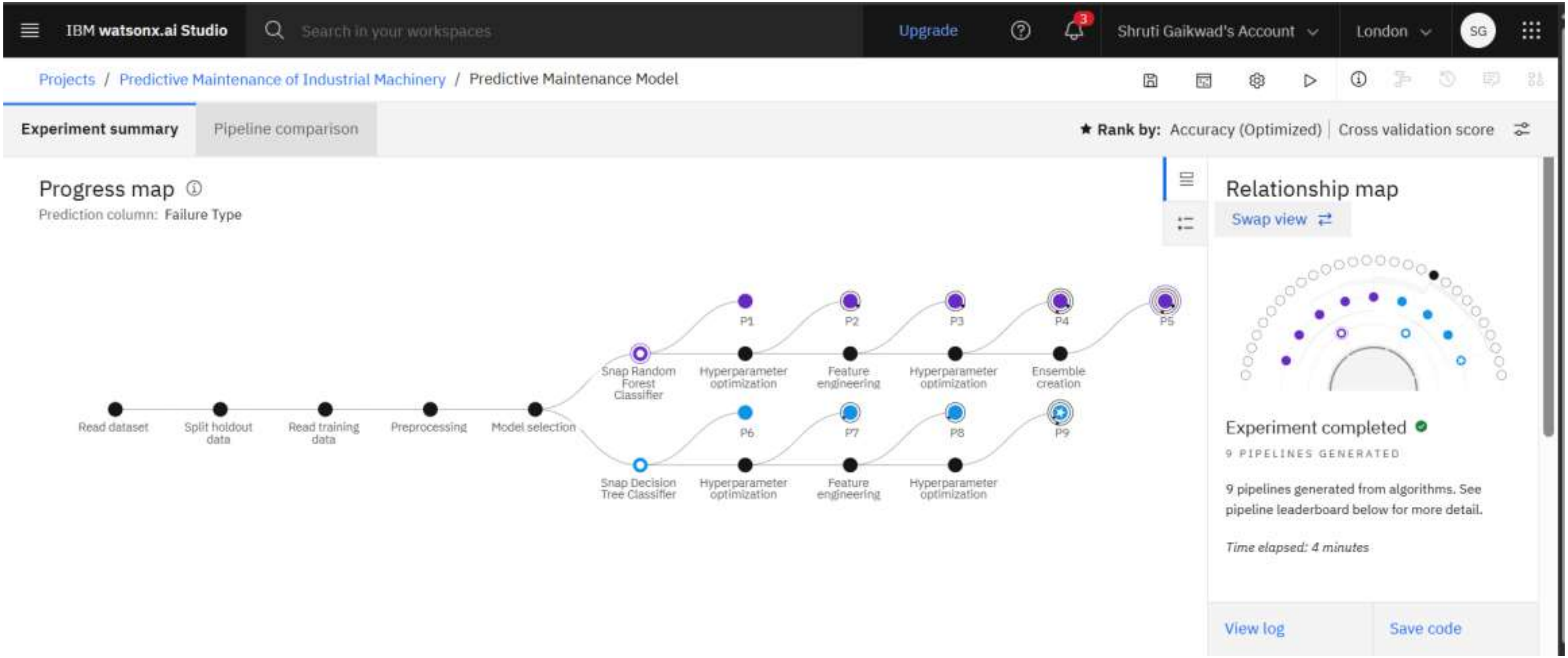
ALGORITHM & DEPLOYMENT

- **Algorithm Selection :**
  - The algorithm was selected using Watsonx.ai AutoAI, which automatically compares multiple classification algorithms.
  - The best-performing algorithm chosen was Decision Tree Classifier, as it handles multi-class classification effectively and works well with tabular sensor data.
  - Random Forest is robust to overfitting and performs well even when data is slightly imbalanced.
- **Data Input:**
  - Input features used to train the model :
    - Type (L, M, H)
    - Air temperature [K]
    - Process temperature [K]
    - Rotational speed [rpm]
    - Torque [Nm]
    - Tool wear [min]
  - Target variable :
    - Failure Type (Includes: No Failure, Tool Wear Failure, Power Failure, etc.)

ALGORITHM & DEPLOYMENT

- **Training Process:**
  - The dataset was uploaded to **Watsonx.ai AutoAI**.
  - AutoAI :
    - Automatically handled preprocessing and feature engineering.
    - Trained multiple models using techniques like cross-validation.
    - Evaluated models based on accuracy and precision.
  - The top-ranked model was saved and promoted for deployment.
- **Prediction Process:**
  - After deployment, the model receives real-time machine sensor data.
  - Based on the input, it predicts the type of failure that might occur.
  - This helps in taking preventive action before the actual failure happens.
- **Deployment :**
  - The selected model was:
    - Promoted to a **Deployment Space** on IBM Cloud.
    - Deployed as an **Online Web Service** using Watsonx.ai.
  - Users can test the deployed model by sending new machine data and getting predicted failure types instantly.

RESULT



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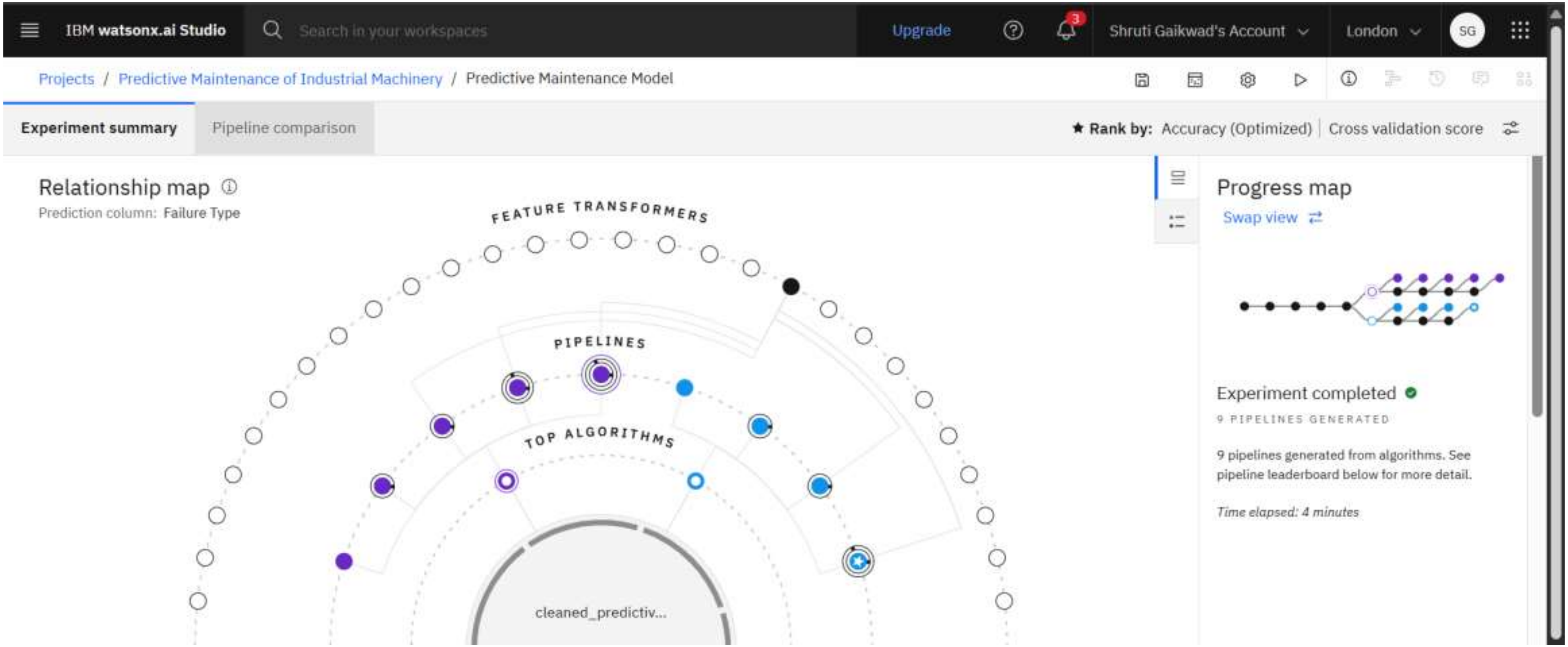
RESULT



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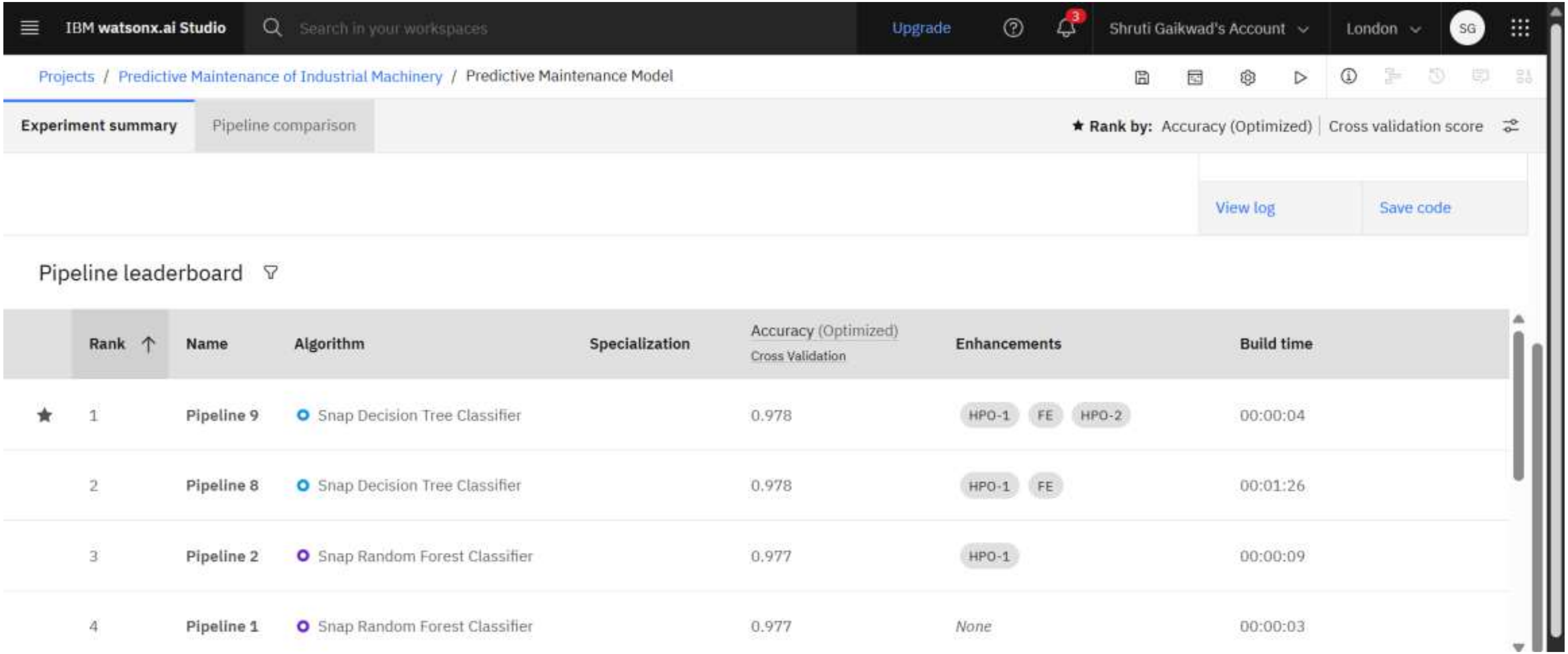
RESULT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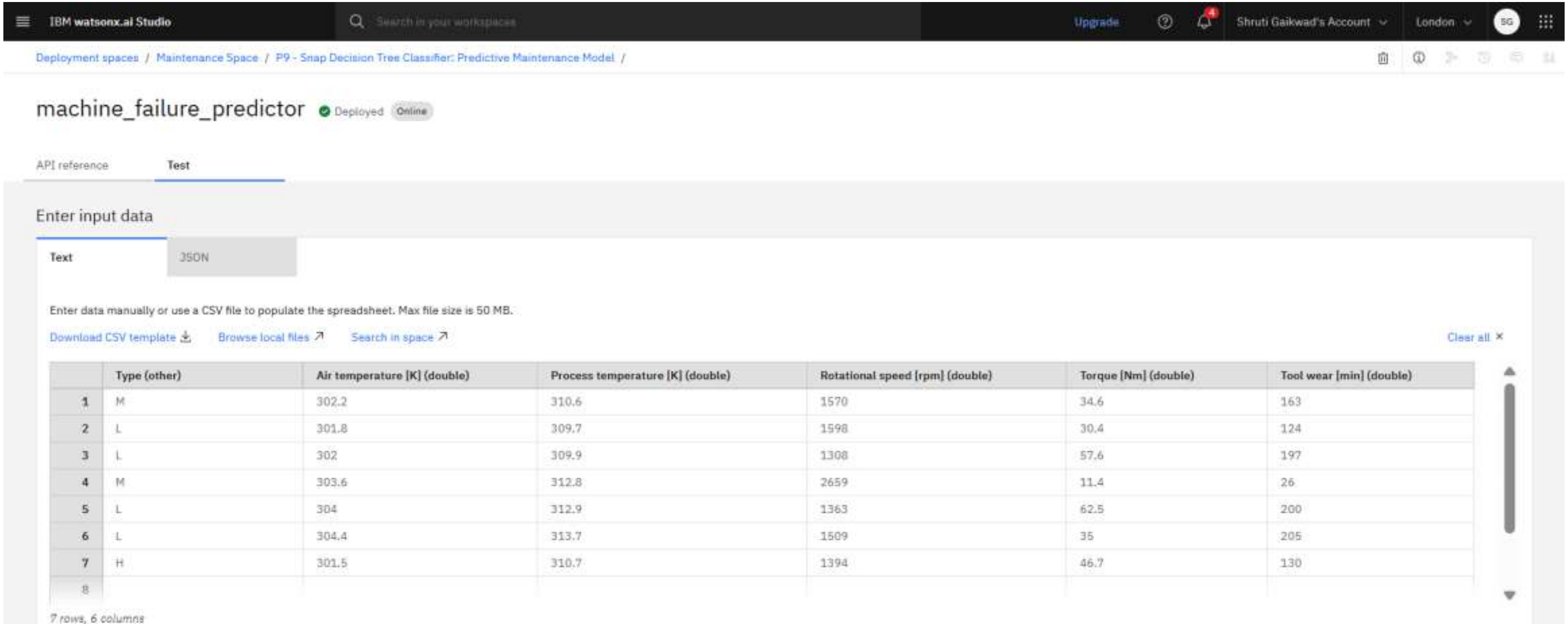
Projects / Predictive Maintenance of Industrial Machinery / Predictive Maintenance Model
Experiment summary
Pipeline comparison
Rank by: Accuracy (Optimized) | Cross validation score
View log
Save code
Pipeline leaderboard
Rank
Name
Algorithm
Specialization
Accuracy (Optimized)
Cross Validation
Enhancements
Build time
1 Pipeline 9 Snap Decision Tree Classifier 0.978 HPO-1 FE HPO-2 00:00:04
2 Pipeline 8 Snap Decision Tree Classifier 0.978 HPO-1 FE 00:01:26
3 Pipeline 2 Snap Random Forest Classifier 0.977 HPO-1 00:00:09
4 Pipeline 1 Snap Random Forest Classifier 0.977 None 00:00:03

RESULT



	Type (other)	Air temperature [K] (double)	Process temperature [K] (double)	Rotational speed [rpm] (double)	Torque [Nm] (double)	Tool wear [min] (double)
1	M	302.2	310.6	1570	34.6	163
2	L	301.8	309.7	1598	30.4	124
3	L	302	309.9	1308	57.6	197
4	M	303.6	312.8	2659	11.4	26
5	L	304	312.9	1363	62.5	200
6	L	304.4	313.7	1509	35	205
7	H	301.5	310.7	1394	46.7	130
8						

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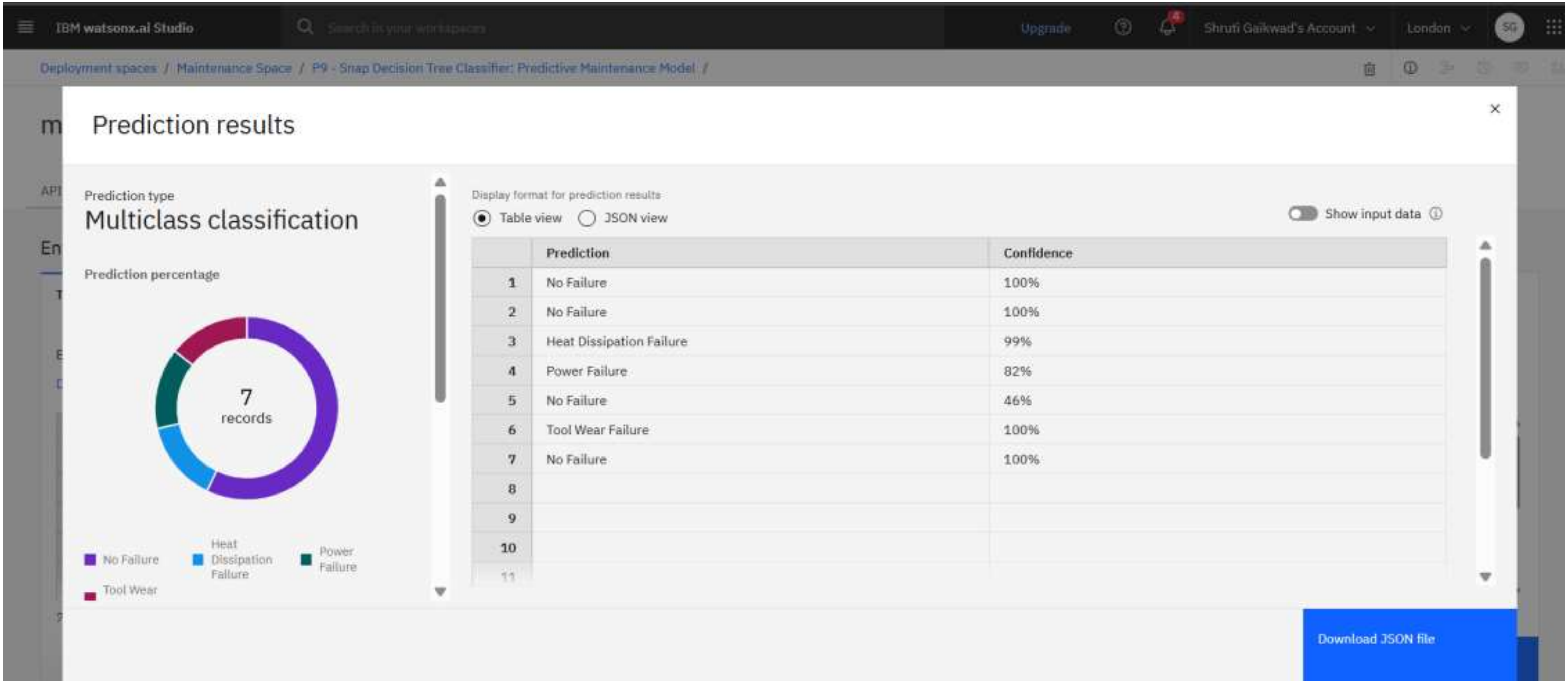
RESULT



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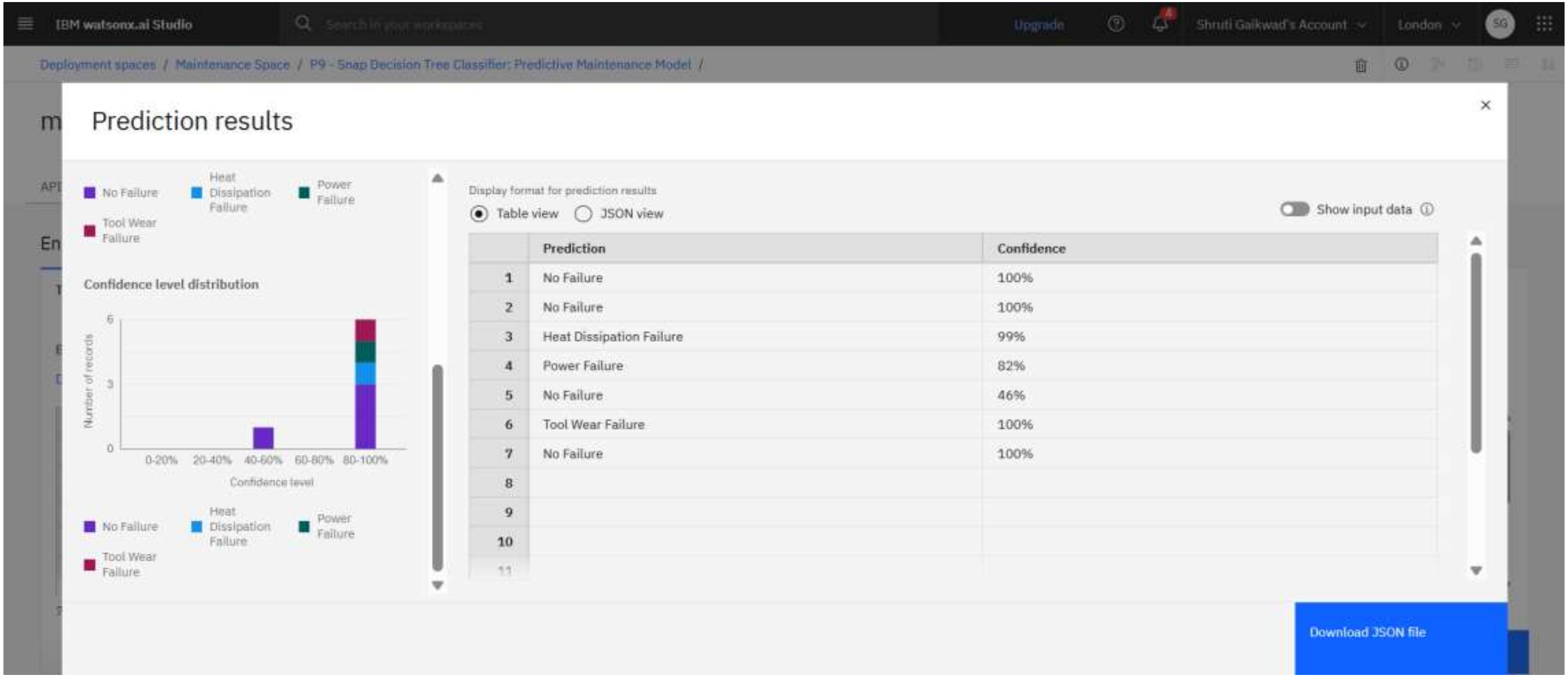
RESULT



IBM watsonx.ai Studio
Upgrade
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Deployment spaces / Maintenance Space / P9 - Snap Decision Tree Classifier: Predictive Maintenance Model /
Prediction results
No Failure
Heat Dissipation Failure
Power Failure
Tool Wear Failure
Confidence level distribution
Number of records
0
3
6
0-20%
20-40%
40-60%
60-80%
80-100%
Confidence level
Display format for prediction results
Table view
JSON view
Show input data
Prediction
Confidence
1 No Failure 100%
2 No Failure 100%
3 Heat Dissipation Failure 99%
4 Power Failure 82%
5 No Failure 46%
6 Tool Wear Failure 100%
7 No Failure 100%
8
9
10
Download JSON file

CONCLUSION

- The project successfully developed a supervised machine learning model to predict the type of failure in industrial machines using real-time sensor data. By leveraging IBM Watsonx.ai's AutoAI, the system automatically selected the best-performing model, enabling accurate classification of failures such as tool wear, power failure, and overstrain. This solution helps industries move toward predictive maintenance, reducing unexpected downtime and maintenance costs. During implementation, challenges like class imbalance and sensor data interpretation were addressed. The project demonstrates the effectiveness of machine learning in improving industrial efficiency, with potential for future enhancements like real-time IoT integration and expanded failure categories.

FUTURE SCOPE

- Integrate **real-time IoT sensor data** to enable live failure prediction and faster decision-making.
- Expand the system to **include more sensor types**, such as vibration, sound, oil quality, and machine usage history.
- Use **advanced machine learning techniques** like deep learning or ensemble models to improve prediction accuracy.
- Implement **edge computing** for on-site prediction without relying solely on cloud infrastructure.
- Extend the system to work with **different types of industrial machines** across various sectors (e.g., automotive, manufacturing, power plants).
- Enable **dashboard-based monitoring tools** for maintenance teams to visualize failure trends and model predictions.
- Regularly update the model with **new failure cases** to keep improving accuracy over time.

REFERENCES

- **Kaggle Dataset** – https://www.kaggle.com/datasets/shivamb/machine-predictive-maintenance-classification
- **IBM Cloud Lite** – https://cloud.ibm.com
- **IBM Watsonx.ai Documentation** – https://www.ibm.com/cloud/watsonx-ai

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Completion date: 29 Jul 2025 (GMT)

Learning hours: 20 mins

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