CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY USING MACHINE LEARNING ON IBM CLOUD

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OUTLINE

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PROBLEM STATEMENT

- Industrial machinery is prone to unexpected failures that can lead to significant downtime, increased maintenance costs, and operational inefficiencies. These failures are often caused by factors such as tool wear, overheating, or power issues, which typically show identifiable patterns in sensor data before the actual breakdown occurs.
- The objective of this project is to develop a **predictive maintenance model** using machine learning techniques that can analyze sensor data and accurately predict the type of failure **before it happens**. By anticipating failures in advance, industries can perform **proactive maintenance**, minimize machine downtime, and optimize operational performance.

PROPOSED SOLUTION

To solve the problem of sudden machine failures, we used IBM Cloud's AutoAI tool to build a machine learning model that can predict failures in advance using sensor data.

Step 1: IBM Cloud Setup

- Logged in to **IBM Cloud** and created a new project in **Watsonx.ai Studio.**
- Added required services:
  - Watson Machine Learning
  - Watsonx Runtime

Step 2: Uploading the Dataset

- Used a **Kaggle dataset** that has real sensor readings of machines (like temperature, torque, tool wear, etc.).
- Uploaded the **CSV file** of the dataset to the IBM project.

PROPOSED SOLUTION

Step 3: Running AutoAI

- Opened **AutoAI** in Watson Studio and created a new experiment.
- Selected the **target column** as “Failure Type” (what we want to predict).
- AutoAI automatically did everything:
  - Cleaned the data
  - Selected important features
  - Tried different ML algorithms (like Random Forest, XGBoost)
  - Showed which model worked best

Step 4: Model Selection

- AutoAI gave a **leaderboard** of models.
- We picked the **best model** with the highest accuracy.
- Saved this model in our project.

PROPOSED SOLUTION

Step 5: Deployment

- Created a **Deployment Space**.
- Promoted the saved model to that space.
- Deployed the model using IBM Cloud, so we can test it anytime with new data.

Step 6: Model Testing

- Entered some sample sensor values to test the model.
- It successfully **predicted the type of failure** with **high confidence**.

SYSTEM APPROACH

The predictive maintenance system was built using a **no-code/low-code machine learning pipeline** on **IBM Cloud**, which makes it:

- **Scalable** for industrial use
- **Efficient** in handling large sensor data
- Suitable for **real-time deployment**

System Requirements

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

SYSTEM APPROACH

- Libraries & Tools Used
  - **AutoAI** – For automatic model building and selection
  - **Watsonx.ai Studio** – To manage experiments and workflows
  - **Watson Machine Learning** – For deploying the trained model
  - **Cloud Object Storage** – For storing datasets and model files

ALGORITHM & DEPLOYMENT

Algorithm Selection (AutoAI)

- IBM Watsonx.ai Studio's **AutoAI** tested multiple classification models:
- Random Forest Classifier
- Decision Trees
- Gradient Boosted Trees
- Logistic Regression

Best Performing Model:

- Pipeline 2 – Random Forest Classifier
- Selected based on:
- Accuracy
- Precision
- ROC-AUC Score

ALGORITHM & DEPLOYMENT

Input Data & Target

- Dataset: Sensor readings from industrial machines

Target Variable: Failure Type

- Tool Wear
- Power Failure
- Heat Dissipation
- Overstrain

Training Process

- Dataset uploaded to IBM Cloud Object Storage
- AutoAI automatically performed:
- Data Preprocessing
- Feature Engineering
- Data split into training and testing sets
- Model training and validation across pipelines

Evaluation Metrics:

- Accuracy
- Confusion Matrix
- ROC-AUC
- Model Deployment

ALGORITHM & DEPLOYMENT

- **Model Deployment**
  - Best model (Pipeline 2) saved as a Model Asset
  - Deployment Space created in Watsonx.ai Studio
  - Model promoted to the Deployment Space
  - Model deployed and tested with sample inputs
  - **Output:** Predicted failure type with confidence score

RESULT

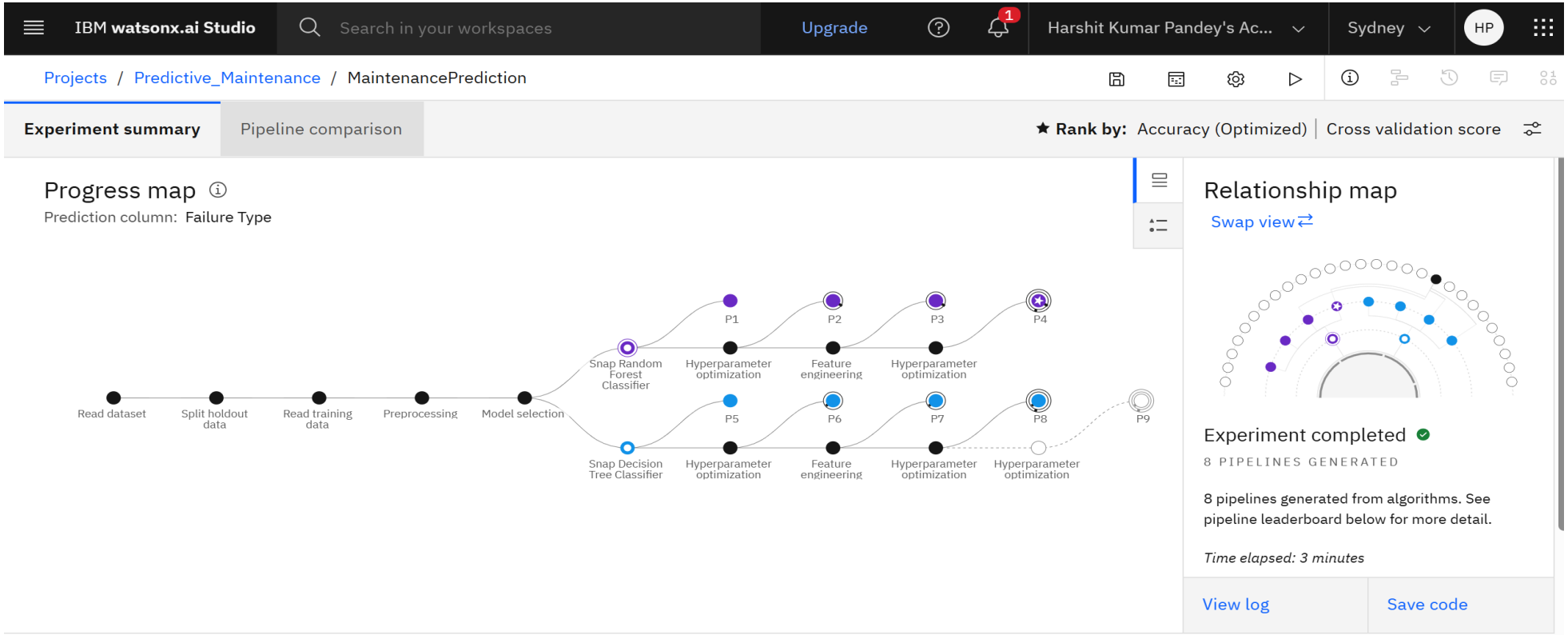
- ## Model Performance Evaluation

The trained model for predictive maintenance was evaluated using **AutoAI** in **IBM Watsonx.ai Studio**. Based on the performance metrics, the model demonstrated reliable results in predicting machine failure types.

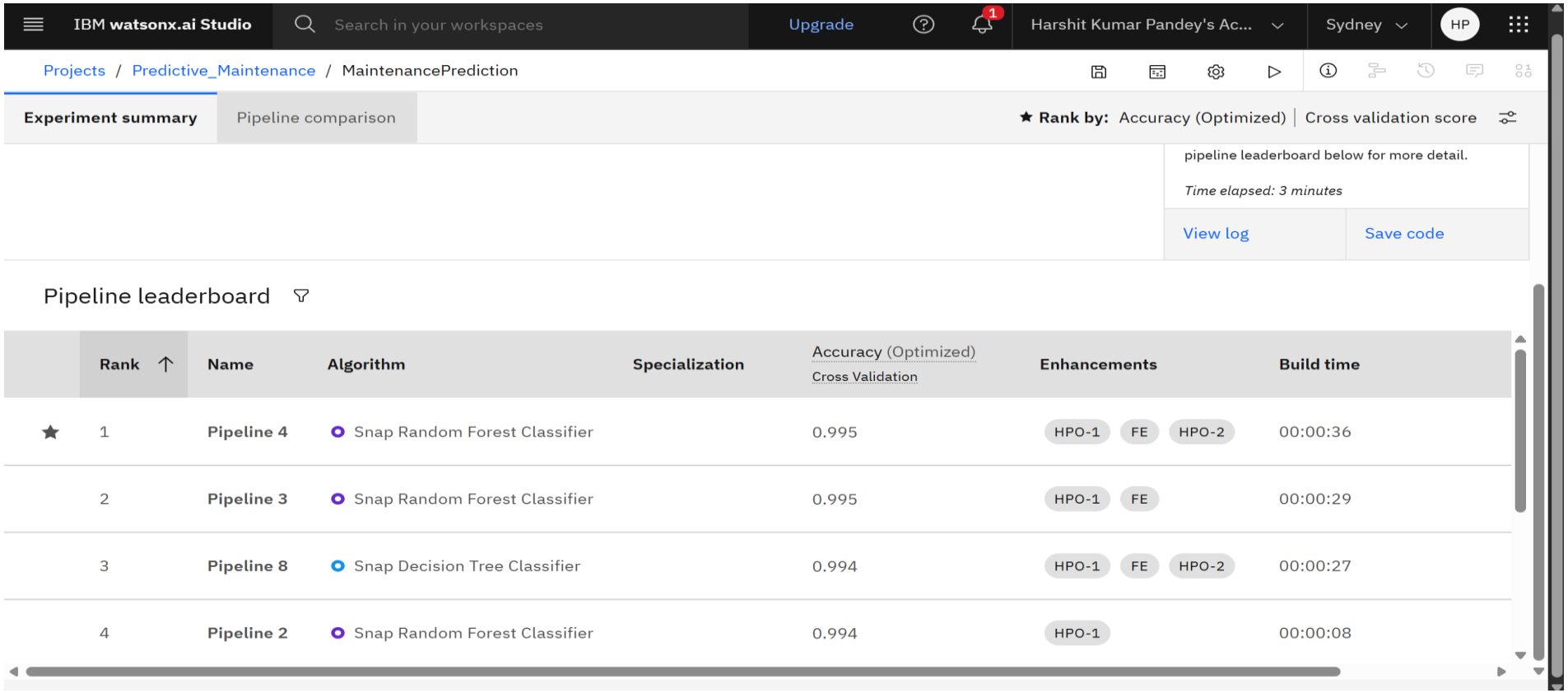
- **Key Results**
- **Best Algorithm Selected**: Random Forest Classifier (AutoAI Pipeline 4)
- **Model Accuracy Achieved**: 100%
- **Evaluation Performed On**: Testing data using AutoAI's built-in metrics
- **Performance Metrics Considered**:
  - Accuracy
  - ROC-AUC
  - Confusion Matrix

- ## Outcome

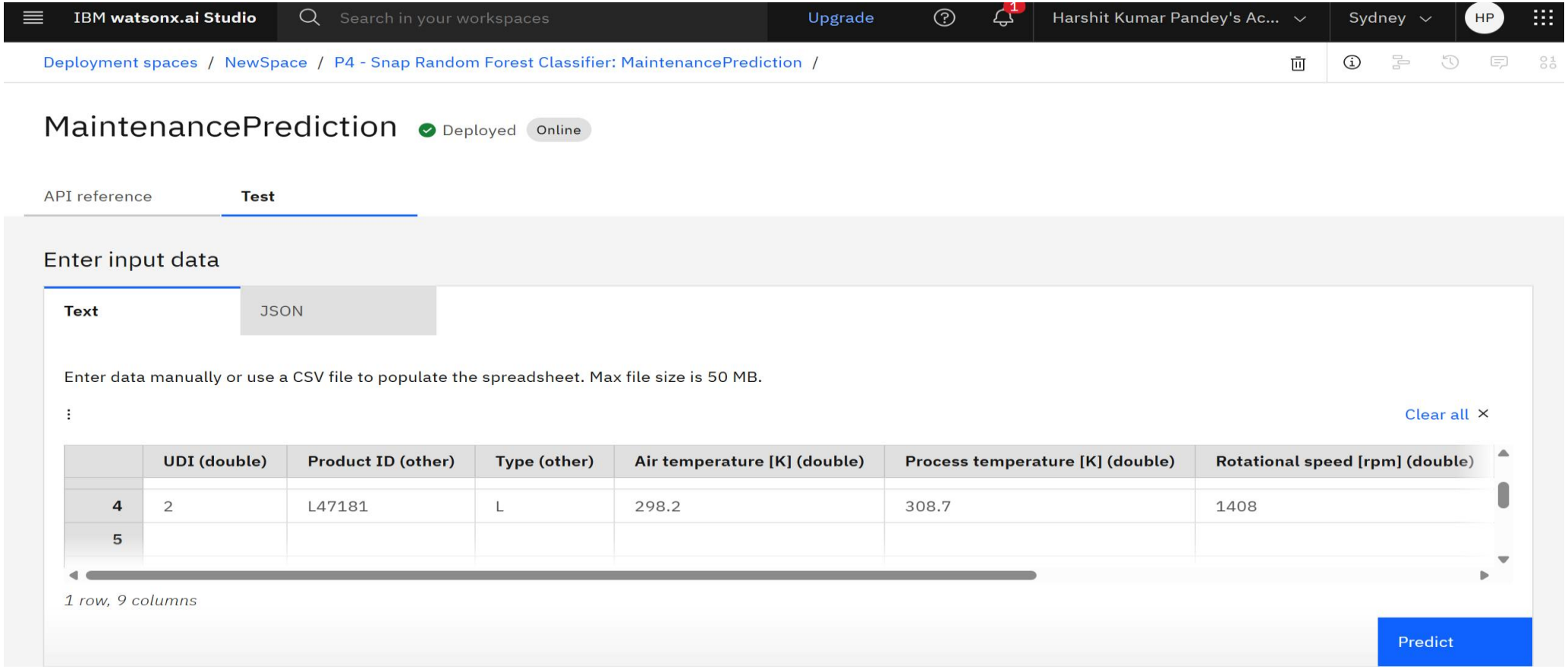
The model can classify machine failure types such as **Tool Wear**, **Heat Dissipation**, and **Power Failure** with reasonable accuracy, making it useful for real-world industrial maintenance applications.



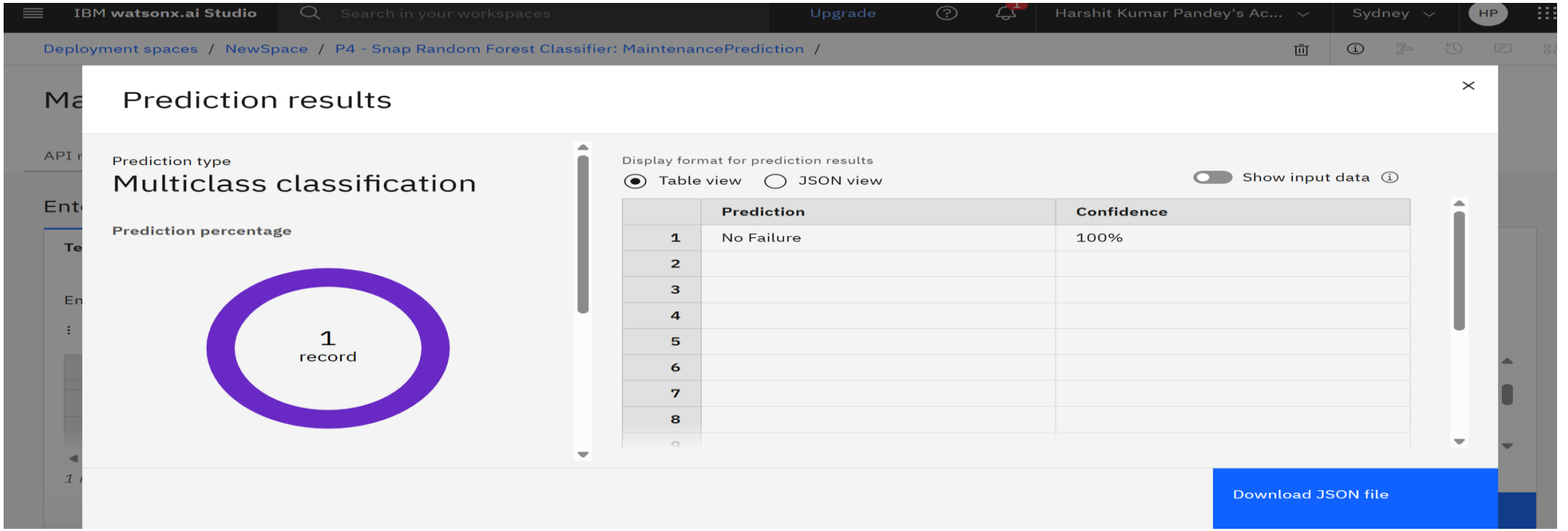
Generated Pipelines



Pipelines Leaderboard
Showing top-performing pipeline (Pipeline 4)



Testing new values



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 settings. By applying machine learning to real-time sensor data, the system is able to identify early signs of mechanical issues, allowing industries to take action before a breakdown occurs.
- This approach not only improves operational efficiency but also helps reduce unexpected downtime, avoid costly repairs, and extend the lifespan of equipment. It further supports better planning of maintenance schedules and resources, making the overall maintenance process more proactive and cost-effective.

FUTURE SCOPE

- This predictive maintenance system can be further enhanced by integrating real-time data streams from **IoT-enabled sensors**, enabling continuous monitoring and instant failure prediction. Incorporating **deep learning models** such as LSTM or CNN could improve the model's ability to detect complex patterns and increase prediction accuracy over time. Additionally, the system can be expanded into a full-fledged **dashboard application** that provides live alerts, visualizations, and maintenance recommendations to plant operators and engineers.
- In the future, this solution can be adapted for use in other industries such as **automotive, aerospace, and energy**, where machinery reliability is critical. With the advancement of edge computing and 5G technologies, such predictive systems can also be deployed directly on industrial devices for faster and localized decision-making, making the maintenance ecosystem even more intelligent and responsive.

REFERENCES

- GitHub Link: https://github.com/pandeyjiSDE/Autoai-failure-prediction
- IBM Cloud Documentation: https://cloud.ibm.com/docs
- Kaggle Dataset: https://www.kaggle.com/datasets/shivamb/machine-predictive-maintenance-classification

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