CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY

PRESENTED BY

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OUTLINE

- **Problem Statement**
- **Proposed System / Solution**
- **System Development Approach** (Technology Used)
- **Algorithm & Deployment**
- **Result** (Output Images)
- **Conclusion**
- **Future Scope**
- **References**
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PROBLEM STATEMENT

Industrial machinery experiences different types of failures — such as tool wear, heat dissipation issues, and power failure.

Traditional maintenance is either reactive (post-failure) or scheduled at fixed intervals, which is inefficient. These failures can lead to unexpected downtime and increased operational costs. Predicting these failures ahead of time is crucial to schedule proactive maintenance and ensure optimal productivity. The goal is to create a machine learning classification model to anticipate failure types using real-time sensor data.

PROPOSED SOLUTION

The proposed system uses a supervised machine learning classification model to predict the type of failure using real-time sensor data from industrial machines. It is implemented entirely using IBM Cloud services.

- **Data Source:** The dataset used is from Kaggle and contains labeled historical sensor readings from industrial machines. It includes features such as air temperature, process temperature, rotational speed, torque, tool wear, machine type, and failure type.
- **Data Pre-processing:** The dataset was cleaned and prepared using IBM Watson Studio's Data Refinery tool. This included removing missing/null values, handling categorical variables, removing unnecessary columns, preparing a clean dataset ready for modeling.
- **Machine Learning Algorithm:** Using AutoAI, multiple classification models were trained and compared (e.g., XGBoost, Random Forest, Logistic Regression). AutoAI automatically performed feature engineering, hyperparameter optimization, and pipeline ranking. The best-performing pipeline was selected based on accuracy and F1-score.
- **Deployment:** The best-performing model was deployed using Watson Studio's Deployment Spaces. The model was published as a REST API endpoint, allowing integration with systems for real-time inference. Thus it can receive live sensor inputs and return the predicted machine failure type, enabling proactive maintenance.
- **Evaluation:** AutoAI evaluated models using multiple metrics i.e., Accuracy, Precision, Recall, F1-score. Confusion matrix and performance charts were reviewed to confirm reliability across all failure categories.

SYSTEM APPROACH

- **System Requirements :**
  - Desktop Environment
  - Web Browser
  - IBM Cloud
- **Cloud Components / Services :**
  - IBM watsonx.ai Studio (AutoAI)
  - IBM watsonx.ai Runtime
  - IBM Cloud Object Storage
  - IBM Data Refinery
  - IBM Watson Machine Learning (via Deployment Spaces)

ALGORITHM & DEPLOYMENT

- **Algorithm Selection**

  AutoAI experimented with classifiers including XGBoost, Random Forest, and Logistic Regression. **Random Forest Classifier** algorithm was selected based on performance.

- **Input Features**

  Air Temperature, Process Temperature, Rotational Speed, Torque, Tool Wear, and Machine Type.

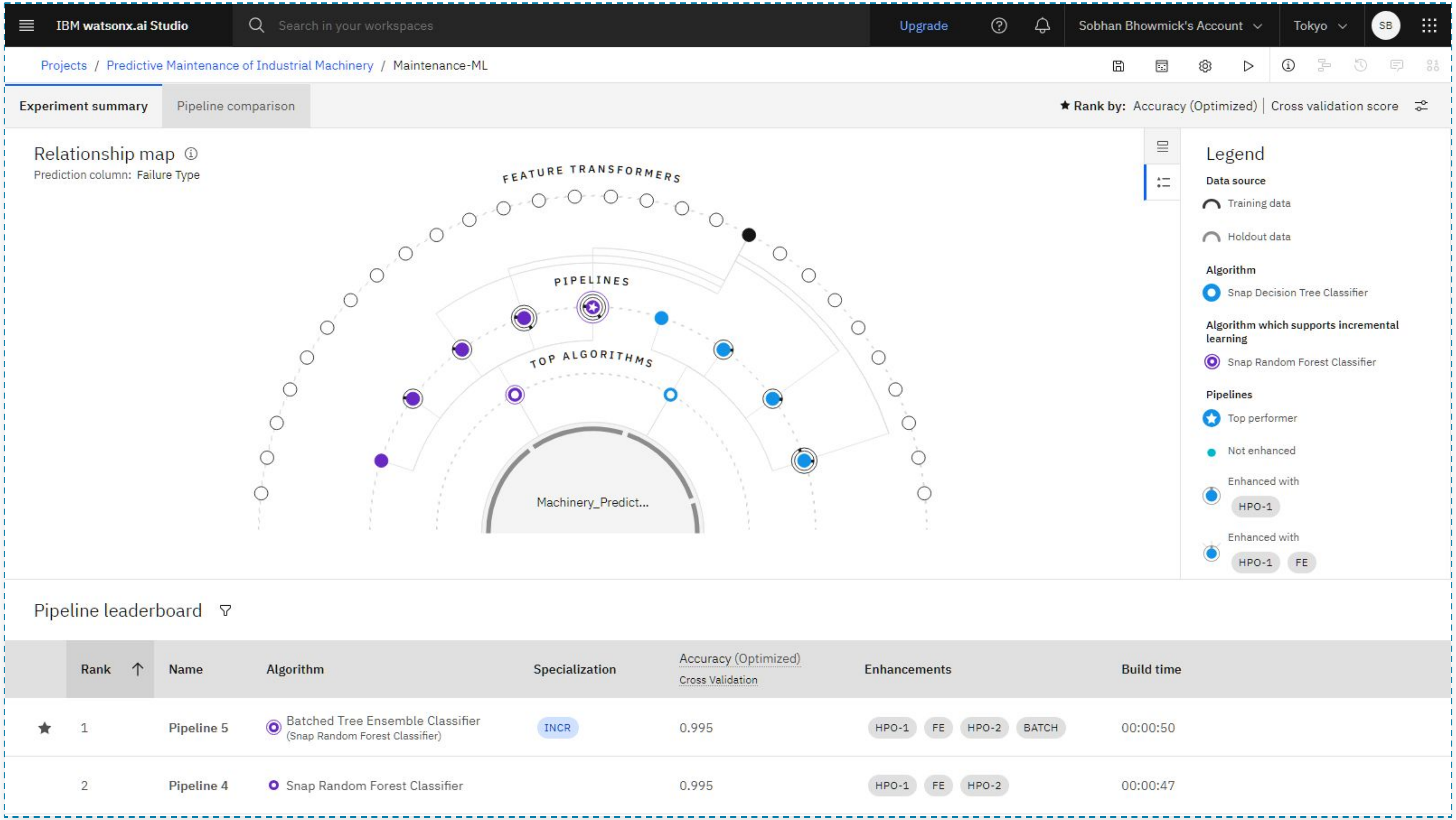
- **Training**

  AutoAI handled feature transformation, cross-validation, and hyperparameter tuning automatically.

- **Prediction Process**

  The deployed model predicts whether the machine will fail and the specific failure type (Tool Wear, Heat Dissipation, Power Failure, etc.) based on real-time operational data.

RESULT



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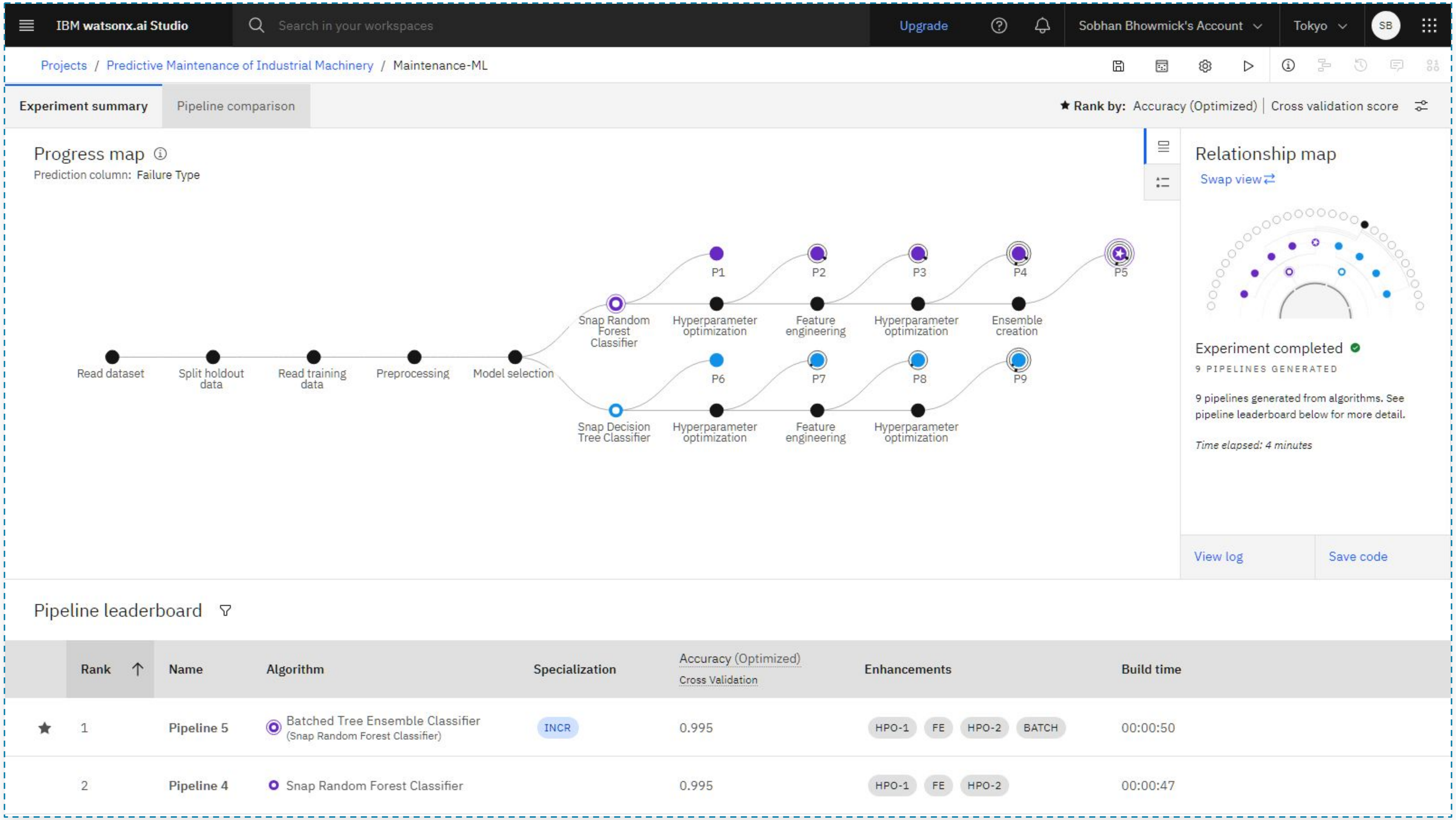
Experiment summary
Pipeline comparison
Rank by: Accuracy (Optimized) | Cross validation score
Relationship map
Prediction column: Failure Type
FEATURE TRANSFORMERS
PIPELINES
TOP ALGORITHMS
Machinery_Predict...
Legend
Data source
Training data
Holdout data
Algorithm
Snap Decision Tree Classifier
Algorithm which supports incremental learning
Snap Random Forest Classifier
Pipelines
Top performer
Not enhanced
Enhanced with
HPO-1
Enhanced with
HPO-1
FE
Pipeline leaderboard
Rank
Name
Algorithm
Specialization
Accuracy (Optimized)
Cross Validation
Enhancements
Build time
1
Pipeline 5
Batched Tree Ensemble Classifier
(Snap Random Forest Classifier)
INCR
0.995
HPO-1
FE
HPO-2
BATCH
00:00:50
2
Pipeline 4
Snap Random Forest Classifier
0.995
HPO-1
FE
HPO-2
00:00:47

RESULT



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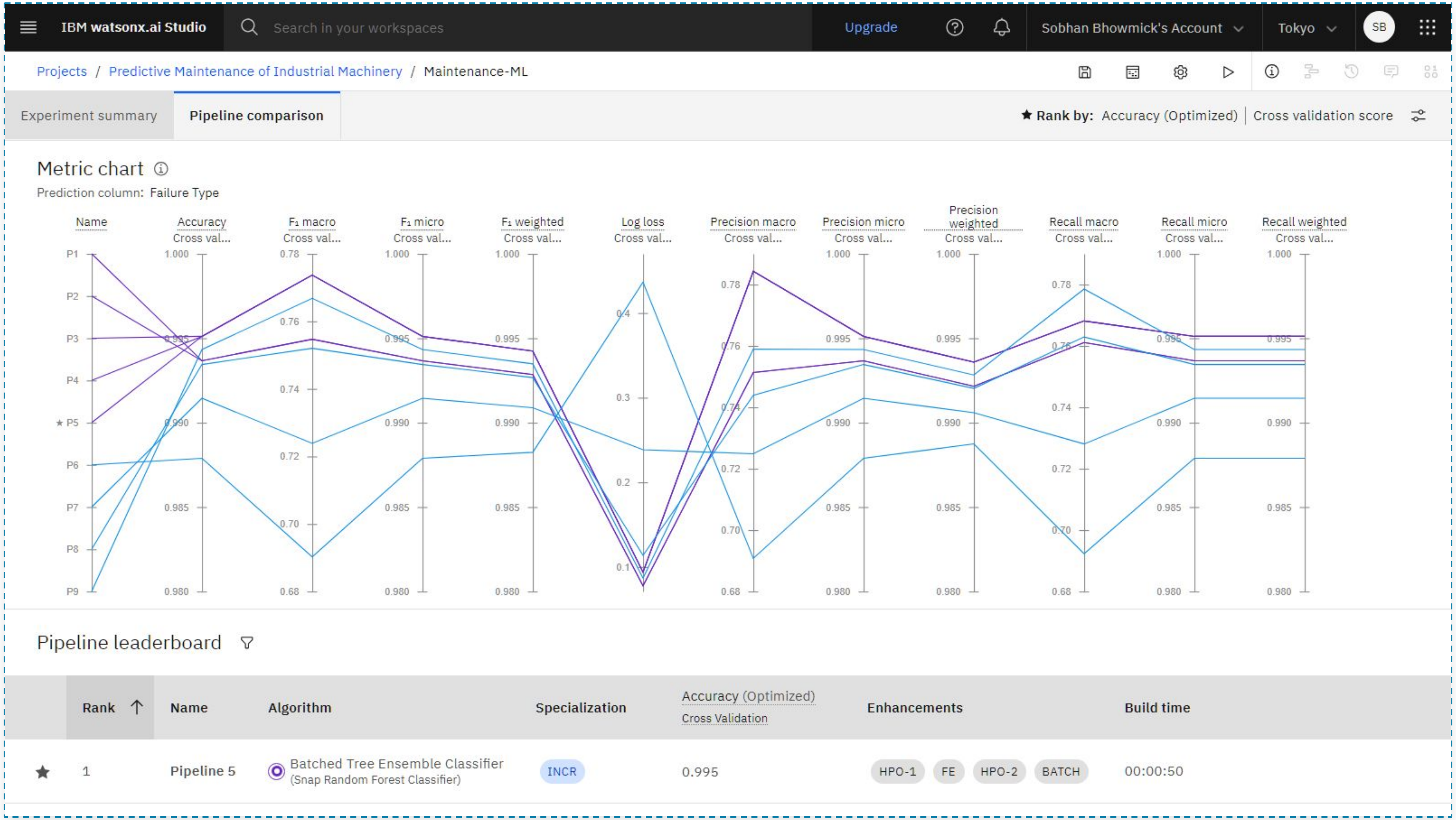
Experiment summary
Pipeline comparison
Rank by: Accuracy (Optimized) | Cross validation score
Progress map
Prediction column: Failure Type
Read dataset
Split holdout data
Read training data
Preprocessing
Model selection
Snap Random Forest Classifier
Snap Decision Tree Classifier
Hyperparameter optimization
Feature engineering
Ensemble creation
P1
P2
P3
P4
P5
P6
P7
P8
P9
Relationship map
Swap view
Experiment completed
9 PIPELINES GENERATED
9 pipelines generated from algorithms. See pipeline leaderboard below for more detail.
Time elapsed: 4 minutes
View log
Save code
Pipeline leaderboard
Rank
Name
Algorithm
Specialization
Accuracy (Optimized)
Cross Validation
Enhancements
Build time
1
Pipeline 5
Batched Tree Ensemble Classifier
(Snap Random Forest Classifier)
INCR
0.995
HPO-1
FE
HPO-2
BATCH
00:00:50
2
Pipeline 4
Snap Random Forest Classifier
0.995
HPO-1
FE
HPO-2
00:00:47

RESULT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Experiment summary
Pipeline comparison
Rank by: Accuracy (Optimized) | Cross validation score
Metric chart
Prediction column: Failure Type
Name
Accuracy Cross val...
F1 macro Cross val...
F1 micro Cross val...
F1 weighted Cross val...
Log loss Cross val...
Precision macro Cross val...
Precision micro Cross val...
Precision weighted Cross val...
Recall macro Cross val...
Recall micro Cross val...
Recall weighted Cross val...
P1
P2
P3
P4
P5
P6
P7
P8
P9
Pipeline leaderboard
Rank
Name
Algorithm
Specialization
Accuracy (Optimized) Cross Validation
Enhancements
Build time
1
Pipeline 5
Batched Tree Ensemble Classifier (Snap Random Forest Classifier)
INCR
0.995
HPO-1
FE
HPO-2
BATCH
00:00:50

RESULT

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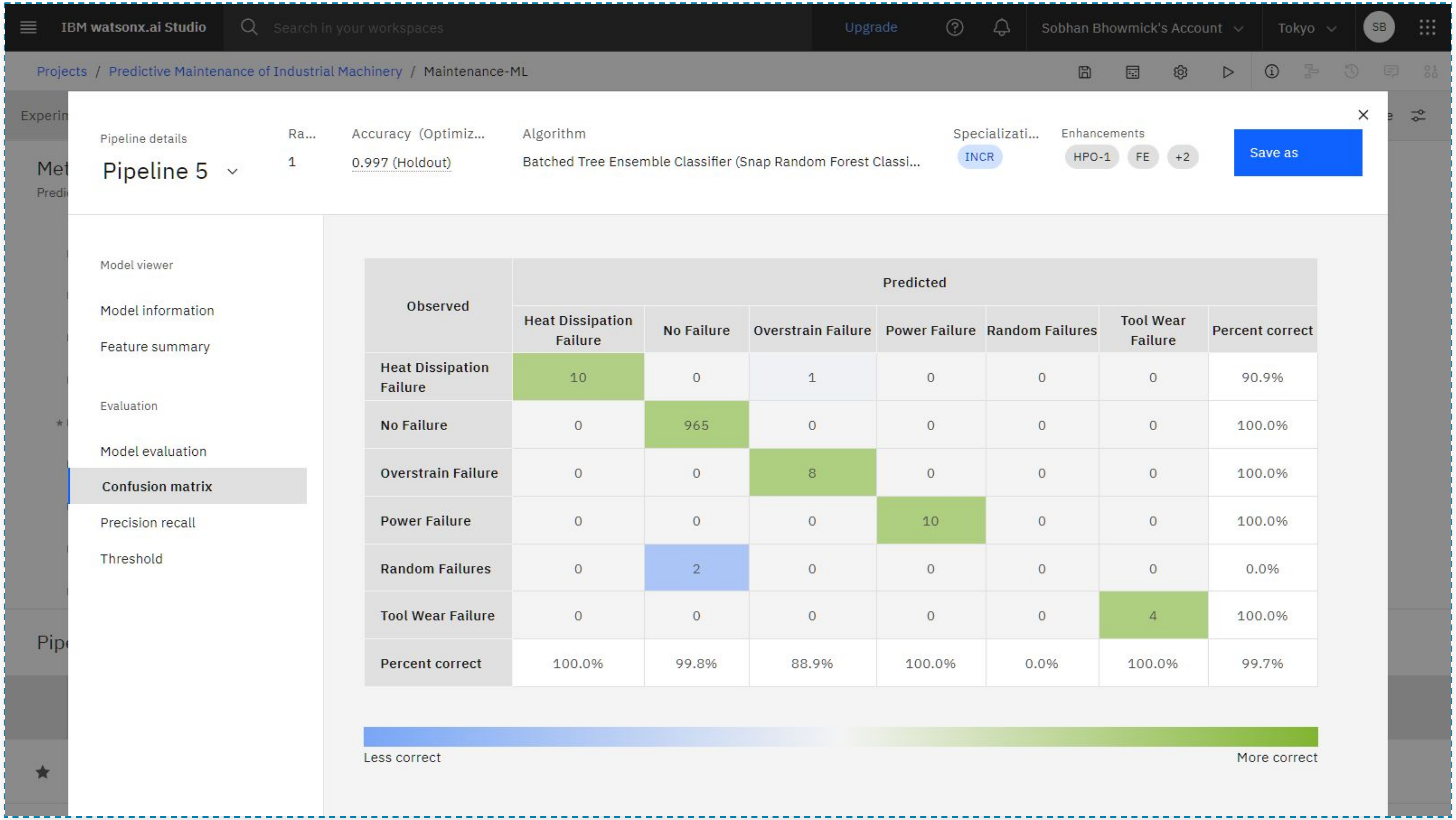
Experiment summary | Pipeline comparison

★ Rank by: Accuracy (Optimized) | Cross validation score

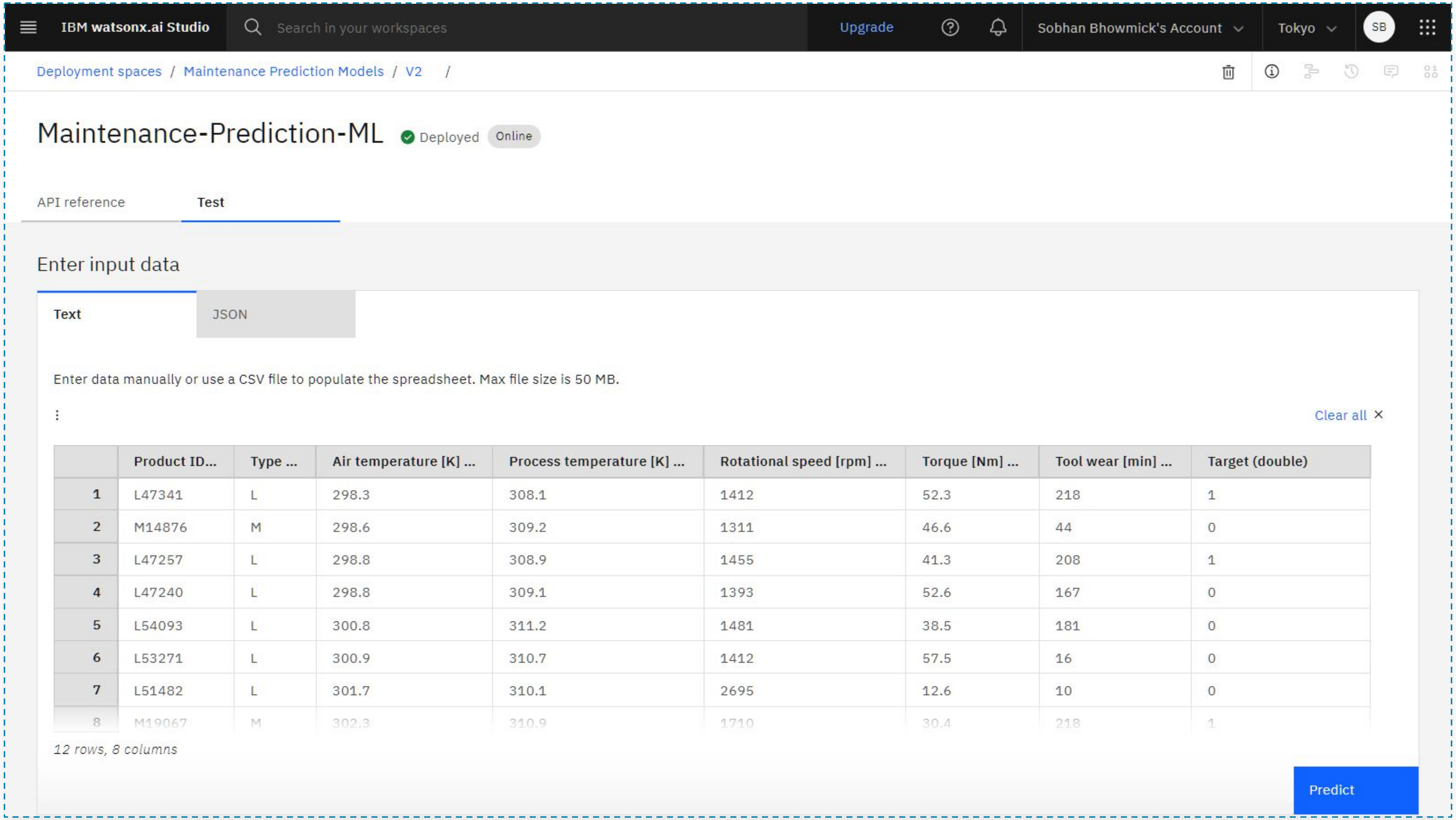
	Rank ↑	Name	Algorithm	Specialization	Accuracy (Optimized) Cross Validation	Enhancements	Build time
★	1	Pipeline 5	Batched Tree Ensemble Classifier (Snap Random Forest Classifier)	INCR	0.995	HPO-1 FE HPO-2 BATCH	00:00:50
	2	Pipeline 4	Snap Random Forest Classifier		0.995	HPO-1 FE HPO-2	00:00:47
	3	Pipeline 3	Snap Random Forest Classifier		0.995	HPO-1 FE	00:00:35
	4	Pipeline 9	Snap Decision Tree Classifier		0.994	HPO-1 FE HPO-2	00:00:05
	5	Pipeline 2	Snap Random Forest Classifier		0.994	HPO-1	00:00:09
	6	Pipeline 1	Snap Random Forest Classifier		0.994	*None*	00:00:02
	7	Pipeline 8	Snap Decision Tree Classifier		0.993	HPO-1 FE	00:01:22
	8	Pipeline 7	Snap Decision Tree Classifier		0.991	HPO-1	00:00:59
	9	Pipeline 6	Snap Decision Tree Classifier		0.988	*None*	00:00:54

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	0	965	0	0	0	0	100.0%
Overstrain Failure	0	0	8	0	0	0	100.0%
Power Failure	0	0	0	10	0	0	100.0%
Random Failures	0	2	0	0	0	0	0.0%
Tool Wear Failure	0	0	0	0	0	4	100.0%
Percent correct	100.0%	99.8%	88.9%	100.0%	0.0%	100.0%	99.7%

RESULT



	Product ID...	Type ...	Air temperature [K] ...	Process temperature [K] ...	Rotational speed [rpm] ...	Torque [Nm] ...	Tool wear [min] ...	Target (double)
1	L47341	L	298.3	308.1	1412	52.3	218	1
2	M14876	M	298.6	309.2	1311	46.6	44	0
3	L47257	L	298.8	308.9	1455	41.3	208	1
4	L47240	L	298.8	309.1	1393	52.6	167	0
5	L54093	L	300.8	311.2	1481	38.5	181	0
6	L53271	L	300.9	310.7	1412	57.5	16	0
7	L51482	L	301.7	310.1	2695	12.6	10	0
8	M19067	M	302.3	310.9	1710	30.4	218	1

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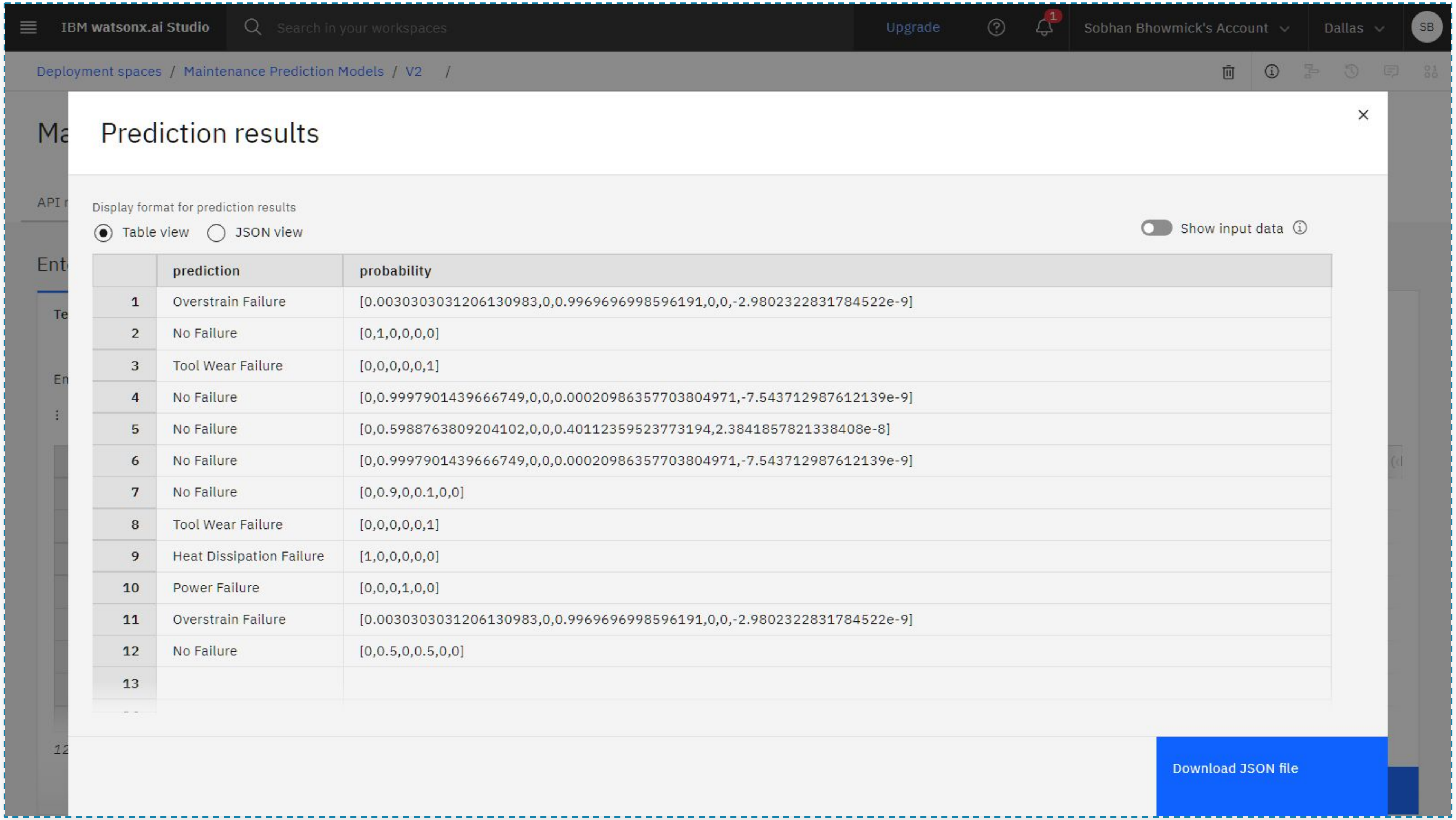
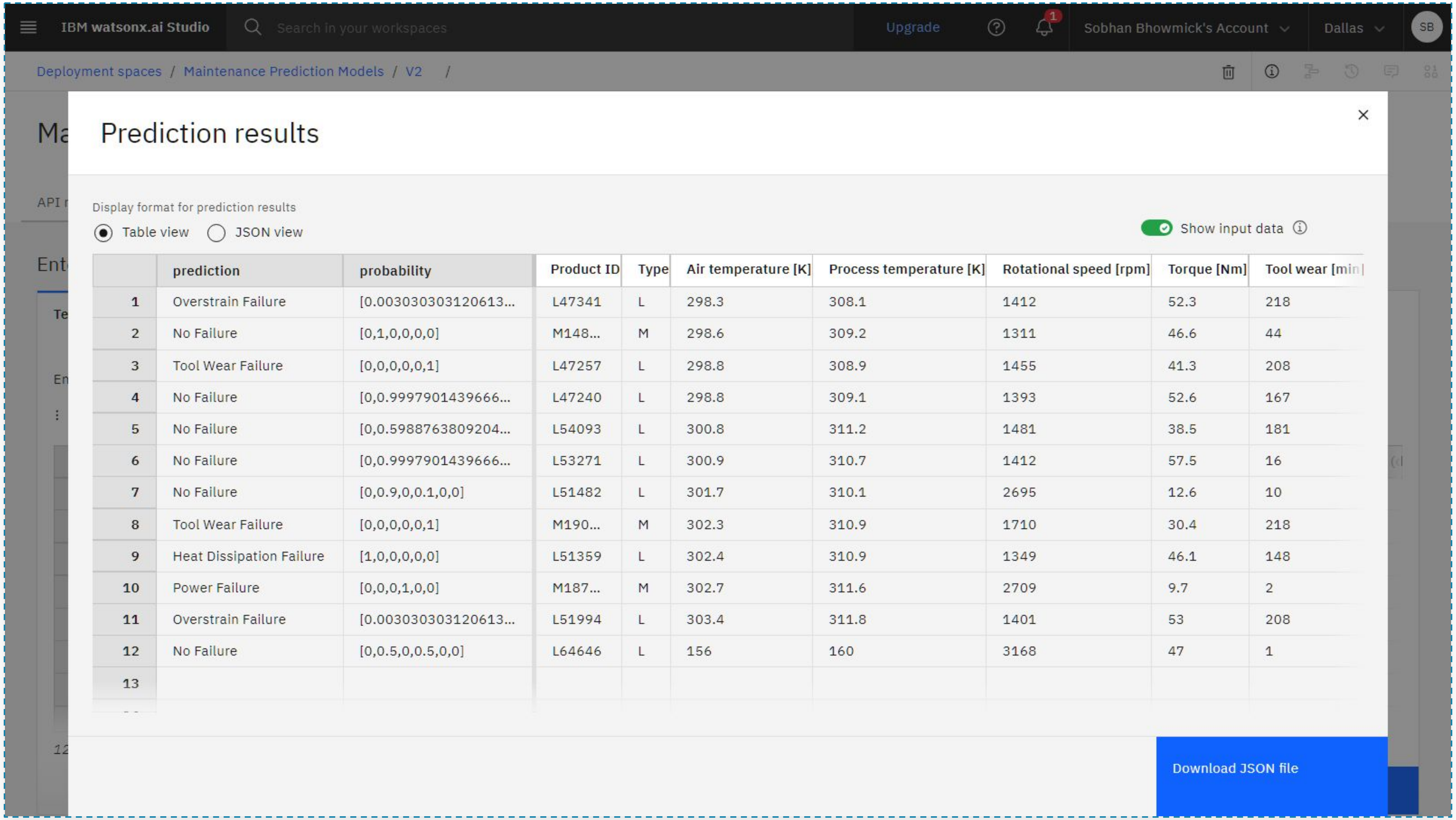
RESULT



	prediction	probability
1	Overstrain Failure	[0.0030303031206130983,0,0.9969696998596191,0,0,-2.9802322831784522e-9]
2	No Failure	[0,1,0,0,0,0]
3	Tool Wear Failure	[0,0,0,0,0,1]
4	No Failure	[0,0.9997901439666749,0,0,0.00020986357703804971,-7.543712987612139e-9]
5	No Failure	[0,0.5988763809204102,0,0,0.40112359523773194,2.3841857821338408e-8]
6	No Failure	[0,0.9997901439666749,0,0,0.00020986357703804971,-7.543712987612139e-9]
7	No Failure	[0,0.9,0,0.1,0,0]
8	Tool Wear Failure	[0,0,0,0,0,1]
9	Heat Dissipation Failure	[1,0,0,0,0,0]
10	Power Failure	[0,0,0,1,0,0]
11	Overstrain Failure	[0.0030303031206130983,0,0.9969696998596191,0,0,-2.9802322831784522e-9]
12	No Failure	[0,0.5,0,0.5,0,0]
13		

RESULT



	prediction	probability	Product ID	Type	Air temperature [K]	Process temperature [K]	Rotational speed [rpm]	Torque [Nm]	Tool wear [min]
1	Overstrain Failure	[0.003030303120613...	L47341	L	298.3	308.1	1412	52.3	218
2	No Failure	[0,1,0,0,0,0]	M148...	M	298.6	309.2	1311	46.6	44
3	Tool Wear Failure	[0,0,0,0,0,1]	L47257	L	298.8	308.9	1455	41.3	208
4	No Failure	[0,0.9997901439666...	L47240	L	298.8	309.1	1393	52.6	167
5	No Failure	[0,0.5988763809204...	L54093	L	300.8	311.2	1481	38.5	181
6	No Failure	[0,0.9997901439666...	L53271	L	300.9	310.7	1412	57.5	16
7	No Failure	[0,0.9,0,0.1,0,0]	L51482	L	301.7	310.1	2695	12.6	10
8	Tool Wear Failure	[0,0,0,0,0,1]	M190...	M	302.3	310.9	1710	30.4	218
9	Heat Dissipation Failure	[1,0,0,0,0,0]	L51359	L	302.4	310.9	1349	46.1	148
10	Power Failure	[0,0,0,1,0,0]	M187...	M	302.7	311.6	2709	9.7	2
11	Overstrain Failure	[0.003030303120613...	L51994	L	303.4	311.8	1401	53	208
12	No Failure	[0,0.5,0,0.5,0,0]	L64646	L	156	160	3168	47	1
13									

CONCLUSION

The project successfully demonstrates predictive maintenance using IBM Cloud's AI ecosystem. A robust machine learning model was built to predict machinery failures in advance, enabling proactive maintenance decisions. The integration of Watsonx.ai Studio, Data Refinery, and Watson Machine Learning streamlined the entire ML workflow — from data preparation to model deployment. The final model achieved high prediction accuracy across multiple failure classes, reducing the risk of downtime and supporting data-driven decision-making in industrial operations.

FUTURE SCOPE

- **Integrate IBM Watson IoT Platform:** Stream real-time sensor data from industrial machines for continuous monitoring and live failure prediction.
- **Use IBM Event Streams (Apache Kafka):** Enable event-driven architecture to process large volumes of telemetry data and trigger real-time alerts.
- **Adopt IBM Db2 on Cloud or Cloudant:** Store historical maintenance logs and sensor data for longitudinal analysis and retraining of the model.
- **Deploy via IBM Code Engine or Kubernetes Service:** Scale the predictive maintenance API seamlessly to handle thousands of requests in production environments.
- **Incorporate IBM Watson OpenScale:** Monitor model performance, detect drift, and ensure fairness and explainability in AI predictions.
- **Enhance insights using IBM Cognos Analytics:** Build dashboards to visualize predicted failure trends, uptime statistics, and model metrics for business stakeholders.

REFERENCES

- **Kaggle Dataset :** https://www.kaggle.com/datasets/shivamb/machine-predictive-maintenance-classification
- **IBM Cloud Documentation :** https://cloud.ibm.com/docs/cloud-object-storage
- **IBM Cloud Object Storage Documentation :** https://cloud.ibm.com/docs/cloud-object-storage
- **IBM Watsonx.ai Studio Documentation :** https://dataplatform.cloud.ibm.com/docs/content/wsj/getting-started/welcome-main.html?context=wx&audience=wdp
- **IBM AutoAI & Watson Machine Learning :** https://www.ibm.com/products/watson-studio/autoai

GitHub Repository Link :

https://github.com/5OBHAN/Predictive-Maintenance-of-Industrial-Machinery

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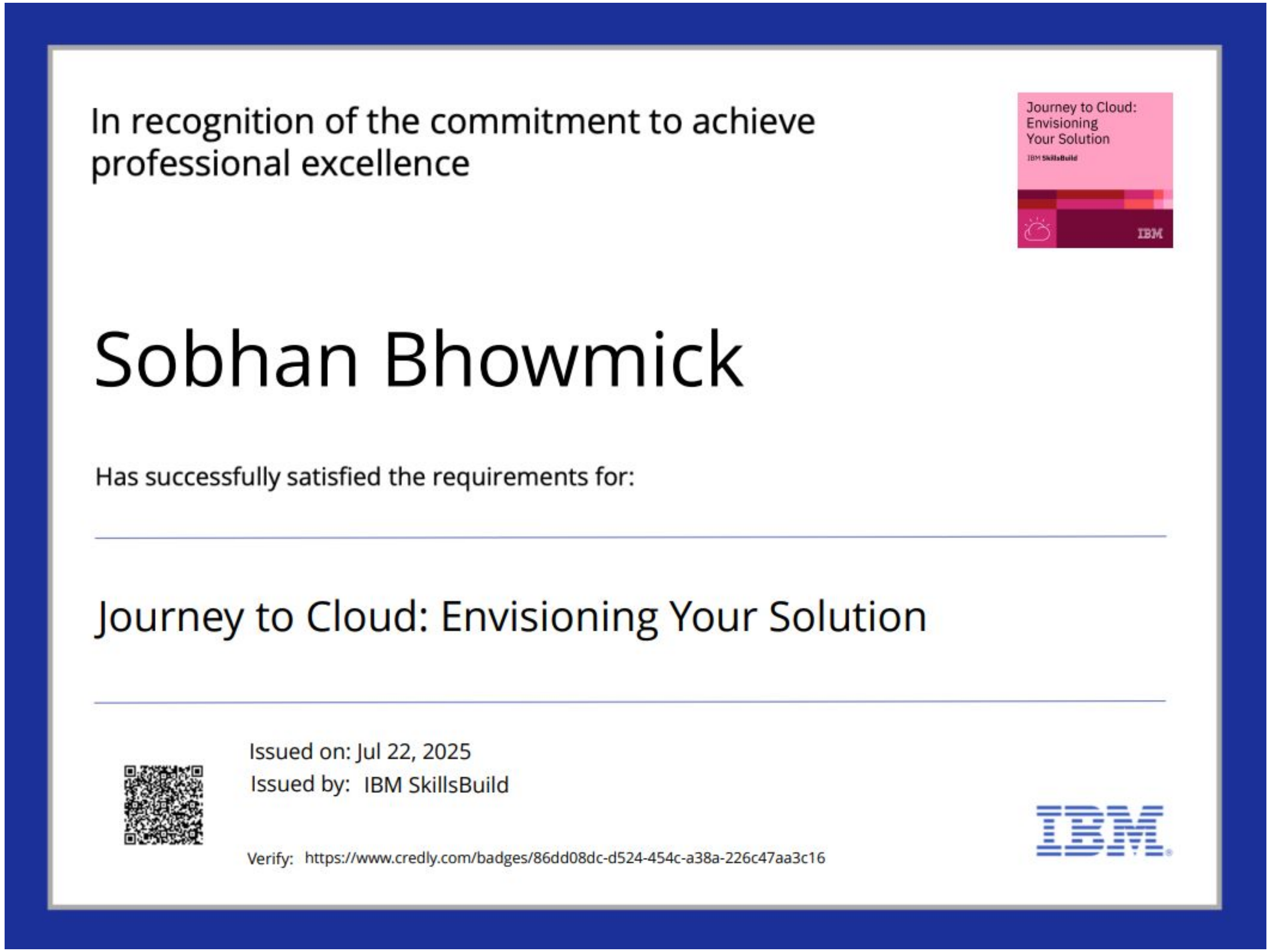

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According to the Adobe Learning Manager system of record

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Learning hours: 20 mins

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