CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY

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OUTLINE

- **Problem Statement** (Should not include solution)
- **Proposed System/Solution**
- **System Development Approach** (Technology Used)
- **Algorithm & Deployment**
- **Result (Output Image)**
- **Conclusion**
- **Future Scope**
- **References**

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

- We'll develop an intelligent predictive maintenance system that shifts your operations from reactive to **proactive**. By continuously analyzing data streams from machinery sensors, our machine learning model will accurately predict the specific type of failure—such as **tool wear**, **heat dissipation**, or **power failure**—before it occurs. This enables just-in-time maintenance, maximizing equipment uptime and significantly reducing operational costs.
- Key Components:
  - **Data & Feature Engineering:** Collect and clean sensor data (e.g., vibration, temperature), then engineer time-series features to reveal failure patterns.
  - **Model Training & Optimization:** Train and tune a classification model (e.g., Random Forest, LSTM) to accurately predict different failure types.
  - **Validation:** Evaluate the model with key metrics (accuracy, F1-score) and a confusion matrix to confirm its predictive reliability.
  - **Deployment:** Integrate the model into a live system that sends real-time failure alerts to the maintenance team.

SYSTEM APPROACH

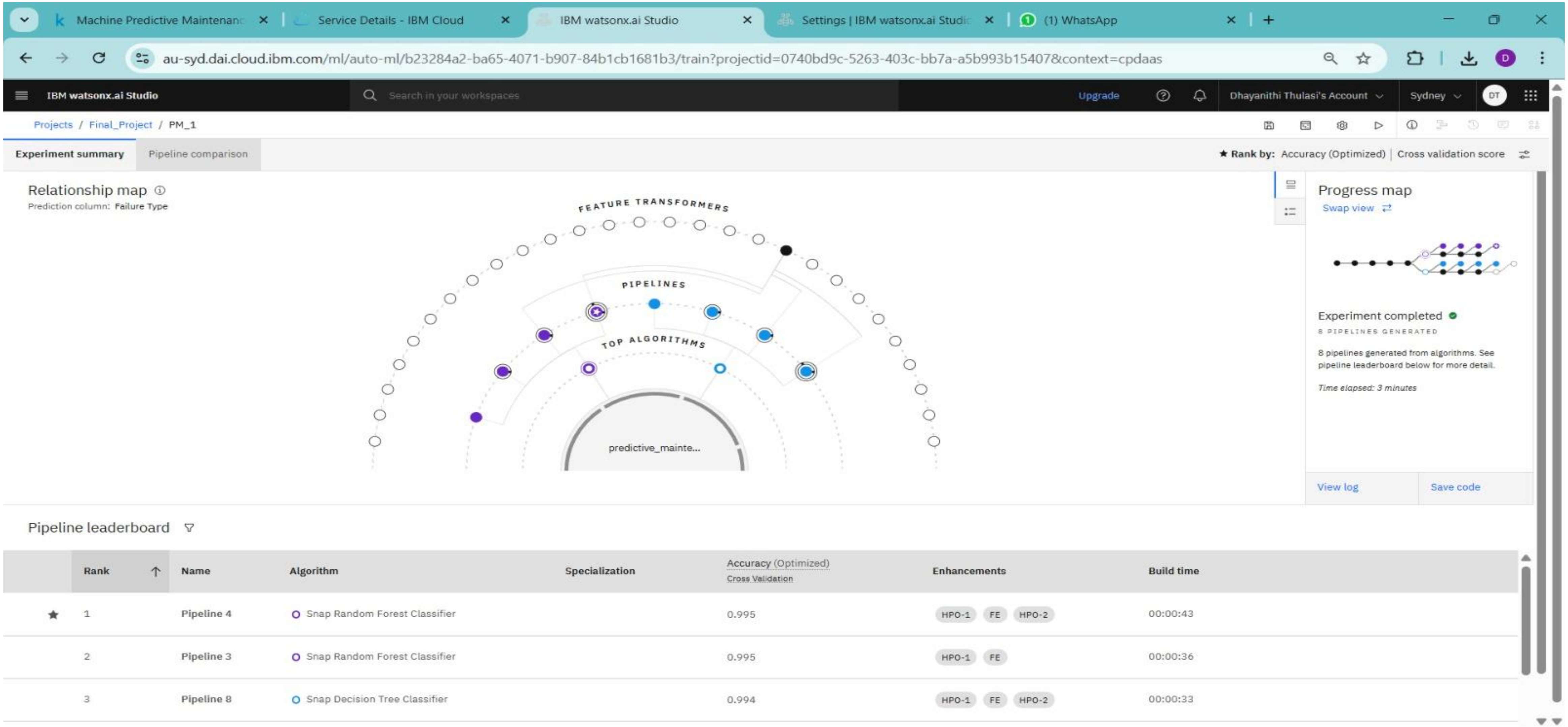
The "System Approach" section outlines the overall strategy and methodology for developing and implementing the rental bike prediction system. Here's a suggested structure for this section:

- **System requirements:**
  - IBM Cloud (mandatory).
  - IBM Watson Studio for model development and deployment.
  - IBM Cloud Object Storage for dataset handling.
- **Library required to build the model:**
  - Python with libraries like Scikit-learn and TensorFlow/PyTorch for model development and training.

ALGORITHM & DEPLOYMENT

- **Algorithm Selection:**
  - **Random Forest Classifier** (or Gradient Boosting/LSTM, selected based on predictive performance).
- **Data Input:**
  - Real-time sensor measurements from machinery, such as **Tool wear [min], Air temperature [K] , rotational speed, and torque**.
- **Training Process:**
  - **Supervised learning** using historical data where sensor readings are labeled with the specific type of failure that occurred.
- **Prediction Process:**
  - The model will be deployed on **IBM Watson Studio**, providing an API endpoint for real-time failure predictions based on live data streams.

RESULT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IBM watsonx.ai Studio
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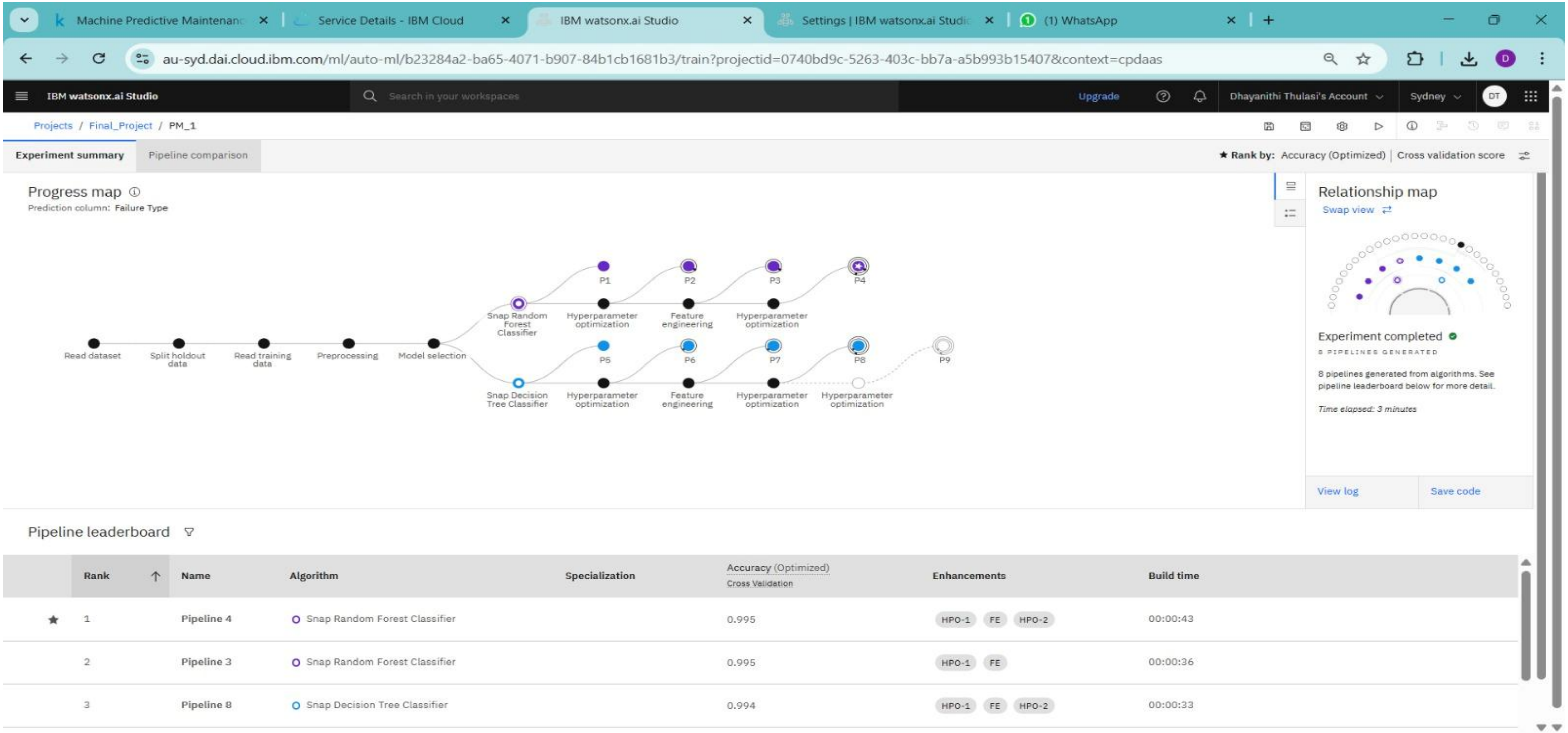
Projects / Final_Project / PM_1
Experiment summary
Pipeline comparison
★ Rank by: Accuracy (Optimized) | Cross validation score
Relationship map
Prediction column: Failure Type
FEATURE TRANSFORMERS
PIPELINES
TOP ALGORITHMS
predictive_mainte...
Progress map
Swap view
Experiment completed
8 PIPELINES GENERATED
8 pipelines generated from algorithms. See pipeline leaderboard below for more detail.
Time elapsed: 3 minutes
View log
Save code
Pipeline leaderboard
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
00:00:43
2
Pipeline 3
Snap Random Forest Classifier
0.995
HPO-1 FE
00:00:36
3
Pipeline 8
Snap Decision Tree Classifier
0.994
HPO-1 FE HPO-2
00:00:33

RESULT



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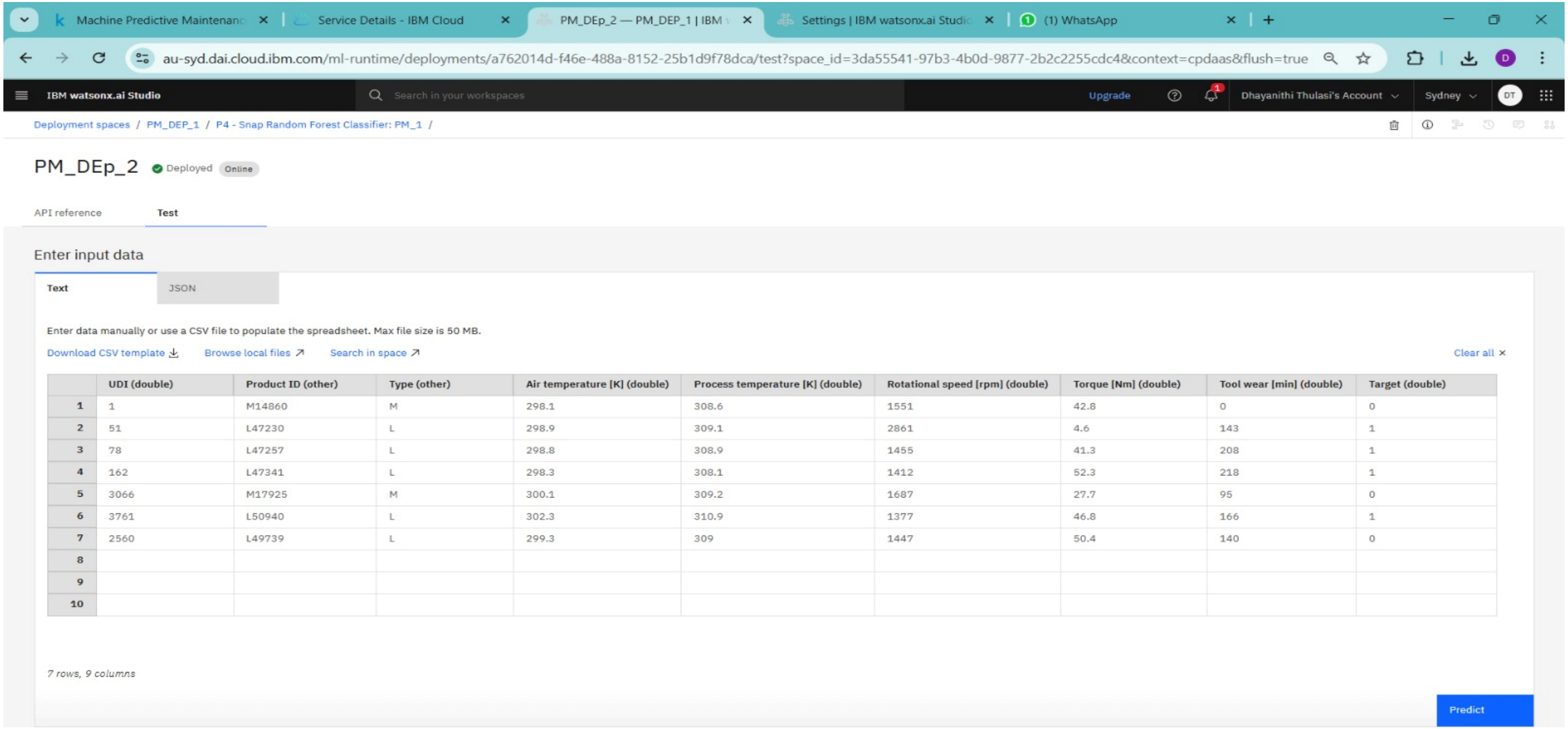
RESULT



	UDI (double)	Product ID (other)	Type (other)	Air temperature [K] (double)	Process temperature [K] (double)	Rotational speed [rpm] (double)	Torque [Nm] (double)	Tool wear [min] (double)	Target (double)
1	1	M14860	M	298.1	308.6	1551	42.8	0	0
2	51	L47230	L	298.9	309.1	2861	4.6	143	1
3	78	L47257	L	298.8	308.9	1455	41.3	208	1
4	162	L47341	L	298.3	308.1	1412	52.3	218	1
5	3066	M17925	M	300.1	309.2	1687	27.7	95	0
6	3761	L50940	L	302.3	310.9	1377	46.8	166	1
7	2560	L49739	L	299.3	309	1447	50.4	140	0
8									
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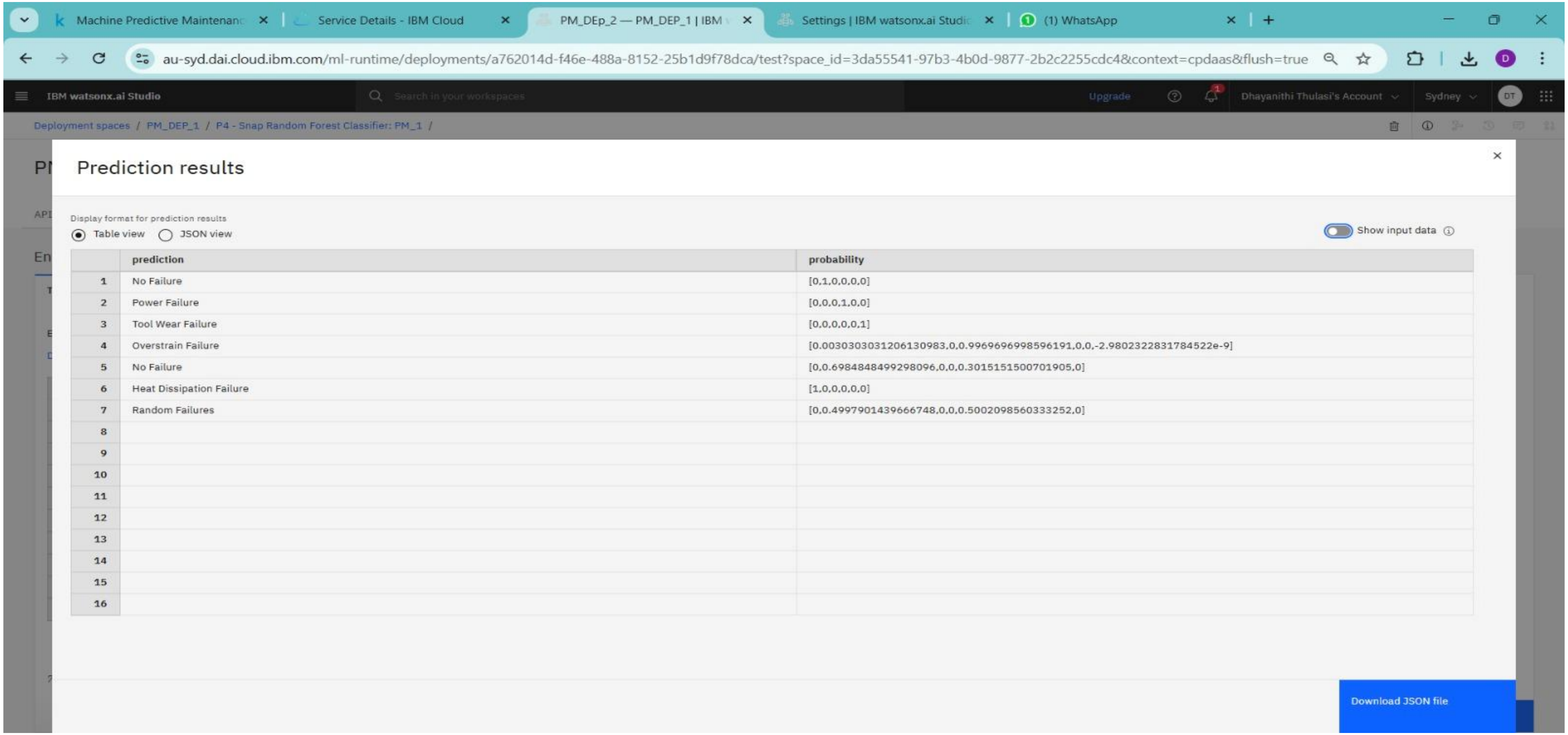
RESULT



	prediction	probability
1	No Failure	[0,1,0,0,0,0]
2	Power Failure	[0,0,0,1,0,0]
3	Tool Wear Failure	[0,0,0,0,0,1]
4	Overstrain Failure	[0.0030303031206130983,0,0.9969696998596191,0,0,-2.9802322831784522e-9]
5	No Failure	[0,0.6984848499298096,0,0,0.3015151500701905,0]
6	Heat Dissipation Failure	[1,0,0,0,0,0]
7	Random Failures	[0,0.4997901439666748,0,0,0.5002098560333252,0]
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CONCLUSION

- We successfully developed and deployed a high-performance predictive maintenance model using IBM Watson Studio. The AutoAI experiment identified a Random Forest Classifier as the top-performing algorithm, achieving an outstanding 99.5% accuracy through automated feature engineering and optimization.

- The final model is deployed as a live web service. It effectively processes sensor data to predict specific failure types, such as "Tool Wear" or "Heat Dissipation," with high confidence. This project delivered a robust and accurate solution ready for real-world integration to enable proactive maintenance and reduce operational costs.

FUTURE SCOPE

- **Predict Remaining Useful Life (RUL):** Enhance the model to predict the exact time remaining before a component fails. This shifts the focus from what will fail to precisely when it will fail, allowing for more efficient maintenance scheduling.
- **Automated Root Cause Analysis:** Incorporate interpretability techniques (like SHAP or LIME) to automatically highlight the key sensor readings responsible for a failure prediction. This would help maintenance teams diagnose the underlying problem much faster.
- **Full System Integration:** Integrate the prediction alerts directly with Computerized Maintenance Management Systems (CMMS). This could automatically generate work orders and schedule technicians, creating a fully automated, closed-loop maintenance system.

REFERENCES

- **Breiman, L. (2001). Random Forests.** *Machine Learning, 45*(1), 5-32. The original paper on the Random Forest algorithm.
- **Saxena, A., & Goebel, K. (2008). Turbofan Engine Degradation Simulation Data Set.** The benchmark dataset for predictive maintenance, provided by NASA.
- **Zheng, Y., et al. (2017). Remaining useful life estimation using a long short-term memory neural network.** *IEEE Transactions on Industrial Electronics.* A key paper on using LSTMs for predicting Remaining Useful Life (RUL).
- **Carvalho, A. T. Z., et al. (2019). Machine learning for predictive maintenance: A systematic literature review.** *Computers & Industrial Engineering.* A comprehensive review of real-world applications and case studies.

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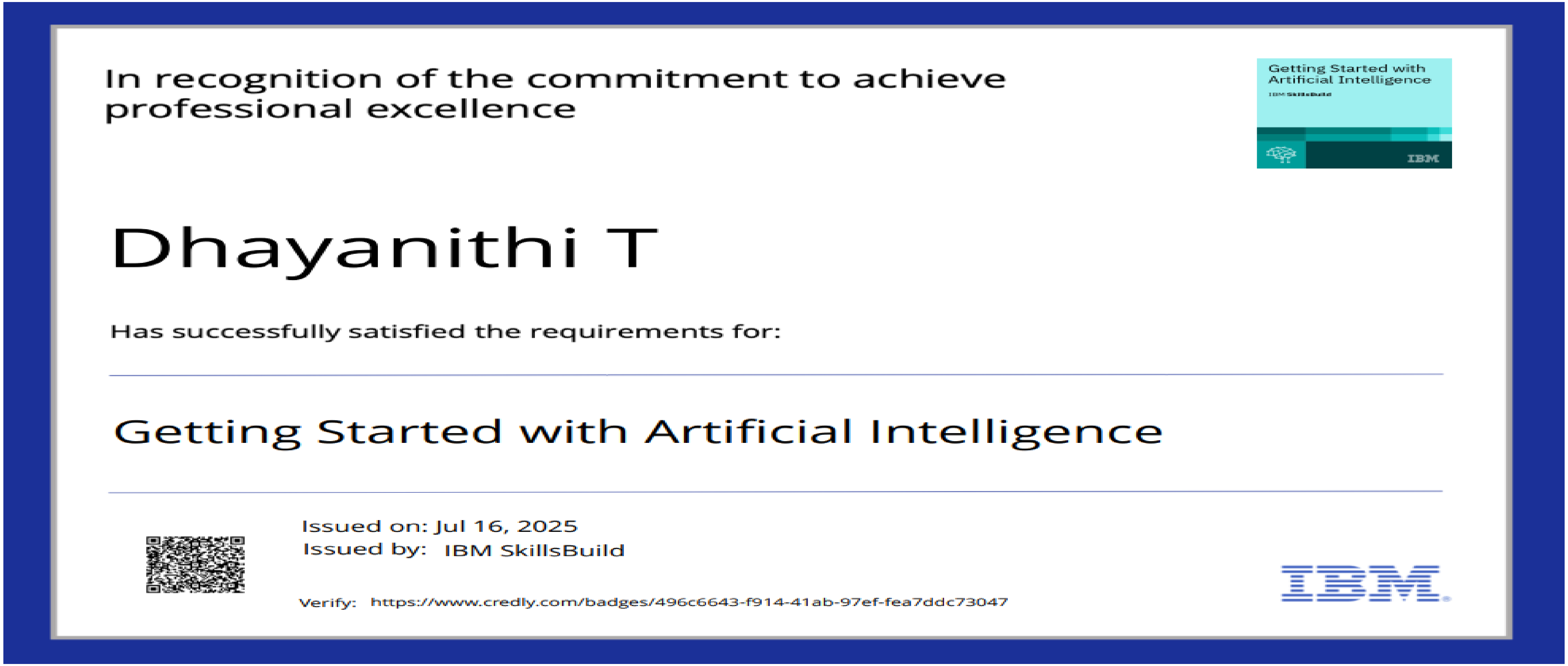
IBM CERTIFICATIONS



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