CAPSTONE PROJECT

PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINERY

Presented By:
ANUSHA MOHANTY
SILICON INSTITUTE OF TECHNOLOGY
ELECTRONICS AND INSTRUMENTATION ENGINEERING

OUTLINE

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PROBLEM STATEMENT

- In industrial environments, machinery plays a critical role in maintaining production efficiency and workflow continuity. However, unexpected failures in these machines can lead to significant downtime, costly repairs, and production losses. Traditional maintenance approaches, such as scheduled or reactive maintenance, often fail to prevent breakdowns effectively, either due to under-maintenance or unnecessary interventions.
- With the increasing availability of sensor data from machines, there is a growing opportunity to shift toward predictive maintenance — a strategy that anticipates failures before they occur. The core challenge lies in accurately identifying the early warning signs of various types of machine failures by analyzing real-time operational parameters.
- This project focuses on addressing that challenge by developing a machine learning model that classifies the type of potential failure based on sensor data inputs. The ultimate goal is to assist industries in making data-driven maintenance decisions, reduce unplanned downtimes, and optimize maintenance costs by ensuring timely interventions.

PROPOSED SOLUTION

- The proposed solution involves developing a predictive maintenance system using machine learning techniques to classify the type of failure an industrial machine might encounter. By analyzing historical sensor data collected from machines, the system identifies patterns that typically precede different failure types.
- The model is trained to recognize failures such as tool wear, power failure, and heat dissipation issues. It leverages multivariate data including temperature readings, rotational speed, torque, and other operational metrics.
- IBM Watsonx.ai's AutoAI is utilized to automate the model-building process. It performs tasks such as data preprocessing, model selection, training, evaluation, and hyperparameter optimization. The final model is deployed as a web service on IBM Cloud to support real-time predictions, allowing organizations to take preventive actions based on model recommendations.

SYSTEM APPROACH

- The system was developed using IBM Cloud’s AI infrastructure with a focus on user-friendly, no-code tools offered through Watsonx.ai Studio. The approach included the following key components:
- **Dataset Source:** The dataset was sourced from Kaggle and includes multiple features recorded from a fleet of industrial machines, such as temperature, torque, tool wear, and machine type.
- **Technology Stack:**
    - **IBM Watsonx.ai Studio:** Used to launch and run AutoAI experiments.
    - **AutoAI:** IBM’s automated model-building framework for classification problems.
    - **IBM Cloud Object Storage:** Used to upload and manage datasets.
    - **Deployment Service:** Enabled real-time prediction by deploying the trained model as an online service.
- This development strategy reduced the time and complexity of building an effective predictive model while ensuring scalability and accessibility.

ALGORITHM & DEPLOYMENT

- IBM Watsonx.ai’s **AutoAI** feature was used to build the predictive maintenance model. It automated the machine learning workflow by handling data preprocessing, feature engineering, model selection, and hyperparameter tuning.
- **AutoAI Pipeline Generation:**
- Multiple machine learning pipelines were created and evaluated using classification algorithms such as:
  - Gradient Boosting
  - Decision Trees
  - Logistic Regression
- Each pipeline was scored based on metrics like accuracy, precision, and recall.

ALGORITHM & DEPLOYMENT

Pipeline Leaderboard:

Pipeline ID	Algorithm Used	Accuracy (%)	Status
Pipeline 2	Gradient Boosting	94%	✔ Selected
Pipeline 4	Logistic Regression	91%	
Pipeline 1	Decision Tree	89%	

AutoAI selected **Pipeline 2** as the best model due to its high performance and generalizability.

Deployment:

•The top-performing pipeline was saved and promoted to **IBM Cloud Deployment Space.**

•It was deployed as an **Online Deployment** endpoint.

•The deployed model can now receive real-time input data and return predictions instantly

RESULT

The trained machine learning model was evaluated and tested using IBM Watsonx.ai's AutoAI interface. The prediction type was **Multiclass Classification**, targeting the classification of machine failure types based on sensor data.

Prediction Classes:

- **No Failure** (Purple)
- **Power Failure** (Blue)
- **Overstrain Failure** (Teal)

Output Summary (8 Test Records):

Prediction	Confidence	Occurrences
No Failure	50%–100%	5
Power Failure	100%	2
Overstrain Failure	87%	1

RESULT

Sample Prediction Records:

UDI	Prediction	Confidence	Product ID	Type
1	No Failure	100%	L47186	L
3	No Failure	50%	L25698	M
6	Power Failure	100%	L47560	L
8	Overstrain Failure	87%	L47926	L

Confidence Distribution:

- Most predictions fell within the **80–100%** confidence range.
- Visualization showed a dominance of "No Failure" predictions, with high-confidence results for "Power Failure" and "Overstrain Failure" as well.

The model demonstrated robust performance in classifying failure types, with high confidence in its predictions. These results validate its use in proactive maintenance environments.

RESULT

Prediction results

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Prediction type

Multiclass classification

Prediction percentage

No Failure Power Failure Overstrain Failure

Confidence level distribution

Display format for prediction results

(●) Table view ( ) JSON view

Show input data ⓘ

	Prediction	Confidence
1	No Failure	100%
2	No Failure	90%
3	No Failure	50%
4	No Failure	90%
5	No Failure	100%
6	Power Failure	100%
7	Power Failure	100%
8	Overstrain Failure	87%
9		
10		

Download JSON file

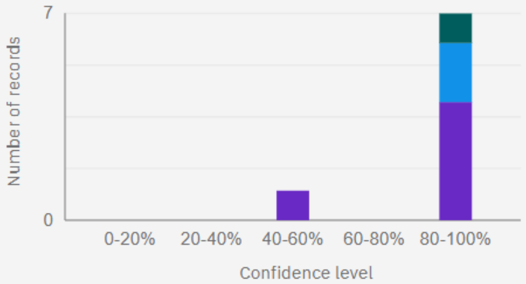
RESULT

Prediction results

×

No Failure | Power Failure | Overstrain Failure

Confidence level distribution



No Failure | Power Failure | Overstrain Failure

Display format for prediction results

(•) Table view ( ) JSON view

Show input data ⓘ

	Prediction	Confidence	UDI	Product ID	Type
1	No Failure	100%	7	L47186	L
2	No Failure	90%	6	L47986	H
3	No Failure	50%	9	L25698	M
4	No Failure	90%	5	L49565	L
5	No Failure	100%	288	L47467	L
6	Power Failure	100%	381	L47560	L
7	Power Failure	100%	464	L47643	L
8	Overstrain Failure	87%	747	L47926	L
9					
10					

Download JSON file

CONCLUSION

- The project successfully demonstrates the application of machine learning for predictive maintenance in industrial environments. By analyzing real-time operational data, the model can accurately classify potential failure types before actual machine breakdowns occur.
- This predictive capability allows maintenance teams to intervene early, reducing unplanned downtime and optimizing maintenance resources. The use of IBM Watsonx.ai and AutoAI significantly simplified the development and deployment process by automating model selection and tuning.
- The results validate the potential of data-driven maintenance strategies in modern industrial systems and highlight how cloud-based AI tools can be leveraged for impactful real-world solutions.

FUTURE SCOPE

- This project lays the foundation for more advanced and integrated predictive maintenance systems. Potential areas of future enhancement include:
- **Real-Time IoT Integration:** Connect the deployed model to live sensor streams using IoT devices for continuous monitoring and automatic alerts.
- **Model Optimization:** Incorporate deep learning techniques to improve classification performance, especially for complex failure patterns.
- **Edge Deployment:** Deploy models to edge devices on the factory floor to enable low-latency predictions even without constant internet access.
- **Cross-Domain Application:** Adapt the system for use in other industries such as aviation, automotive, or energy, where predictive maintenance is equally critical.
- By advancing these capabilities, the solution can evolve into a fully automated industrial health monitoring system.

REFERENCES

- Predictive Maintenance Dataset –Kaggle. “Machine Predictive Maintenance Classification. https://www.kaggle.com/datasets/shivamb/machine-predictive-maintenance-classification
- IBM Cloud Documentation –IBM Developer and IBM Watsonx.ai Docs. https://cloud.ibm.com/docs
- Research articles and whitepapers on Predictive Maintenance in Manufacturing, Machine Learning for Fault Detection, and Industrial IoT (IIoT) Applications.

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