Project Proposal: AI-Powered Predictive Maintenance for Industrial Equipment (MaintenX)

1. Project Description

The **AI-Powered Predictive Maintenance for Industrial Equipment** project aims to utilize **Machine Learning (ML)** and **Deep Learning (DL)** on IoT sensor data to **predict equipment failures before they occur**.

Using the **Microsoft Azure Predictive Maintenance Dataset**, the system analyzes critical sensor data , including **vibration, pressure, voltage, and rotation** to identify early indicators of malfunction and optimize maintenance schedules.

This data-driven approach enables industries to:

- Transition from **reactive** to **proactive** maintenance,
- **Reduce unexpected downtime** and costs,
- **Increase equipment lifespan**, and
- **Optimize operations through AI insights**.

The project integrates **data preprocessing**, **ML/DL model training**, and **deployment via Microsoft Azure**, delivering a scalable and automated predictive maintenance system.

2. Group Members

Name	Email	Role
Mohamed Goma *(Team Leader)*	M.yasser2224@nu.edu.eg	Team coordination, Exploratory Data Analysis (EDA), model tuning, and Deep Learning architecture design
Mohammed Mahrous& Mohammed Haitham	midohany1807@gmail.com	Data preprocessing, feature engineering, and ML experimentation
Loay Rafiq	loaypre2510@gmail.com	Advanced data analysis, model comparison, and feature optimization
Mohammed Haitham & Menntallah	moh.haitham202@gmail.com	Model evaluation, backend integration, and deployment
Mohamed Ebrahim	Mefouda654@gmail.com	API development, hosting, and MLOps pipeline
Mennatullah Mohamed	mennayasser891@gmail.com	Documentation, visualization, and presentation preparation

GitHub Repository: MaintenX

3. Team Leader

Mohamed Yasser Goma

M.yasser2224@nu.edu.eg

ID: 21052213

Responsibilities: Project coordination, exploratory data analysis, deep learning architecture development, and model tuning for performance optimization.

4. About the Dataset

Context

This dataset serves as a comprehensive source for **Predictive Maintenance Model Building**, combining multiple data streams related to machine performance and service history.

It contains information about:

- **Machine conditions and usage:** Sensor-based operational data.
- **Failure history:** Historical component failures.
- **Maintenance history:** Scheduled and unscheduled repairs.
- **Machine metadata:** Model details and age for contextual insights.

Dataset Details

- **Telemetry Time Series Data (PdM_telemetry.csv):**

Hourly averages of **voltage, rotation, pressure, and vibration** from 100 machines during 2015.

- **Error Log (PdM_errors.csv):**

Non-critical operational errors are recorded during machine operation. Each record is timestamped and synchronized to hourly intervals.

- **Maintenance History (PdM_maint.csv):**

Records of both **proactive** (scheduled) and **reactive** (unscheduled) maintenance activities across 2014–2015.

- **Failures (PdM_failures.csv):**

A subset of the maintenance data, representing component replacements due to actual failures.

- **Machine Metadata (PdM_Machines.csv):**

Includes model type, operational age, and other static attributes for each machine.

This dataset enables the development of models that can predict component failures based on time-series telemetry data and maintenance history.

5. Objectives

1. Develop a **predictive maintenance system** capable of identifying potential machine failures in advance.
2. Conduct detailed **EDA and feature engineering** to enhance model accuracy.
3. Implement and compare **ML and DL models** (e.g., XGBoost, CatBoost, LSTM).
4. Deploy an automated prediction **API** with real-time failure alerts.

5. Host and monitor the solution using **Microsoft Azure** for scalability.

6. Tools & Technologies

Category	Tools / Technologies
Dataset	Microsoft Azure Predictive Maintenance Dataset
Data Processing & EDA	Python, Pandas, NumPy, Matplotlib, Seaborn
Machine Learning	Scikit-learn, XGBoost, CatBoost
Deep Learning	PyTorch, LSTM Networks
Deployment & MLOps	Azure Machine Learning, FastAPI, Docker
Visualization & Monitoring	Power BI, Plotly
Collaboration & Version Control	GitHub, Google Colab, Jupyter Notebook

7. Milestones & Deadlines

Milestone	Deliverables	Deadline
1. Data Preprocessing	Clean, merged dataset and missing value handling	**Week 2**
2. Exploratory Data Analysis (EDA)	Correlation reports, trend visualizations, anomaly detection	**Week 3**
3. Feature Engineering	Derived time-based and statistical sensor features	**Week 4**
4. Model Development (ML & DL)	Trained ML models and LSTM-based DL architecture	**Week 6**
5. Model Tuning & Evaluation	Hyperparameter tuning, metrics analysis, and model comparison	**Week 7**
6. Deployment on Azure	Hosted API endpoint and automated pipeline	**Week 8**
7. Documentation & Presentation	Final report, Power BI dashboard, and presentation slides	**Week 9**

8. KPIs (Key Performance Indicators)

Data Quality

Metric	Target
Missing data handled	≥ 98%
Dataset integration accuracy	≥ 95%

Sensor alignment consistency	≥ 90%

Model Performance

Metric	Target
Accuracy / F1-Score	≥ 90%
Precision-Recall Balance	≥ 0.85
Prediction latency	≤ 300 ms

Deployment & Usability

Metric	Target
API uptime	≥ 99%
Response time	≤ 500 ms
Dashboard visualization clarity	≥ 90%

9. Expected Outcome

- A **predictive maintenance model** that anticipates machine component failures with high accuracy.
- A **deployed API** on Microsoft Azure for real-time failure prediction.
- **Comparative analysis** of ML and DL architectures for industrial reliability.
- A **data visualization dashboard** showcasing performance trends and failure forecasts.
- A **complete technical report** documenting workflow, results, and business insights.

10. References

- Microsoft Azure Predictive Maintenance Dataset
- Microsoft Azure Machine Learning Documentation
- Kaggle Predictive Maintenance Tutorials
- G. Babu et al., *Predictive Maintenance using LSTM and IoT Sensor Data*, IEEE, 2022
- “AI & Data Science Track – Round 2 Project Guidelines”

11. Conclusion

This project integrates **AI, IoT, and Cloud technologies** to transform traditional maintenance into a **smart, predictive system**.

By combining **machine learning** and **deep learning** techniques with **Azure cloud infrastructure**, the team aims to create an automated, scalable, and reliable maintenance solution that significantly reduces downtime and enhances industrial productivity.