Predictive Maintenance Using Machine Learning

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🛠️ Overview

This project predicts potential machine failures in industrial and manufacturing sectors using **machine learning techniques**. By analyzing sensor and operational data, it enables:

- **Proactive maintenance scheduling**
- **Reduced downtime**
- **Minimized operational costs**

📊 Dataset Description

- **Source:** Kaggle Predictive Maintenance Dataset
- **Records:** 10,000 data points with 14 features
- **Failure Types:**
  - **Tool Wear Failure**
  - **Heat Dissipation Failure**
  - **Power Failure**
  - **Overstrain Failure**
  - **Random Failures**

🎯 Objective

Develop a **predictive model** to identify impending machine failures, improving:

- **Maintenance scheduling**
- **Reduction of unexpected downtimes**

📋 Key Steps

1. Data Preprocessing

- **No Missing Values:** The dataset contains complete data.
- **Outlier Handling:**
  - Identified using **Interquartile Range (IQR)**.
  - Applied **log transformation** for extreme values.
- **Scaling:**

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- Standardized numerical features (e.g., air temperature, rotational speed).

- **Encoding:**
  - Categorical features transformed using **One-Hot Encoding**.

2. Exploratory Data Analysis (EDA)

- **Key Patterns:**
  - **Temperature Correlation:** Strong positive relationship between air and process temperatures.
  - **Rotational Speed vs Torque:** Inverse correlation observed.

3. Feature Engineering

- **Mechanical Power:** Product of rotational speed and torque.
- **Temperature Difference:** Difference between process and air temperatures.
- Applied **log transformation** to engineered features for stability.

4. Model Training

- **Models Evaluated:**
  - **Random Forest**
  - **Gradient Boosting**
  - **XGBoost**
  - **AdaBoost**
  - **Logistic Regression**
- **Best Model:**
  - **XGBoost** achieved **97.8% accuracy**.

🏆 **Results**

XGBoost Performance

- **Accuracy:** 97.8%
- **Precision:** 0.64
- **Recall:** 0.72
- **F1 Score:** 0.68

Key Insights

- **Proactive Maintenance:** Effectively identifies failures before escalation.
- **Resource Optimization:** Enables efficient scheduling and cost reduction.

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🚀 Key Takeaways

- **Proactive Maintenance:**
  - Identify machine failures early to prevent costly downtimes.
- **Resource Optimization:**
  - Efficient scheduling reduces unnecessary maintenance costs.

🔮 Future Work

- **Real-time Data Integration:** Enable dynamic analysis.
- **IoT Deployment:** Use sensor data for continuous monitoring.
- **Adaptive Model Retraining:** Improve predictions over time.

🙌 Acknowledgments

- **Dataset:** Provided by Kaggle.
- **Libraries:** Utilized open-source tools for development.
