IoT4MOTOR: Predictive Maintenance for HVAC Motors

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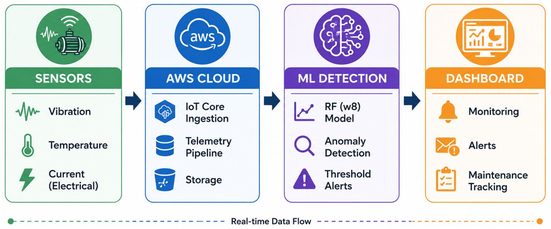
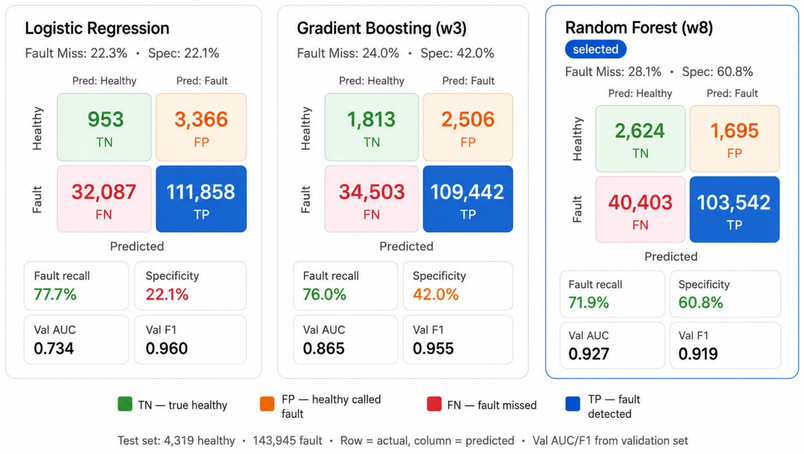
Motivation & Objectives

Industrial HVAC systems require continuous operation, making early fault detection critical for reducing downtime and maintenance costs. IoT4Motor combines **LoRaWAN** sensing, **AWS** cloud infrastructure, and **ML**-based anomaly detection for real-time HVAC motor monitoring.

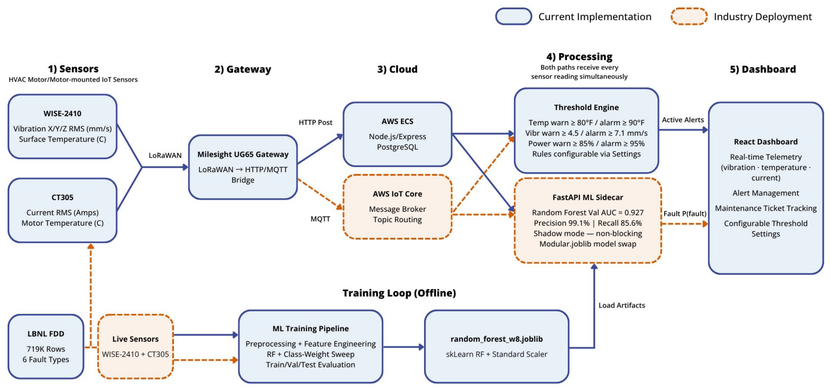


Machine Learning Model

- Parallel ML and threshold-based monitoring architecture designed to support real-time HVAC anomaly detection
- Models evaluated using the LBNL FDD HVAC benchmark dataset containing simulated fault conditions across multiple operational scenarios
- Random Forest (w8) selected as the final model for achieving the highest validation AUC (0.927) and improved specificity, reducing false alarms in facility operations
- Confusion matrix analysis highlights the tradeoff between fault recall and false-positive rate, supporting deployment-oriented model selection rather than maximizing a single metric alone

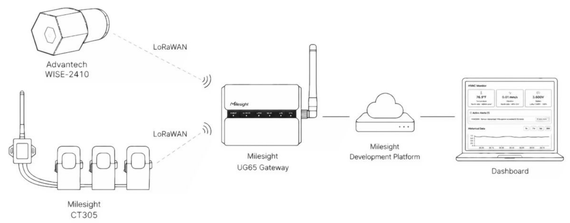


System Design Pipeline



Sensor and Gateway Design

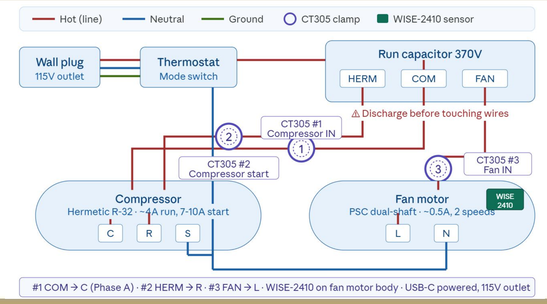
- Sensors are mounted directly on HVAC motors to collect real-time operating data
- LoRaWAN vibration and temperature sensors monitor abnormal motor behavior such as imbalance, overheating, and mechanical degradation
- CT sensors measure current draw to support load analysis and fault detection
- Sensor packets are transmitted wirelessly to the Milesight UG65 LoRaWAN gateway
- The gateway forwards telemetry data to AWS IoT Core for cloud processing, dashboard visualization, and ML-based anomaly detection
- The design supports scalable deployment across multiple HVAC motors and facility locations



Testbench

Wiring schematic of the Frigidaire FFRA051WAE testbench showing:

- Three Milesight CT305 current clamps placed on the compressor input, compressor start winding, and fan motor input
- One Advantech WISE-2410 vibration sensor mounted on the fan motor body

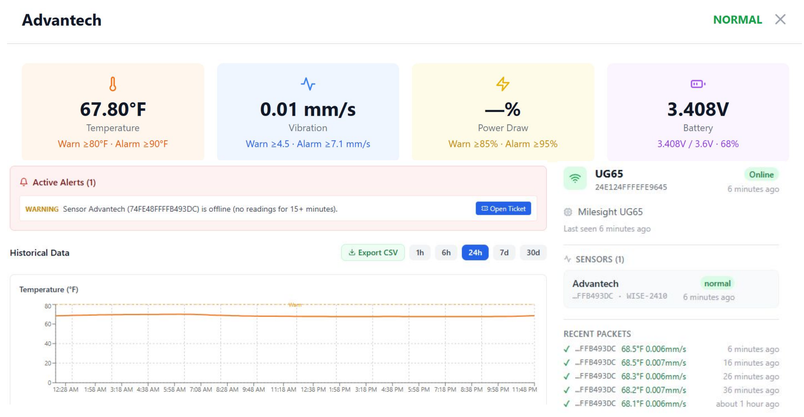


Cloud Infrastructure

- AWS IoT Core ingests real-time telemetry from LoRaWAN gateways
- Backend services perform data storage, alert generation, and anomaly detection
- FastAPI-based inference pipeline integrates threshold-based and ML-based monitoring
- Processed telemetry and alerts are visualized through a centralized dashboard

Dashboard

- Dashboard provides operators with a centralized interface for monitoring motor health issues, sensor readings, and anomaly alerts in real time
  - Real-time motor telemetry
  - Vibration & Temperature visualization
  - Alerts for abnormal behavior
  - Maintenance ticket tracking



Discussion and Future Work

- Condition-based monitoring enables earlier detection of abnormal vibration and temperature behavior in HVAC motors
- Initial results show that vibration, temperature, and current signals provide meaningful indicators for predictive maintenance
- The ML pipeline achieved strong validation performance on the LBNL FDD benchmark dataset (AUC = 0.927) while operating alongside threshold-based safety alerts
- Future work includes expanding field deployments, improving multi-class fault classification, and validating the system using real-world HVAC telemetry from industrial facilities

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[1] International Organization for Standardization. ISO 10816-1: Mechanical Vibration — Evaluation of Machine Vibration by Measurements on Non-Rotating Parts — General Guidelines, 1995
[2] Project HVAC. "HVAC System Monitoring Tips for Homeowners & Managers (2025)," 2025.
[3] Roomsys Blog. "Predictive Maintenance in Smart Buildings Uses Sensors to Prevent HVAC Failures," n.d.