Smart Multi-Sensor Equipment & Environment Health Monitor using Edge AI

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1. Introduction

In industrial environments, equipment health and safety heavily depend on surrounding conditions and internal factors like vibration, temperature, and gas emissions. This project aims to design a low-cost, embedded AI system that continuously monitors these parameters and detects early signs of faults or unsafe conditions.

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2. Objectives

- Monitor multiple physical parameters in real time.
- Detect anomalies or unsafe conditions using on-device AI.
- Alert users through Wi-Fi or BLE to mobile and web dashboards.
- Provide a health score and simple explanations of detected issues.

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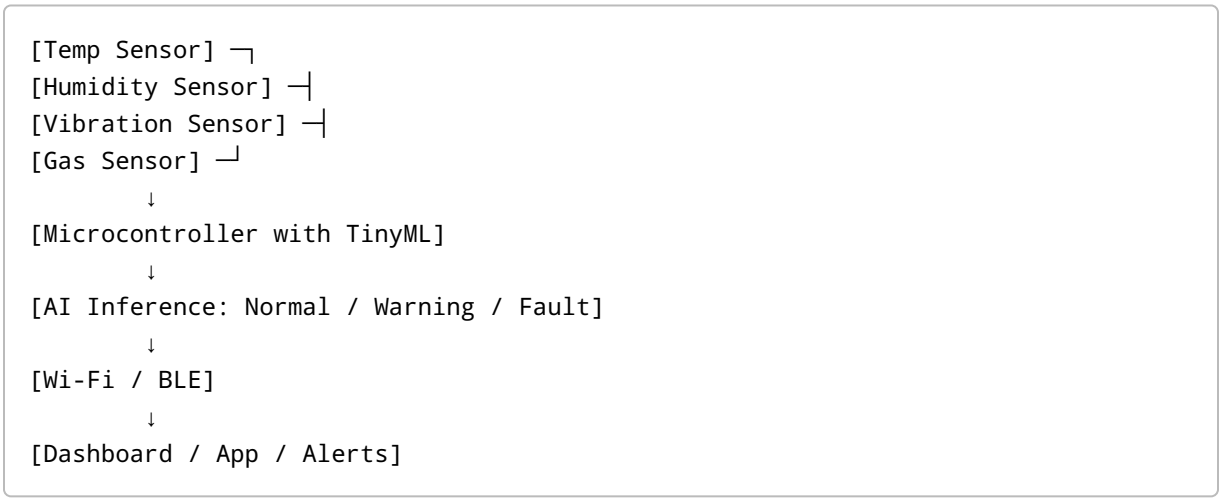
3. System Overview

The system uses low-cost sensors connected to a microcontroller (ESP32 or Arduino Nano 33 BLE Sense) that processes data locally. AI models predict whether conditions are normal or risky, and alerts are sent over wireless networks to operators.

Block Diagram:



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4. Key Features & Innovations

- ⚙️**Multi-modal sensing:** Combines temperature, humidity, vibration, and gas data.
- **Edge AI:** Runs AI locally without relying on cloud services.
- 📊**Health scoring:** Calculates an equipment health score.
- 🔍**Explainability:** Shows which sensor values triggered alerts.
- 📋**Low-cost IoT dashboard:** Real-time view on mobile or PC.

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5. Hardware & Software

Hardware: - ESP32 Dev Board or Arduino Nano 33 BLE Sense - DHT11/DHT22 temperature & humidity sensor - SW-420 vibration sensor or accelerometer - MQ-2 / MQ-135 gas sensor - Optional: OLED display and SD card module

Software: - Arduino IDE / PlatformIO - Edge Impulse / TensorFlow Lite Micro - Node-RED / Blynk / custom dashboard

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6. Workflow

✂️Sensors collect data → ✒️Features extracted (e.g., average, peaks, FFT) → 🛏️AI model classifies state → 🌂Health score calculated → 🌡️ Data and alerts sent to dashboard → 🎒Operators see real-time status and history.

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7. Applications & Benefits

- 📑Industrial motor or transformer monitoring
- 🧮Detect early mechanical/electrical faults
- 🪄Prevent downtime and safety incidents
- 💰Affordable solution for SMEs and local industries

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8. Future Enhancements

- Add AI-driven prediction for remaining useful life (RUL)
- Integrate solar-powered wireless version
- Add camera for visual anomaly detection

Prepared as a technical concept report for academic and industrial reference.

9. Unique and Novel Enhancements

- Self-learning personalization for each machine.

• On-device Explainable AI (XAI) to show why alerts are triggered.
• Proactive control actions based on AI risk predictions.
• Blockchain-based secure logging with post-quantum cryptography.
• Correlation analysis between environmental and equipment data.
• Adaptive sampling to save power and improve device life.