IoT + Machine Learning Predictive Maintenance System for Motor Health Monitoring

1.0 Problem Statement

Industrial motors commonly experience failures due to overheating, excessive vibration, or unstable rotational speed, leading to downtime and safety risks. Manual inspections cannot identify early warning signs. Therefore, a low-cost IoT and machine learning system is required to continuously monitor motor condition and predict potential failures before they occur.

2.0 Objectives

1. Monitor motor **temperature**, **vibration**, and **RPM** using the ESP32 microcontroller.
2. Use a **Raspberry Pi Zero** to run machine learning models for anomaly detection and failure prediction.
   Store processed data in a **cloud database** and visualize motor health using a real-time dashboard.
3. Trigger **local alerts** using LEDs and a buzzer when abnormal motor behaviour is detected

3.0 Components Used in This Project

3.1 Microcontroller & Edge Processor

1. **ESP32 NodeMCU** – Collects motor sensor data and transmits it.
2. **Raspberry Pi Zero** – Performs machine learning inference and anomaly detection.

3.2 Motor Under Test

300C 1.5–6V DC Motor (from IoT Kit)

- Acts as the rotating machine for predictive maintenance testing.
- Supports realistic temperature, vibration, and RPM monitoring for prototype demonstrations.

4.0 Sensors

1. **DS18B20 Temperature Sensor** – Detects overheating on the motor casing.
2. **MPU6050 Accelerometer/Gyroscope** – Measures vibration patterns to identify imbalance or loosened components.
3. **TCRT5000 Reflective IR Sensor (LM393)** – Monitors RPM to detect irregular rotational behaviour.

5.0 Actuators

1. **Active Buzzer** – Provides audible alerts during warning or critical motor conditions
2. **LED Indicators (Green/Yellow/Red)** – Shows motor health status at a glance.
3. **Relay Module (Optional)** – Used to safely shut off the motor during critical alert stages.

6.0 Machine Learning Approach

6.1 Synthetic Data for Training

Because the small prototype motor cannot naturally produce a wide range of failure scenarios, synthetic training data will be generated. This includes simulated patterns such as:

1. Increased vibration amplitude and frequency spikes
2. Gradual temperature rise trends
3. RPM drops, fluctuations, and instability

Synthetic data is created by scaling baseline readings, injecting noise, and modeling typical motor degradation patterns.

6.2 Feature Extraction

1. FFT for vibration frequency analysis
2. Temperature trend slope and rate of increase
3. RPM variance calculations

6.3 Anomaly Detection & Classification

The system classifies motor health into four states:
Normal, **Warning**, **High Risk**, and **Failure Imminent**.
Techniques such as Isolation Forest, statistical thresholds, or lightweight neural networks will be applied.

7.0 Cloud Dashboard and Data Storage

A cloud platform (Supabase) will be used for storing and visualizing motor data.

Dashboard Features

1. **Real-time charts** for temperature, vibration, and RPM
2. **Health status indicator** based on ML predictions
3. **Historical trend graphs** for long-term analysis
4. **Alert logs** showing timestamps and conditions
5. Accessible from any web browser for remote monitoring

Data Flow

ESP32 → Raspberry Pi Zero (ML) → Cloud database → Web dashboard.

8.0 Expected Outcomes

1. A working predictive maintenance prototype for a single motor.
2. Real-time cloud dashboard showing sensor values and health predictions.
3. Early detection of abnormal patterns using synthetic-data-powered machine learning.
4. Improved safety and reduced risk of motor failure through proactive alerts.

Passive Buzzer Module DC 3.3V - 5V
https://shopee.com.my/product/6674515/1934237275?gads_t_sig=VTJGc2RHVmtYMTlxTFVSVVRrdENkVEg0SDd3VWo1MDQyT052d3EvY1B4YXhTcDBvV2M5QkU3VFNKVTZsU2Y4djMvTWI0Z1dLUllSQ21Mdm4rWEM1cHE5a0VCV2cwWkRsSjBhTlJubXBrRFJwK1N0WG1FZnhrUHdUMmUyeVpTbHc&utm_source=chatgpt.com
DS18B20 Temperature Sensor Module
https://shopee.com.my/DS18B20-Temperature-Sensor-Module-Kit-Waterproof-100CM-Digital-Sensor-Cable-Stainless-Steel-Probe-Terminal-Adapter-For-Arduino-i.133282937.23479212569?extraParams=%7B%22display_model_id%22%3A231990257439%2C%22model_selection_logic%22%3A3%7D&sp_atk=00a989bb-4dae-4a76-a58d-8d7967a3839a&xptdk=00a989bb-4dae-4a76-a58d-8d7967a3839a
MPU-6050 modules
https://shopee.com.my/1Set-IIC-I2C-GY-521-MPU-6050-MPU6050-3-Axis-Analog-Gyroscope-Sensors-Accelerometer-Module-For-Arduino-With-Pins-3-5V-DC-i.957629053.22729979309?extraParams=%7B%22display_model_id%22%3A221162475142%2C%22model_selection_logic%22%3A3%7D&sp_atk=4adcea6a-9b19-45f3-9296-ce9e64036c09&xptdk=4adcea6a-9b19-45f3-9296-ce9e64036c09
Reflective infrared sensor module
https://shopee.com.my/product/35780982/1658363855?gads_t_sig=VTJGc2RHVmtYMTlxTFVSVVRrdENkVzBLS2xuUGZzMlQ5NjlFWklmRkZjVExITXY1Q1Q5aTVkRGEzd09wOHJaN0dOaU1zbXYzeWRLcVpTcE1QVTNNUS9mUGZHdG83Zjl1MkVYUDY2T1czdkVKZVVvZjRXMmJuN21vOHVkNHpieWQ