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IIoT-Based Machine Behavior Passport for Low-Cost Adaptive Condition Monitoring and Maintenance Recommendation

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Abstract : *Industrial machines can be very important within manufacturing industries. However, unexpected failures can cause delays and increase maintenance costs. Traditional maintenance strategies can involve static threshold values which can cause issues with detecting early signs of abnormality as every machine will have differing characteristics. This paper describes an IIoT based Machine Behavior Passport which can be used to monitor the behaviour of machines in an adaptive and low cost manner. An ESP32 controller was used along with sensors to monitor the operational status of machines. During the learning phase, the system will record a machine's normal behaviour to create a specific baseline for that machine. The sensors can then be used to compare this baseline with real time data to detect any abnormality. Multiple sensors will be used to calculate a degradation index and produce a Machine Health Score within the range 0-100. The system also aims to detect probable fault conditions and recommend how urgent a maintenance is. An OLED screen was used to display local monitoring data along with a buzzer and LEDs for alerts. The system can also use an MQTT based cloud connection to give remote monitoring capabilities. A Micro SD card can also be used to store data in case of any temporary Wi-Fi issues. An affordable solution to monitor machine conditions and predict maintenance requirements can be provided.*

Keywords: Industrial Internet of Things, Machine Behavior Passport, condition monitoring, predictive maintenance, ESP32, machine health score, MQTT

I. INTRODUCTION

Industrial machines Industrial machines play an important role within manufacturing processes. Many different types of machines are used within industries including motors, pumps, fans, compressors and conveyer systems. It is important that these operate correctly to keep productivity high and reduce costs. During operation machines can suffer from wear, increased vibrations, overheating, fluctuations in current and rotational speeds (RPM). These can indicate that the machine is operating abnormally. If these issues are not detected early they can cause machines to fail causing disruptions to production and increasing maintenance costs.

Traditional maintenance strategies often use static thresholds and regular checks. While this can be an easy solution to implement issues can occur if all abnormalities cannot be detected at the correct times. Static thresholds may not be suitable if every machine has different normal operating behaviours.

By using Industrial Internet Of Things technology we can monitor machines more effectively. We can continuously gather data from sensors and use embedded controllers to analyse this data.

The project uses an ESP32 controller to gather data from the sensors. The system will learn how the machine should operate normally instead of using static thresholds. This information can be stored in a Machine Behavior Passport. These real time values can be compared to the learnt baseline to detect any unusual changes. The system will then give

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a machine health score.The main aim of the project is to provide a low cost and adaptable solution to monitor machine conditions using multiple sensors, edge computing and cloud connectivity.

II. RELATED WORK

Many studies have looked into using IoT based solutions to monitor machine conditions and predict maintenance requirements. Sensors and embedded controllers are used to collect information on how the machine is operating including vibrations, temperatures, current and rotational speeds.Vibrations are often used to detect unusual mechanical behaviour. Temperature sensors can detect abnormal heating, current sensors can highlight how much electrical load there is and RPM sensors can highlight changes in the machine speed. Combining these sensors can give a better understanding of how the machine is operating.

Industrial IoT systems can help with remote monitoring by sending the sensor data to a cloud platform. This means the user does not need to be at the machine to see how it is performing. Machine learning techniques have also been used to detect fault patterns.

However some monitoring solutions rely on static thresholds and do not include many sensors. This can be an issue as the static thresholds may not accurately represent the normal behaviour of all machines. Some fault classification solutions will also require suitable training data to be collected.The project uses a machine specific baseline to overcome these issues. The Machine Behavior Passport will record how the machine should operate normally. Multiple sensor data can be compared to this baseline to detect any abnormal behaviour and give maintenance recommendations.A low cost solution has been created using multiple sensors, ESP32 processing, Machine Health Score, MQTT connection and offline data storage.

III. SYSTEM ARCHITECTURE

A. Hardware Components

MPU6050 Vibration	DS18B20 Temperature	ACS712 Current	IR Sensor RPM
ESP32 Controller Sensor acquisition • Baseline learning Deviation analysis • Health score			
OLED Local status	LED + Buzzer Alerts	MQTT Cloud Remote monitoring	Micro SD Offline log

Fig. 1. Conceptual architecture of the Machine Behavior Passport system.

ESP32 Development Board: The ESP32 is the main controller. It acquires sensor readings, performs edge-side processing, compares data with the stored baseline, calculates the health indicator.

MPU6050 Vibration Sensor: Measures acceleration and motion characteristics that can be analysed to identify unusual vibration behaviour.

DS18B20 Temperature Sensor: Measures the temperature of a monitored machine component and supports detection of abnormal temperature changes.

ACS712 Current Sensor: Measures electrical current used by the connected machine. Changes in current may indicate a change in load or operating condition.

IR RPM Sensor: Measures rotational speed and helps identify departures from expected speed behaviour.

OLED, LEDs, and Buzzer: The OLED displays local readings and machine status. LEDs and a buzzer provide local alerts when the implemented decision rules indicate abnormal operation.

Micro SD Card and MQTT: The Micro SD card stores sensor recordshe network is unavailable. MQTT provides a lightweight communication.

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B. Software Architecture

The software handles the gathering of sensor data, benchmarking, health diagnostics and sending out notifications. It begins by initialising the ESP32, sensors, OLED and notification system. It will then gather sensor data periodically and process it. During training mode, the system will save the normal running behaviour of the machine. This will be saved into the Machine Behavior Passport. Once running normally this data will be compared to the saved data. An analysis of any unusual changes in Vibration, Temperature, Current and RPM will be done. The information will be used to produce a score for the health of the machine. The relevant data will be shown on the OLED. The buzzer and LEDs will notify locally of any issues that have been detected by the decision rules. MQTT communication can be used to send the data from the machine to a cloud system. If there is no network connection the Micro SD card is able to store data locally .

III. CORE CONCEPT AND DESIGN PRINCIPLES

Connect Devices Connects each of the sensors (MPU6050, DS18B20, ACS712 and IR RPM) up to the ESP32 board.Initialisation Initialises the sensors, OLED display, buzzer, LEDs and communication parts.

Data collection Collects the data from the sensors (vibration, temperature, current, rotational speed).Data Processing Receives the sensor data and processes it.Learning The system ‘learns’ what a typical reading would be by storing data from the sensors whilst the machine is operating normally.

Machine Passport Uses the data collected to create a unique baseline for the particular machine.Data Comparison Compares real time sensor data against the stored baseline.Machine Diagnosis Analyzes the sensor data and calculates a multi parameter degradation index based on how the system has been implemented.Machine Health Score Creates a visual representation of the processed information through the use of a Machine Health Score (0-100).

Possible Fault Detection Analyzes the unusual sensor pattern to give an indication of likely faults and how urgent the maintenance is.Display & Alerts Displays the information about the machine on the OLED. The buzzer and LEDs also alert the user if there is any unusual conditions.Communication & Storage Sends data about the machine to the cloud using MQTT. Data can be stored locally using the Micro SD card if there is any issues with the Wi-Fi connection..

IV. OPERATIONAL WORKFLOW

Connect Devices Connects each of the sensors (MPU6050, DS18B20, ACS712 and IR RPM) up to the ESP32 board.Initialisation Initialises the sensors, OLED display, buzzer, LEDs and communication parts.Data collection Collects the data from the sensors (vibration, temperature, current, rotational speed).Data Processing Receives the sensor data and processes it.

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Machine Health Score Creates a visual representation of the processed information through the use of a Machine Health Score (0-100).Possible Fault Detection Analyzes the unusual sensor pattern to give an indication of likely faults and how urgent the maintenance is.Display & Alerts Displays the information about the machine on the OLED. The buzzer and LEDs also alert the user if there is any unusual conditions.Communication & Storage Sends data about the machine to the cloud using MQTT. Data can be stored locally using the Micro SD card if there is any issues with the Wi-Fi connection.

V. IMPLEMENTATION AND TESTING

A. Prototype Development

The prototype is built around an ESP32 controller connected to the MPU6050 vibration sensor, DS18B20 temperature sensor, ACS712 current sensor, and IR RPM sensor. The controller processes sensor values and compares them with

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the machine-specific baseline. An OLED provides local access to key parameters and machine health status. LEDs and a buzzer indicate conditions identified by the decision logic. A Micro SD card supports local data logging, while MQTT provides the remote monitoring path. The software coordinates sensor acquisition, baseline creation, health assessment, alerts, and communication.

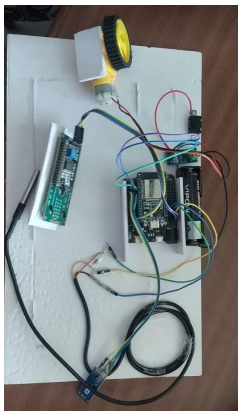


Fig. 2. Prototype assembly showing the ESP32 board, display, motor assembly, wiring, and connected modules.

B. System Test Plan

Test	Purpose	Evidence to record
Sensor test	Check vibration, temperature, current, and RPM acquisition.	Reference values, sensor readings, error, calibration.
Baseline test	Record normal operation to create the passport.	Load, duration, sample count, baseline range.
Health score	Check multi-parameter calculation and score mapping.	Input values, index, score, expected output.
Fault/anomaly	Check whether controlled deviations trigger indications.	Test condition, detections, false alarms, missed detections.
MQTT/cloud	Verify that readings reach the remote platform.	Delivery, timestamps, interruptions.
Alerts	Verify LED and buzzer response.	Trigger condition and response.
Offline storage	Check logging during Wi-Fi interruption.	Records retained and recovery behaviour.

The project description outlines six core tests; offline storage is also listed because it is a stated feature. Numerical results, accuracy measurements, and fault-detection metrics were not supplied and are therefore not claimed here. Measured results should be added before making performance claims.

VI. DISCUSSION

The system combines several sensor inputs to provide a broader view of machine operation. The Machine Behavior Passport provides a machine-specific reference, while comparison with live measurements can help expose changes that may be overlooked by fixed thresholds. The Machine Health Score gives users a compact summary, and individual readings help show which parameters changed. Local alerts can notify personnel near the machine, while MQTT enables remote observation. The low-cost controller and sensors may be useful for smaller and medium-sized industries that cannot deploy expensive monitoring systems.

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Effectiveness depends on sensor calibration, sampling strategy, baseline quality, machine load, and the logic used to calculate the degradation index and health score. Baselines may need to be created for different operating conditions. A poorly chosen baseline can cause false alarms or missed anomalies. Probable fault labels and maintenance urgency should be treated as recommendations until validated against known fault conditions. Further evaluation should report repeatability, detection rate, false-positive rate, communication reliability, and performance across different loads and machines.

VII. CONCLUSION

This paper details an IIoT based Machine Behaviour Passport that can be used for cheap adaptive monitoring and recommendation of maintenance. The system uses an ESP32 controller along with several sensors to monitor vibration, temperature, electrical current and RPM. Unlike traditional methods this system learns how a machine should behave and creates a baseline for this machine. This can then be compared to real time data to see if anything is abnormal. The system combines several sensors to create a degradation index and a Machine Health Score (ranging from 0-100). This system aims to identify probable faults and how urgent maintenance is. Local monitoring is enabled by using an OLED, buzzer and LEDs. Remote monitoring is done using MQTT. Micro SD is used to save sensor data during short periods of no Wi-Fi. This system provides a cheap way to monitor the health of a machine and would be useful for smaller/medium industries. More testing with calibrated data, different loads and recorded performance metrics can help prove how reliable this system is and improve the fault detection.

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REFERENCES

[1] Kolok et al., “Low-Cost IoT-Based Predictive Maintenance Using Vibration,” 2025. Further publication details should be verified.
[2] M. Madhan Mohan et al., “IIoT-Based Predictive Maintenance and Energy Monitoring System,” 2025. Further publication details should be verified.
[3] “Non-Intrusive Low-Cost IoT-Based Hardware System for Sustainable Predictive Maintenance of Industrial Pump Systems,” 2024. Author and publication details should be verified.
[4] Harsh et al., “Predictive Maintenance of Industrial Machines Using Machine Learning and IoT,” 2024. Further publication details should be verified.
[5] “Machine Learning and IoT-Based Predictive Maintenance Approach for Industrial Applications,” 2024. Author and publication details should be verified.
[6] Y. Lei, N. Li, L. Guo, N. Li, T. Yan, and J. Lin, “Machinery health prognostics: A systematic review from data acquisition to RUL prediction,” Mechanical Systems and Signal Processing, 2018.
[7] T. P. Carvalho et al., “A Systematic Literature Review of Machine Learning Methods Applied to Predictive Maintenance,” Computers & Industrial Engineering, 2019.
[8] A. K. S. Jardine, D. Lin, and D. Banjevic, “A review on machinery diagnostics and prognostics implementing condition-based maintenance,” Mechanical Systems and Signal Processing, 2006.
[9] T. Zonta et al., “Predictive Maintenance in the Industry 4.0: A Systematic Literature Review,” Computers & Industrial Engineering, 2020.
[10] J. Lee, B. Bagheri, and H. A. Kao, “A Cyber-Physical Systems architecture for Industry 4.0 based manufacturing systems,” Manufacturing Letters, 2015.