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**GITAM School of Technology**

**Department of Electrical, Electronics and Communication Engineering**

**Capstone Project**

**Problem Statement:** Health Monitoring system for automobiles using engine parameters ENGINE PARAMETERS

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**Duration:** 06/08/2024 to 18/03/2025

**DECLARATION**

**I/We declare that the project work contained in this report is original and it has been done by me under the guidance of my project guide.**

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**CERTIFICATE**

**This is to certify that M. Lok ignesh, R. Mokshitha, K. Sowmya bearing BU21EECE0100099, BU21EECE0100160, BU21EECE0100475 has satisfactorily completed the Mini Project Entitled in partial fulfillment of the requirements as prescribed by the University for VIIth semester, Bachelor of Technology in “Electrical, Electronics and Communication Engineering” and submitted this report during the academic year 2024-2025.**

**[Signature of the Guide] [Signature of HOD]**

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# **Chapter 1: Introduction**

Modern automobiles rely on advanced sensors and onboard diagnostics to ensure optimal performance and safety. As vehicles become more complex, traditional diagnostic methods may no longer be sufficient to detect faults in real time. Efficient and accurate health monitoring of automobiles is crucial for preventing unexpected breakdowns and enhancing vehicle reliability.

To address this challenge, **Machine Learning (ML)** offers a promising solution. By leveraging artificial intelligence, ML algorithms can analyze vast amounts of engine data, detect anomalies, and predict potential failures more accurately than traditional diagnostic approaches. Unlike conventional methods, ML-based systems can continuously adapt to changing engine conditions and identify rare faults that may not follow predefined failure patterns. This adaptive approach enables predictive maintenance, reducing downtime and repair costs while improving overall vehicle performance and safety.

## **Overview of the problem statement**

## Automobile health monitoring is crucial for ensuring vehicle safety and efficiency. Existing solutions focus on OBD-II based diagnostics and IoT-enabled monitoring but often lack real-time processing and predictive analytics. Our system overcomes these limitations by integrating Wokwi simulation, cloud-based analytics, and AI-driven anomaly detection.

## **1.2. Existing Projects and Challenges**

**Previous projects primarily focus on engine diagnostics and fuel efficiency monitoring using onboard vehicle sensors. These systems often fail to provide real-time remote monitoring and predictive insights. Challenges include:**

* **High implementation cost due to reliance on hardware sensors.**
* **Limited scalability as data processing is confined to local storage.**
* **Lack of predictive analytics, making fault detection reactive rather than proactive.**

**Our project overcomes these challenges by using cloud-based storage, AI-driven insights, and cost-effective simulation before physical implementation.**

# 

# **1.3 Objectives and Goals**

# **Implement a real-time automobile health monitoring system.**

# **Establish MQTT-based communication between Wokwi and Node-RED.**

# **Store and analyze data using ThingSpeak cloud.**

# **Develop AI-based anomaly detection and nonlinear regression models for future predictions.**

**Goals:**

**Main Goals**

* Reduce breakdowns, increase uptime, enhance driver safety, and minimize accident risks.
* Improve fuel efficiency, enhance engine performance, and reduce emissions.
* Enable predictive maintenance, optimize maintenance schedules, and reduce overall costs.
* Provide peace of mind, improve customer loyalty, and offer personalized maintenance recommendations.

**Additional Goals**

* Provide features that allow owners to remotely monitor and control their vehicles
* Incorporate technologies like autonomous emergency braking, lane departure warning, and blind spot monitoring.
* Use eco-friendly materials in vehicle construction.
* Offer personalized maintenance plans and services based on individual driving habits and preferences.

**Chapter 2: Literature Review**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S.NO | Title | Author | Published Year | Publications | Abstract |
| 1. | Experimental analysis on battery based health monitoring system for electric vehicle | D. Selvabharathi⇑, N. Muruganantham | August 2020 | Department of EEE, Periyar Maniammai Institute of Science & Technology, Vallam, Thanjavur 613403, India | Electric vehicles are the future and the most important part of an electric vehicle is its battery which pro vides the power to the vehicle and also its weakest part. Batteries are prone to degradation, heating and general age related effects. So a constant monitoring system is required to keep the battery in check and keep the user posted about its various variables. This project provides a management system for a battery by monitoring various factors like main power voltage, cell voltage, etc. |
| 2. | State of Charge, State of Health, and State of Function Monitoring for EV BMS | Zong-You Hou, Pang-Yen Lou, and Chua-Chin Wang | 2017 | In 2017 IEEE International Conference on consumer electronics  (ICCE) | The computation and monitoring of three key indi ces, namely, state of charge (SOC), state of health (SOH), and state of function (SOF) for EV (electrical vehicle) BMS (battery management system) are proposed in this work. Because most of SOC definitions are directly related to nominal capacity, the ac curacy of residual capacity is doubtful. Therefore, the SOC is re defined by present maximum capacity to reduce the error of the SOC estimation. The measurement of the proposed SOC demon strates that the maximum error is 0.334 %. Moreover, this paper also proposes SOF based on SOC and SOH to reveal the driving power of the system. |
| 3. | Automotive Internal-Combustion-Engine Fault Detection and Classification Using Artificial Neural Network Techniques | Ryan Ahmed, Mohammed El Sayed, S. Andrew Gadsden, Jimi Tjong, Saeid Habibi | JANUARY2015 | IEEETRANSACTIONS ONVEHICULARTECHNOLOGY,VOL.64,NO.1 | In this paper, an engine fault detection and classification technique using vibration data in the crank angle domain is presented. These data are used in conjunction with artificial neural networks (ANNs), which are applied to detect faults in a four-stroke gasoline engine built for experimentation. A com parative study is provided between the popular backpropagation (BP) method, the Levenberg–Marquardt (LM) method, the quasi Newton (QN) method, the extended Kalman filter (EKF), and the smooth variable structure filter (SVSF). The SVSF is a relatively new estimation strategy, based on the sliding mode concept. It has been formulated to efficiently train ANNs and is consequently re ferred to as the SVSF-ANN. |
| 4. | Predictive Maintenance of Motors using Machine Learning | Nithish Kanna J L Krishnakumar G, Muhammad Aadhil M, Dr. Ajay V P | Issue 4 April 2024 | Department of Electronics & Communication Engineering, Kumaraguru College of Technology | The suggested predictive maintenance system makes use of sensor readings, operating conditions, and failure incidences from previous motor operation data. Machine learning models are trained on a large dataset, which enables them to identify patterns and correlations suggestive of possible motor breakdowns. A variety of algorithms are used to build a strong prediction model, including ensemble approaches, neural networks, and support vector machines. By continuously analysing real time data from motors, the predictive maintenance model can identify possible flaws before they become serious failures. Because of this, maintenance teams may plan interventions during scheduled downtime, maximising the use of available resources and reducing unforeseen outages. By extending the lifespan of motors and lowering maintenance costs, the application of this predictive maintenance strategy supports overall sustainability initiatives. |

# **Chapter 3: Strategic Analysis and Problem Definition**

# **3.1 SWOT Analysis**

A SWOT analysis was conducted to evaluate the strengths, weaknesses, opportunities, and threats related to the real-time health monitoring system for automobiles.

**Strengths:**

* **Advanced sensor technology:**The availability of accurate and reliable sensors for measuring engine parameters.
* **Data analytics capabilities:** The ability to process and analyze large amounts of data to identify patterns and anomalies.
* **Predictive maintenance potential:** The potential to prevent breakdowns and reduce maintenance costs through early detection of issues.
* **Improved safety:** The ability to identify and address potential safety hazards related to engine malfunctions.
* **Enhanced customer satisfaction**: The potential to improve customer satisfaction by providing peace of mind and reducing vehicle downtime.

**Weaknesses:**

1. **Data privacy concerns:** The collection and storage of sensitive vehicle data raises privacy concerns.
2. **Complexity of integration**: Integrating a health monitoring system with existing vehicle electronics can be complex.
3. **Dependency on technology:** The system's effectiveness relies on the reliability and accuracy of sensors and data analytics algorithms.
4. **Potential for false positives or negatives:** The system may generate false alarms or fail to detect certain issues.

**Opportunities:**

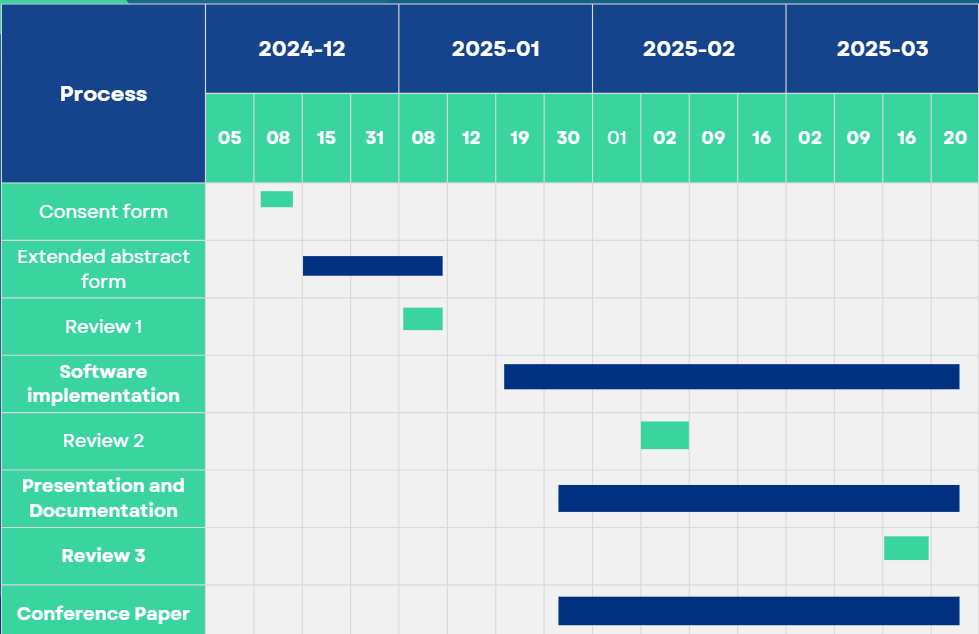
* **Advancements in machine learning:** Improvements in machine learning algorithms can enhance the accuracy and reliability of predictive maintenance models.
* **New business models:** The development of new business models based on health monitoring data, such as usage-based insurance or predictive maintenance services.
* **Growing demand for connected vehicles:**The increasing popularity of connected vehicles presents opportunities for integrating health monitoring systems with other vehicle features.
* **Regulatory requirements:** The increasing emphasis on vehicle safety and emissions regulations may drive the adoption of health monitoring systems.

**Threats:**

* **Competitive pressures:** The emergence of competing technologies or business models may erode the market position of health monitoring systems.
* **Economic downturns:** Economic downturns may reduce consumer demand for advanced vehicle features, including health monitoring systems.
* **Regulatory changes:** Changes in regulations or standards may impact the design and implementation of health monitoring systems

### 

### **3.2 Project Plan - GANTT Chart**



##### 3.3 **Refinement of problem statement**

The problem statement was refined based on the literature review and SWOT analysis. The primary focus is to develop a real-time, cloud-based health monitoring system for automobiles that provides early fault detection and predictive maintenance using IoT and AI. This project addresses the limitations of traditional vehicle diagnostics by enabling remote monitoring, data analytics, and proactive maintenance planning.

**Chapter 4: Methodology**

**4.1 System Design**

The health monitoring system is designed to ensure accurate real-time tracking of environmental conditions using sensor-based data acquisition, wireless communication, and cloud-based analytics. The key components of our system include:

* **ESP32 with DHT22 Sensor:**
  + The ESP32 microcontroller is used for data processing and communication.
  + The DHT22 sensor captures temperature and humidity readings with high accuracy and stability.
  + Data is read at predefined intervals and pre-processed before transmission.
* **Wokwi Simulation Environment:**
  + To eliminate hardware dependency and facilitate virtual testing, the system is simulated using Wokwi.
  + This ensures efficient debugging, real-time performance analysis, and flexibility in modifying the system before deployment.
* **MQTT Protocol for Data Transmission:**
  + Data from ESP32 is transmitted to Node-RED using the MQTT (Message Queuing Telemetry Transport) protocol.
  + MQTT ensures lightweight, low-latency, and efficient data exchange over the network, making it ideal for IoT applications.
* **Thing-Speak Cloud for Centralized Data Storage and Processing:**
  + Collected data is stored in ThingSpeak Cloud, providing a centralized platform for real-time analysis and historical trends.
  + It enables secure remote access, visualization, and predictive analytics for decision-making.

**4.2 Data Acquisition**

The system continuously collects environmental data using DHT22, an advanced digital sensor with a capacitive humidity sensor and thermistor. The key steps involved in data acquisition are:

1. **Sensor Readings:**

* The **DHT22** sensor captures **temperature** and **humidity** readings at regular intervals.
* These readings are converted into digital format and sent to the **ESP32** microcontroller for processing.

1. **Real-Time Data Processing:**

* The ESP32 processes the sensor data to remove noise and ensure accuracy.
* Data is formatted into a structured message for efficient transmission.

1. **Data Transfer to Cloud:**

* The processed sensor data is published to **MQTT topics** and forwarded to **Node-RED** for visualization.
* Simultaneously, data is **logged into ThingSpeak**, allowing further analytics and historical data tracking.

#### **4.3 Data Transmission & Processing**

**1. Data Transmission**

The transmission of data follows a multi-stage pipeline:

* ESP32 collects sensor readings and transmits them over Wi-Fi.
* MQTT broker (e.g., Mosquitto) ensures seamless data flow between ESP32 and cloud applications.
* Node-RED receives, processes, and visualizes data in real-time.
* ThingSpeak stores long-term data for AI-based analytics.

**2. Data Processing & Analysis**

1. **Real-Time Visualization on Node-RED Dashboard:**

* Data is displayed on a customized dashboard for real-time monitoring.
* Alerts and notifications can be integrated for threshold-based warnings.

1. **ThingSpeak Cloud Analytics:**

* ThingSpeak allows remote access to collected data, enabling efficient trend analysis and historical tracking.
* It provides an API for seamless integration with third-party applications.

1. **MATLAB-Based Predictive Analysis:**

* Regression models are applied to analyze temperature and humidity variations.
* Anomaly detection algorithms identify irregular patterns that may indicate sensor faults or environmental changes.
* AI-based predictive maintenance techniques help prevent system failures before they occur.

**Chapter 5: Implementation**

**5.1 Wokwi Simulation**

Wokwi is a powerful online simulation platform that enables the virtual testing of ESP32 and DHT22 sensors without requiring physical hardware. By using Wokwi, we can:

* Eliminate hardware dependency, reducing costs associated with physical components.
* Debug and refine the system in a controlled environment before actual deployment.
* Simulate real-time sensor behaviour, ensuring smooth integration with data processing components.

**Integration with MQTT and Node-RED**

* The simulated DHT22 sensor provides temperature and humidity readings, which are processed by ESP32 in real time.
* The ESP32 publishes the sensor data to an MQTT broker, which acts as an intermediary for efficient data transmission.
* The data is then subscribed to by Node-RED, allowing real-time visualization of the temperature and humidity trends.
* The entire workflow ensures a seamless flow of information from sensor simulation to cloud-based analytics.

**5.2 Node-RED Dashboard**

Node-RED is an open-source flow-based development tool that provides real-time monitoring and control of IoT systems. The Node-RED dashboard is used to display:

* **Live Temperature and Humidity Trends**
  + The dashboard continuously updates with real-time sensor readings, ensuring accurate monitoring of environmental conditions.
  + Graphical representations such as line graphs and gauges help visualize fluctuations in temperature and humidity levels.
* **Abnormality Detection**
  + The system incorporates threshold-based alerts to detect extreme temperature or humidity conditions.
  + If the readings exceed predefined safe limits, alerts or notifications are triggered to prompt immediate action.
  + This feature is crucial for applications such as climate control in smart homes, industrial automation, and agricultural monitoring.
* **Data Logging and Historical Analysis**
  + The dashboard stores historical sensor readings, enabling users to track long-term trends and patterns.
  + This historical data serves as the foundation for predictive maintenance and anomaly detection algorithms.

**5.3 ThingSpeak Cloud Analysis**

ThingSpeak is an IoT analytics platform that enables the storage, processing, and visualization of real-time sensor data. Once the sensor data is transmitted to ThingSpeak Cloud, advanced analytics and AI-based predictions can be performed.

**Statistical Metrics**

To better understand sensor behaviour and environmental patterns, the system computes key statistical metrics, including:

* **Mean (Average):** Provides an overall idea of the typical temperature and humidity levels over a period of time.
* **Median:** Helps in identifying skewed distributions where extreme values might impact the average.
* **Maximum & Minimum Values:** Highlights extreme fluctuations in environmental conditions.
* **Standard Deviation:** Measures the variability in sensor readings, ensuring consistency in data accuracy.

**Data Visualization Techniques**

To extract meaningful insights, various data visualization techniques are employed:

* **K-Means Clustering**
  + This unsupervised machine learning technique groups similar sensor readings into distinct categories.
  + Helps identify common environmental conditions and detect outliers in temperature and humidity trends.
  + Enables better classification of data based on different operating conditions.
* **Graph Neural Networks (GNNs)**
  + GNNs are utilized to model complex relationships between sensor readings over time.
  + They help in identifying patterns that may not be obvious in traditional statistical analysis.
  + By leveraging graph-based representations, sensor readings are interconnected to predict anomalous behaviours in the environment.

**Prediction Models**

One of the key objectives of the system is to provide predictive insights using advanced AI and machine learning techniques. The following predictive models are used:

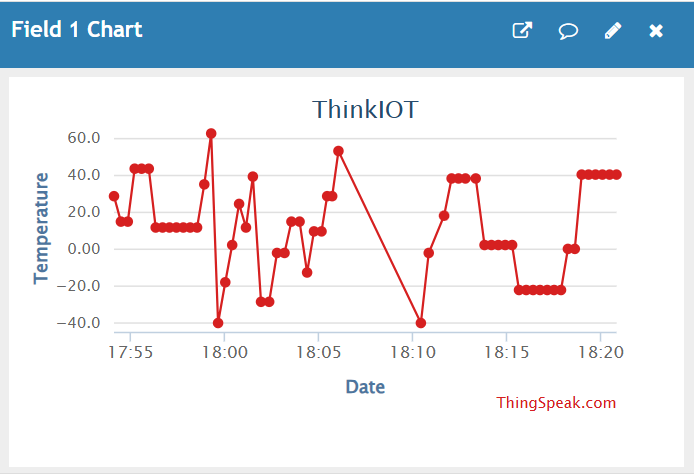
* **Nonlinear Regression for Future Trends** 
  + Nonlinear regression models help predict future temperature and humidity levels based on historical data.
  + These models account for seasonal variations, sensor drift, and environmental influences that impact readings.
  + Predictive insights enable proactive decision-making, such as adjusting HVAC systems, optimizing industrial processes, or ensuring ideal storage conditions in warehouses.

# **Chapter 6: Results**

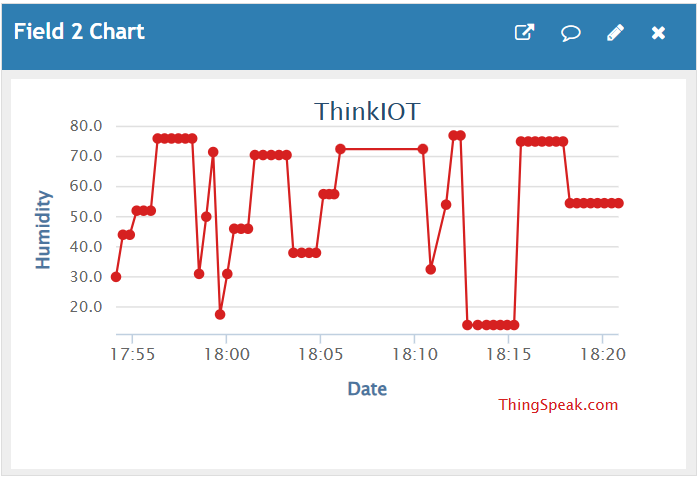
ThingSpeak is a cloud-based platform that helps organizations collect, visualize, and analyze data in real-time from internet-connected devices.

**Sending the values of Temperature and Humidity to Thingspeak:**

Temperature values:

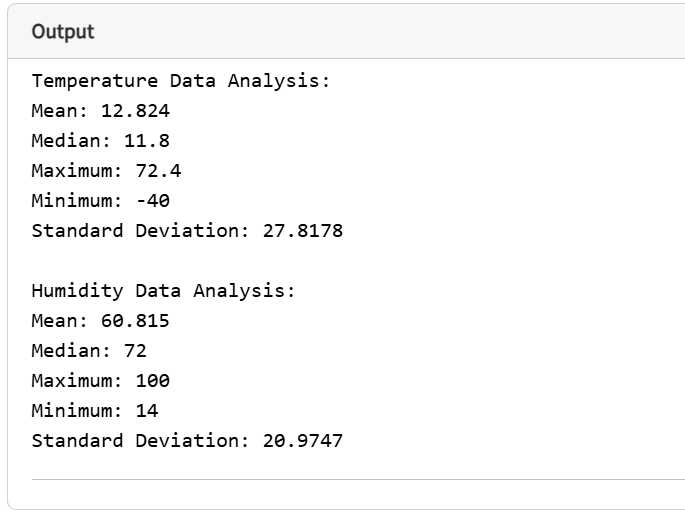


Humidity values:



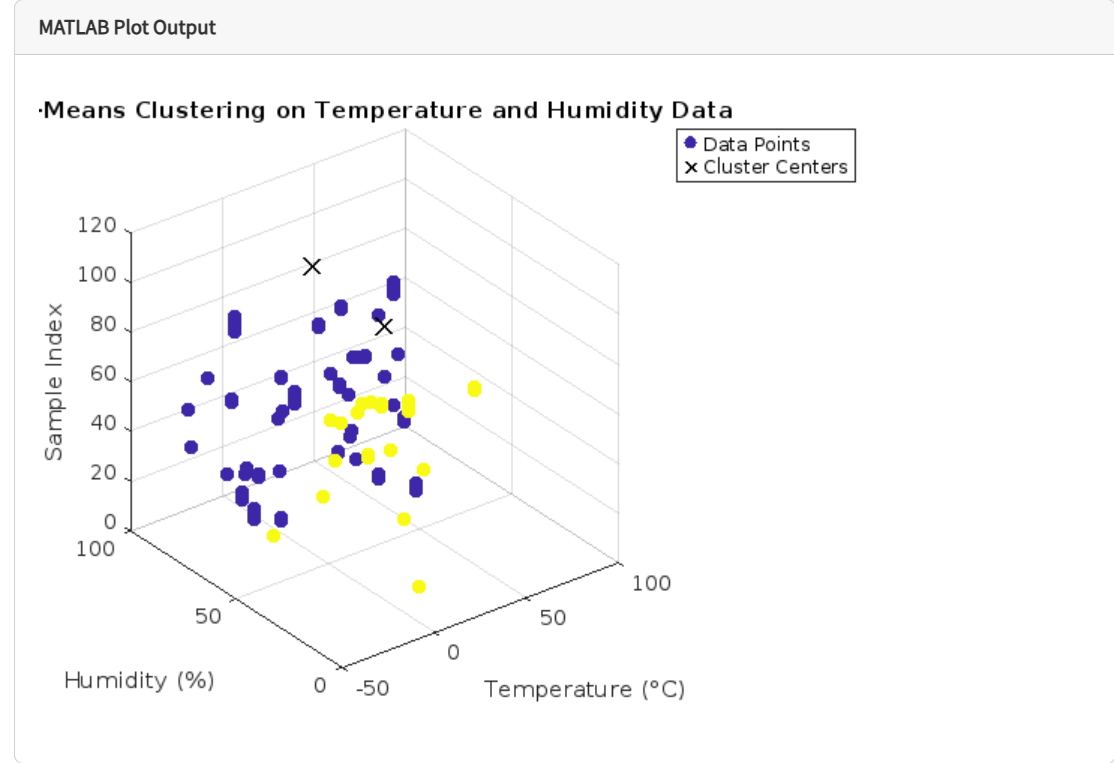
**Analyzing the data in Thingspeak using MATLAB analyze:**

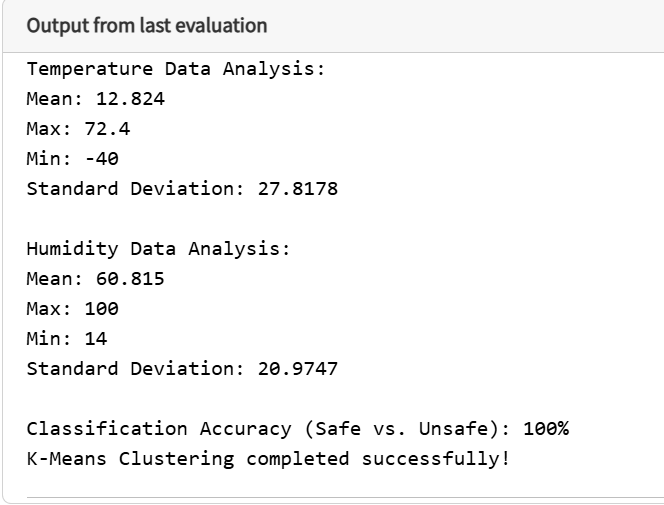
Statistical analysis is a fundamental pillar of data analysis because it provides a rigorous and objective framework for understanding patterns, making inferences, quantifying relationships, testing hypotheses, and summarizing data. However, it is most effective when used in conjunction with other data analysis techniques and a strong understanding of the data's context.

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**K-Means Clustering :**

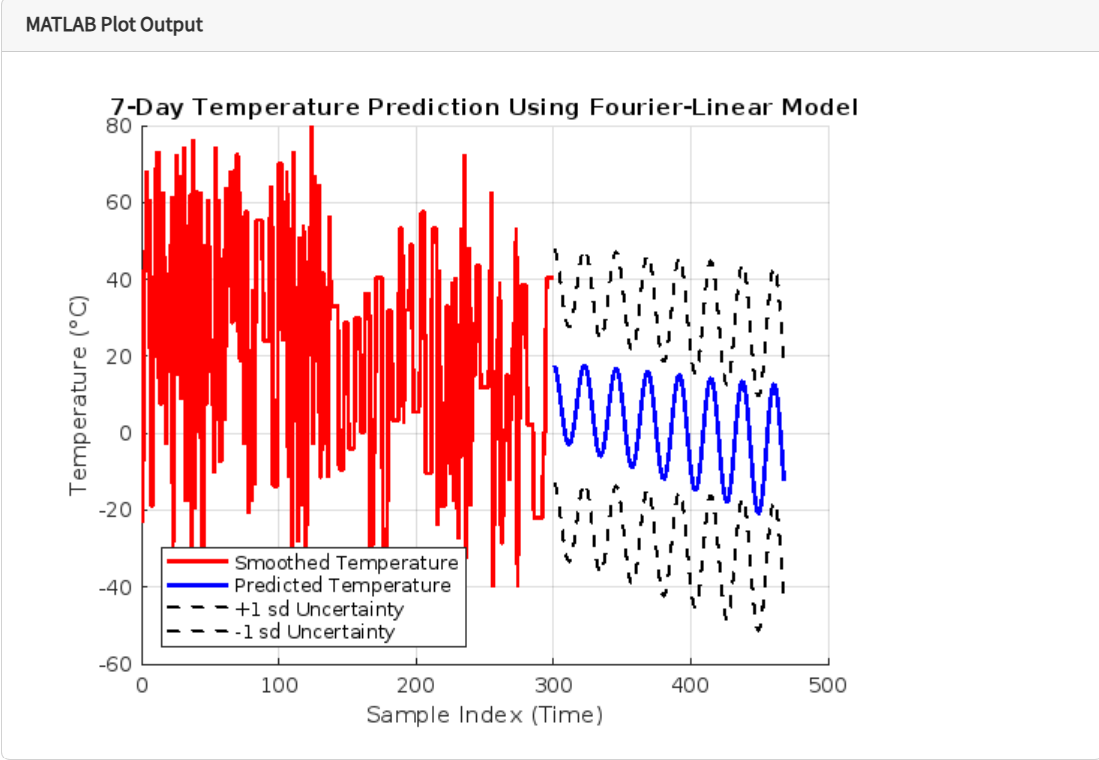
Choosing K-Means over GMM for its simplicity, speed, and effectiveness with well-separated, spherical clusters of roughly equal size and variance. It's also easier to interpret due to its crisp cluster assignments and has fewer parameters to tune.

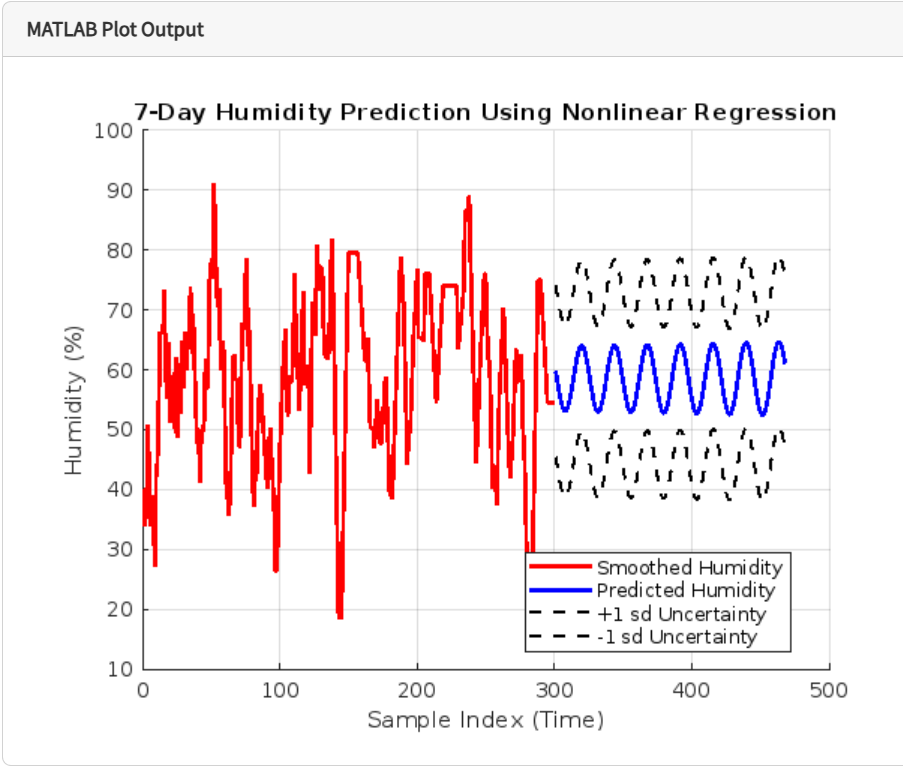


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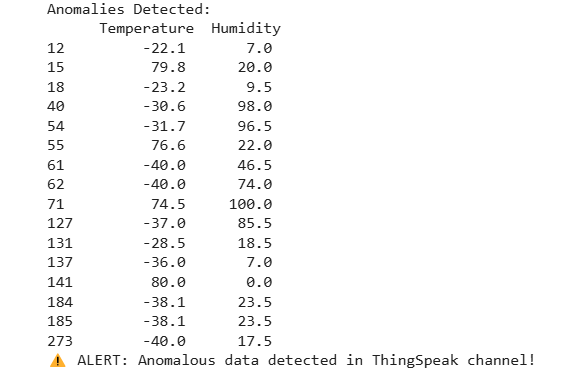
**Prediction of Temperature and Humidity:**

The increasing popularity of non-linear supervised algorithms stems from their ability to model the complex, non-linear relationships prevalent in many real-world datasets, handle feature interactions, and achieve higher predictive accuracy in various challenging domains.





**Anomalies detection :**

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**Chapter 7: Conclusion & FUTURE SCOPE**

The successful implementation of an AI-driven automobile health monitoring system has demonstrated a cost-effective and efficient solution for real-time vehicle diagnostics. By leveraging IoT-enabled sensors, cloud computing, and AI-based analytics, the system ensures continuous monitoring of engine parameters, enhancing vehicle reliability and performance.

The integration of ThingSpeak and MATLAB significantly improved data processing, anomaly detection, and predictive maintenance by analyzing historical trends and real-time sensor readings. Additionally, the Wokwi simulation environment allowed for extensive testing without hardware dependency, reducing development time and costs.

**Key achievements of this project include:**

* Real-time data acquisition from engine sensors.
* Cloud-based analytics for performance assessment.
* Machine learning-based fault prediction for proactive maintenance.
* User-friendly visualization through Node-RED dashboards.

By addressing challenges in automotive health monitoring, the project lays a solid foundation for intelligent vehicular diagnostics, helping to prevent potential failures and optimize engine performance.

**Future Scope**

The proposed system serves as a **scalable** and **adaptable** solution for future advancements in **vehicle health monitoring**. The following improvements and enhancements can be considered for further development:

* 1. **Integration of Additional Sensors for Advanced Engine Diagnostics**

Currently, the system primarily monitors **temperature and humidity**. Future iterations could include:

* **Oxygen (O₂) and Carbon Monoxide (CO) Sensors** for monitoring air-fuel mixture and emissions.
* **Oil Pressure and Coolant Temperature Sensors** – to detect engine overheating and lubrication issues.
* **Vibration and Knock Sensors** – for early detection of engine misfires or component failures.

These additions would provide **comprehensive diagnostics**, ensuring the engine operates at peak efficiency while maintaining environmental compliance.

* 1. **Enhancement of AI Models for Predictive Maintenance**

The current system uses **nonlinear regression and anomaly detection** for fault prediction. Future improvements could include:

* **Deep Learning Models (LSTM & CNNs)** to analyze time-series sensor data and detect hidden patterns.
* **Reinforcement Learning** to optimize vehicle performance based on driving habits and environmental conditions.
* **Edge AI Processing** deploying lightweight AI models on **ESP32** to reduce cloud dependency and latency.

Advanced **AI-driven predictive maintenance** would **increase vehicle lifespan, reduce operational costs, and enhance safety** by predicting failures before they occur.

* 1. **Development of a Mobile Application for Real-Time Monitoring**

To enhance accessibility and usability, a **mobile application** can be developed that allows users to:

* **Monitor engine health** in real-time via smartphone.
* **Receive automated alerts** for abnormal readings or potential failures.
* **View maintenance recommendations** based on AI-driven predictions.
* **Schedule vehicle servicing** based on data-driven insights.

The app would **improve user experience and convenience**, allowing drivers and fleet managers to monitor vehicle health anytime, anywhere.

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