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IoT- Based Hazard Detection for Husk Storage Warehouse

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Abstract: An IoT-based protection system for husk storage warehouses plays a crucial role in enhancing safety, efficiency, and risk management. The storage of husk can be quite challenging due to the combustible nature of organic materials, which necessitates comprehensive environmental monitoring. To address these challenges, innovative technologies can be implemented to monitor fire hazards and ensure air quality within husk storage facilities. This prototype utilizes an Arduino microcontroller, along with various sensors, including temperature and humidity sensors, smoke detectors, flame sensors, and dust sensors. By analyzing key parameters collected from these sensors, the system enables proactive preventive measures and effective counteractions against potential hazards.
Keywords: IoT, Environmental Monitoring, Risk Management, Real Time Monitoring

I. INTRODUCTION

In power plants, rice husk serves as a vital fuel source, and managing its storage presents unique challenges due to its combustible nature. To enhance safety and efficiency in husk storage warehouses, an innovative IoT-based hazard detection system has been developed. This system significantly mitigates risks associated with handling such combustible materials, as these warehouses are particularly susceptible to various hazards, including fire outbreaks, excessive heat accumulation, dust explosions, and the release of toxic gases all of which can threaten human safety and operational integrity. The IoT solution utilizes a network of real-time sensors strategically installed throughout the warehouse to monitor critical environmental parameters continuously. Key metrics tracked include temperature fluctuations, humidity levels, gas concentrations (particularly of methane and carbon monoxide), and dust particle concentrations.

This robust monitoring capability empowers warehouse operators to swiftly respond to any hazardous conditions that arise, effectively reducing the potential for incidents. Moreover, the system's data analytics component enables the accumulation and analysis of sensor data over time. This analysis not only helps identify trends and patterns that could indicate emerging risks but also supports predictive maintenance. By anticipating equipment failures or hazardous conditions, the warehouse can operate more efficiently and safely, ultimately improving overall operational effectiveness. In practical terms, when sensor readings indicate that any environmental parameter exceeds predefined safety thresholds, the IoT system triggers immediate alerts for warehouse personnel and management.

These alerts manifest as audible alarms, visual signals, or notifications on centralized dashboards, ensuring that key stakeholders are informed without delay. This timely communication facilitates either automatic intervention through pre-programmed safety protocols or manual actions taken by trained staff to address the critical situation. Furthermore, the real-time monitoring capabilities of this IoT system create a comprehensive view of the storage conditions. It continuously assesses critical elements such as temperature, humidity, dust levels, smoke, and potential fire indicators. Such detailed surveillance supports effective risk management strategies and enhances maintenance practices by enabling a proactive approach to potential issues. Overall, the integration of advanced sensors and connected devices fosters a work environment that prioritizes safety and efficiency in husk storage facilities. By enabling timely interventions and reducing the likelihood of accidents, this proactive hazard detection system not only safeguards employees but also ensures the protection of valuable stored materials, thereby contributing to a more effective and secure operational framework.

II. LITERATURE SURVEY

This section reviews existing studies on IoT-based hazard Detection for Husk Storage Warehouse. It examines prior research to establish the knowledge gap and justify the study's significance.

A. Smart Warehouse Using IoT. Prof. Dhanashree Joshi, Pradnya Wagh, Geetika Salunkhe, and Anushka Shirke (IJMRSET),2024 [4]

This paper addresses the challenges of traditional warehouse management systems and proposes a solution leveraging the Internet of Things (IoT). It highlights the inefficiencies of manual systems, which are prone to errors and high costs, and outlines a framework for automating warehouse operations using advanced IoT-enabled devices. The authors integrate sensors such as MQ-2, DHT-11, flame sensors, and light sensors with Arduino-based controllers, enabling real-time monitoring of critical parameters like temperature, humidity, and fire risk. Notifications and automated responses are managed through a web application, enhancing operational efficiency, reducing losses due to uncontrolled environments, and minimizing human labour. This work builds upon these concepts by offering a comprehensive system that combines environmental monitoring with automation and real-time notifications.

B. IoT-Based Smart Warehouse Monitoring System. Janak Borwankar, Sanika Pandit, Vilok Patel, and Jagannath Nirmal (SSRN), (2023) [8]

This paper emphasizes the development of a comprehensive system to address challenges in warehouse management, particularly post-harvest losses and inefficient monitoring. The proposed system integrates multiple hardware and software components to enable real-time tracking and environmental control. It employs the ESP32 microcontroller as the central processor, interfaced with sensors such as the DHT11 for temperature and humidity, MQ2 for gas detection, and a load cell for weight measurement. These components monitor critical parameters, ensuring optimal storage conditions and safety. Data collected by the sensors are transmitted via the ESP32's Wi-Fi capabilities to Firebase, a cloud-based platform. This cloud integration allows secure storage and remote accessibility through a mobile application, enabling warehouse managers to monitor conditions and receive alerts for anomalies.

C. IoT Warehouse Monitoring Systems. Aishwarya S Wagh and Dr. Sunil Morade (IJSDR),2021 [2]

This paper outlines the development of an IoT-based warehouse monitoring system aimed at reducing food losses and increasing food safety, particularly in agricultural settings. By utilizing technologies such as ESP32 microcontrollers, sensors for temperature, humidity, and gas detection, and real-time data visualization on a dashboard, the system enables continuous monitoring of warehouse conditions. The integration with mobile applications allows farmers to receive real-time notifications via text or email, enhancing their ability to monitor and control their storage conditions remotely. The system leverages cloud-based solutions, including Amazon AWS, for data storage and processing, ensuring that information is accessible anytime and anywhere. This approach offers a low-cost, efficient solution that improves food security, reduces human intervention, and enhances decision-making for better management of warehouse environments.

D. Remote Monitoring System for Cold Storage Warehouse Using IoT. R. K. Yadav, Soumya Gupta, Mehak Singh, and Arushi Verma (IJRASET), (2020) [10]

This paper aims to design a remote monitoring system for cold storage warehouses using IoT technology. The system monitors critical environmental factors such as temperature, humidity, gas levels, and light intensity to ensure the preservation of stored food items. The integration of sensors like DHT11, MQ3, and LDR with a Raspberry Pi platform enables real-time tracking of these parameters. Alerts are sent via SMS if any readings surpass preset thresholds, ensuring immediate action can be taken to prevent spoilage. The system's automation and remote accessibility, made possible through IoT, significantly enhance food safety by allowing continuous monitoring even when the warehouse operator is not physically present. This work contributes to reducing food wastage and improving cold storage management through a cost-effective, efficient solution.

E. Smart Network Enabled Sensor Device for Field and Warehouse Management. J. Lidwina Jennifer, HR. Illakiah (IRJET), (2020) [7]

This paper is structured around the integration of IoT technology and sensor systems to monitor and manage field and warehouse environments efficiently. The approach relies on a combination of hardware and software to collect and process environmental data. The key hardware components include sensors such as the DHT11 moisture sensor, LM35 temperature sensor, PIR sensor for motion detection, and a smoke sensor for fire detection. These sensors are connected to an Arduino Uno controller, which processes the data and communicates with a mobile application via an ESP8266 Wi-Fi module. The system enables real-time monitoring of parameters such as soil moisture and warehouse temperature.

When abnormal conditions are detected, automated responses, like turning on a pump or activating cooling systems, are triggered through the Blynk app, which serves as a user interface. The methodology is designed to minimize manual intervention by providing automated control over field irrigation, warehouse temperature, and fire or intrusion alerts.

F. Smart Warehouse Monitoring Using IoT. K.Mohanraj, S.Vijayalakshmi, N.Balaji, R.Chithrakkannan, and R.Karthikeyan (IJEAT), (2019) [9]

This paper focuses on the implementation of an IoT-based smart warehouse monitoring system designed to capture and manage environmental changes within a warehouse. The system integrates multiple sensors, such as temperature, humidity, vibration, and fire sensors, which are connected to a Raspberry Pi controller. The Raspberry Pi utilizes IoT technology to communicate real-time data to concerned officials via SMS, enabling timely interventions. The proposed model ensures continuous monitoring by setting thresholds for various environmental parameters, and once these limits are exceeded, alerts are generated. Python is used for programming the Raspberry Pi, making the system cost-effective and scalable. The system's reliance on cloud storage further enhances data accessibility and provides improved monitoring capabilities compared to traditional systems.

G. Real-Time Monitoring in Agricultural Warehouse Using IoT. Shreyas B, Nadeem, Sadhan, and Pramod (IRJET), (2017) [12]

This paper centers around the development of an IoT-based system for real-time monitoring of agricultural warehouses. The system uses a Raspberry Pi as both a microcontroller and server, connected to various sensors that measure environmental parameters like temperature, humidity, light, and smoke levels. These sensors provide continuous data, which is processed and displayed on a web application developed using Python and Flask. The web app allows users to monitor and control warehouse conditions remotely, either via a mobile phone or computer, in real-time. The Raspberry Pi handles sensor data, using an analog-to-digital converter where necessary, and the system is designed for cost-effectiveness and ease of deployment. The sensors trigger alerts when conditions deviate from pre-set thresholds, ensuring timely action to prevent crop spoilage. Additionally, the use of web technologies like HTML, CSS, and JavaScript allows for a user-friendly interface to manage the warehouse environment.

H. Implementation Of an IoT-Based Food Protection in Warehouse. Gopal Krishna B V, Heena Kousar, Shravani V, and Soniya P (IRJET), (2020) [6]

This paper revolves around implementing an IoT-based system to address food preservation challenges in warehouses. The proposed solution integrates technologies such as Raspberry Pi, Wireless Sensor Networks (WSN), and multiple sensors, including PIR, ultrasonic, temperature, and fire sensors, to monitor and protect stored food grains. The system processes sensory data, triggers appropriate responses like activating alarms or capturing images, and sends real-time notifications to users. The modular implementation ensures iterative development and testing for robust operation. The focus on automation, remote monitoring, and data analysis highlights its potential to mitigate issues like rodent attacks, fire, and adverse environmental conditions, thereby enhancing food security with minimal human intervention.

I. Implementation of IoT-Based Smart Warehouse Monitoring System. Sowmya T K, Shreya V Agadi, Saraswathi K G, Puneeth B Nirvani, and Prajwal S (IJERT), (2018) [13]

This paper focuses on developing a cost-effective and efficient IoT-based system for monitoring environmental conditions in warehouses for fruits and vegetables. The system architecture incorporates a PIC16F877A microcontroller, which processes real-time data collected from four sensors (temperature, humidity, light, and gas) and transmits it via a WiFi module to a cloud-based platform, ThingSpeak. The platform enables data visualization and analysis using MATLAB, allowing for timely adjustments to storage conditions. The system flow emphasizes minimal human intervention and real-time data acquisition, providing an optimized and scalable solution for warehouse monitoring. However, the methodology relies heavily on existing sensor capabilities and cloud connectivity, which may require further refinement for broader applications and long-term robustness.

J. A Review of Enabling Technologies and Solutions for IoT-Based Smart Warehouse Monitoring System. Alem Colakovic, Samir Causevic, Amel Kosovac, and Ermin Muharemovic (2020) [3]

This paper outlines the design of an IoT-based system for smart warehouse monitoring, emphasizing the integration of diverse enabling technologies and structured system architecture. It employs sensors for parameters like temperature, humidity, and light, along with components such as NodeMCU and Raspberry Pi, to collect and process data. The system operates through a layered conceptual model involving sensing, aggregation, data filtering, and forwarding to cloud or fog computing layers for analysis and storage. The proposed framework highlights flexibility through modularity, enabling real-time monitoring and control while minimizing risks like temperature fluctuations. The incorporation of cloud and local server options enhances scalability and cost-effectiveness, though the reliance on specific infrastructure suggests room for refinement in adaptability to broader contexts.

K. Design of Monitoring System for Waste Management using IoT. Shreya Chougule, Shrutika Raut (2021) [11]

The paper outlines the design of a Monitoring System for Waste Management using IoT, examines previous research and field studies surrounding the implementation of smart dustbins and IoT-based waste management. It showcases technologies such as Arduino Uno, ultrasonic sensors, GSM modems, and Wi-Fi modules, which are utilized to create smart bins capable of monitoring waste levels and connecting with collection systems. The authors identified key challenges, including bin durability, sustainability of the system, and overall cost-effectiveness. Additionally, to understand human behavior towards inadequate waste disposal, a public survey was conducted. The results revealed that 70% of respondents tend to dispose of waste around bins rather than within them, primarily because the bins are often full or cluttered with unmanaged waste. These insights underpin the development of an intelligent monitoring system aimed at ensuring effective tracking and timely collection of waste. The goal is to tackle pressing urban sanitation issues while promoting cleaner environments in smart cities.

L. RFID Enabled Smart Data Analysis in a Smart Warehouse Monitoring System using IoT. A. Sagaya Selvaraj., S. Anusha. (2021) [1]

The paper focuses on RFID-enabled smart Data Analysis in a Smart Warehouse Monitoring System using IoT proposes an intelligent system for real-time monitoring of machines in industrial warehouses. It integrates RFID technology, sensors, Arduino Uno, a Wi-Fi module, and IoT platforms like ThingSpeak and IO Adafruit to track various parameters such as temperature, vibration, sound, and motion. By using RFID tags and readers, each machine's state is continuously monitored, and any faults are immediately reported through alerts via a buzzer system. The collected data is uploaded to the cloud for analysis and record-keeping, enabling supervisors to detect and address issues proactively. This system enhances safety, efficiency, and accuracy in industrial operations, offering low maintenance, centralized control, and real-time fault detection. The study also suggests future improvements to make the system even more compact and reliable for broader industrial applications.

III.METHODOLOGY

The process of implementing the IoT-based hazard protection system is organized into a single process that involves real-time monitoring, wireless communication, and automatic control systems. The hardware configuration, shown in Fig. 1, revolves around an Arduino UNO microcontroller, which provides the core of the system. Various sensors, such as temperature and humidity module, flame, smoke, and dust sensors, are interfaced with the Arduino to monitor the environmental parameters of the husk storage warehouse. These sensors are capable of sensing critical parameters that may reflect fire hazards, e.g., increasing temperature, the occurrence of flames, smoke, or suspended combustible dust. The Arduino receives the input signals from these sensors and, according to preset thresholds, initiates measure of protection. Upon sensing a hazardous condition, the Arduino switches on output devices, e.g., a buzzer (to alert individuals in proximity), a ventilation fan (to oppose smoke or heat), and a sprinkler or extinguisher system to extinguish fire.

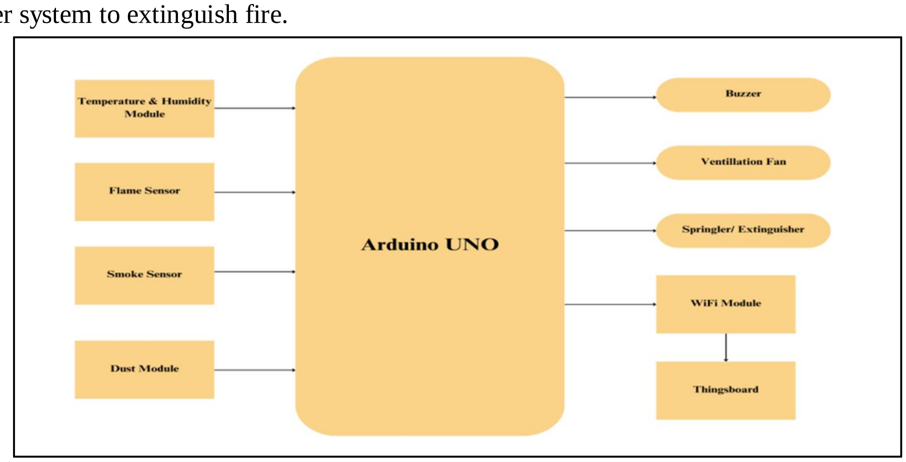

Fig.1 Block Diagram of IoT-based protection system

To enhance remote monitoring capability, a Wi-Fi module (ESP8266) is integrated with the Arduino, enabling real-time data transfer to the ThingsBoard IoT platform. The integration, as shown in Fig. 2, is a three-phase operational workflow: initially, the system gathers data from sensors; secondly, it sends the data to the cloud via Wi-Fi; and lastly, it supports automated control actions and alerts. The workflow ensures continuous data visibility and forms the basis for preventive safety measures, providing alerts and automated responses to specific conditions. Integrated, the system provides a proactive approach to warehouse safety through the combination of embedded electronics with IoT technology for effective risk management and timely intervention in actual threats.

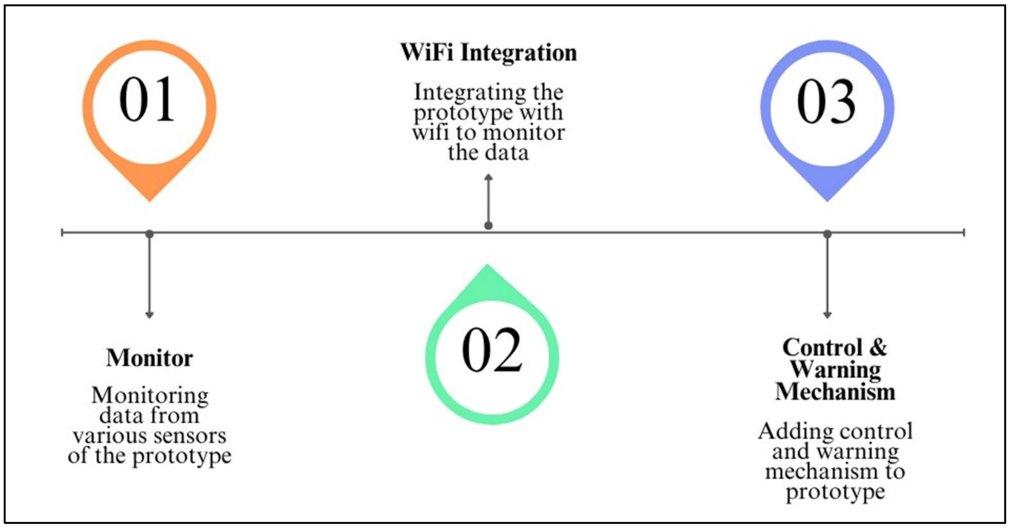

Fig. 2 Operational Workflow of IoT-based protection system

IV. RESULT & DISCUSSION

The setup is shown in the figure.3 represents an IoT-based hazard detection system for husk storage warehouses, featuring smart environmental monitoring and safety, built using an Arduino Uno as the central controller. The circuit integrates several sensors and actuators to simulate dust sensing, fire detection, gas sensing, temperature and humidity monitoring, and automatic response mechanisms. At the bottom of the enclosure, you can see a DHT11 sensor used for measuring temperature and humidity, a dust module for calculating dust particle density, and an MQ-2 gas sensor for detecting smoke or flammable gases, such as LPG. A flame sensor is also present to visually detect fire. It also features an ESP8266 Wi-Fi module for transferring data from the setup to the online dashboard. These sensors feed data to the Arduino, which processes it and triggers responses. For actuation, a DC motor with a propeller (acting as an exhaust fan) is mounted at the top left and controlled using an L298N motor driver module, centrally located on the breadboard. On the opposite side, a servo motor can open a hatch or perform mechanical actions (acts as a sprinkler) during alerts. Additionally, a buzzer module is installed to provide audio alarms. All components are interconnected via jumper wires through a breadboard for organized prototyping. The system is powered through a barrel jack connection, ensuring a sufficient energy supply for motors and sensors. This setup can be used for applications such as a fire safety alert system in storage areas, warehouses, or smart homes.

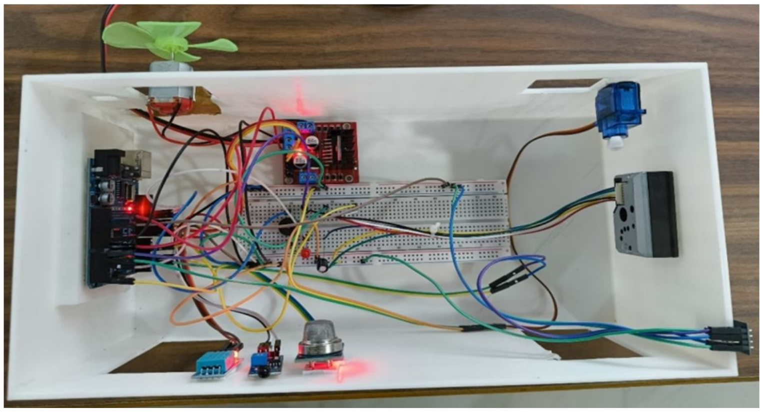

Fig.3 Overall experimental setup

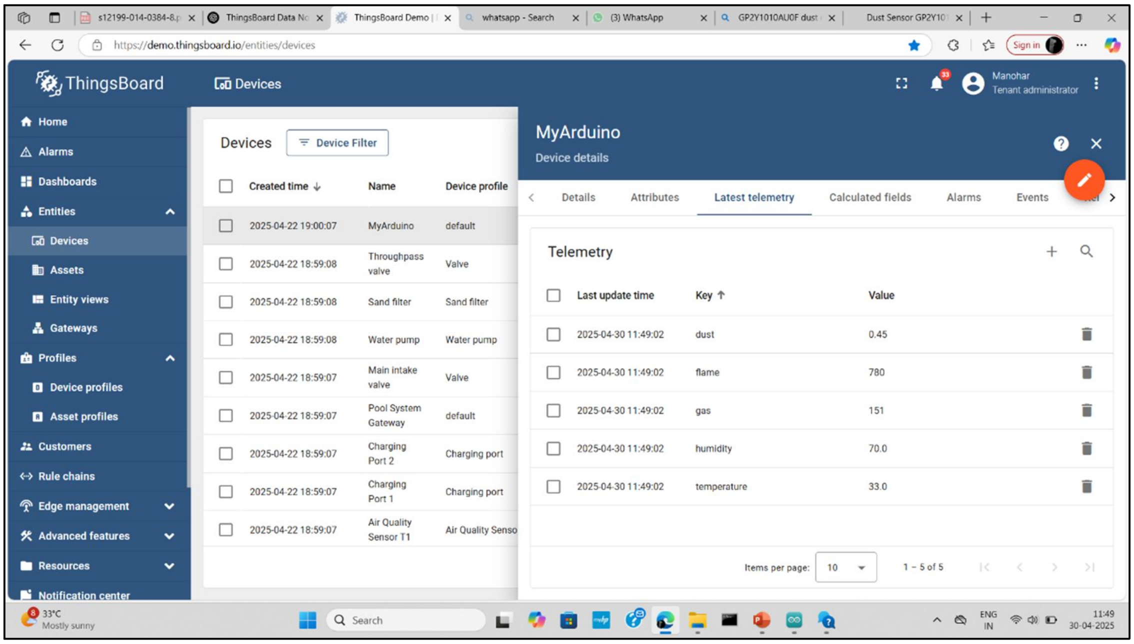

Fig.4 ThingsBoard Data Dashboard Result

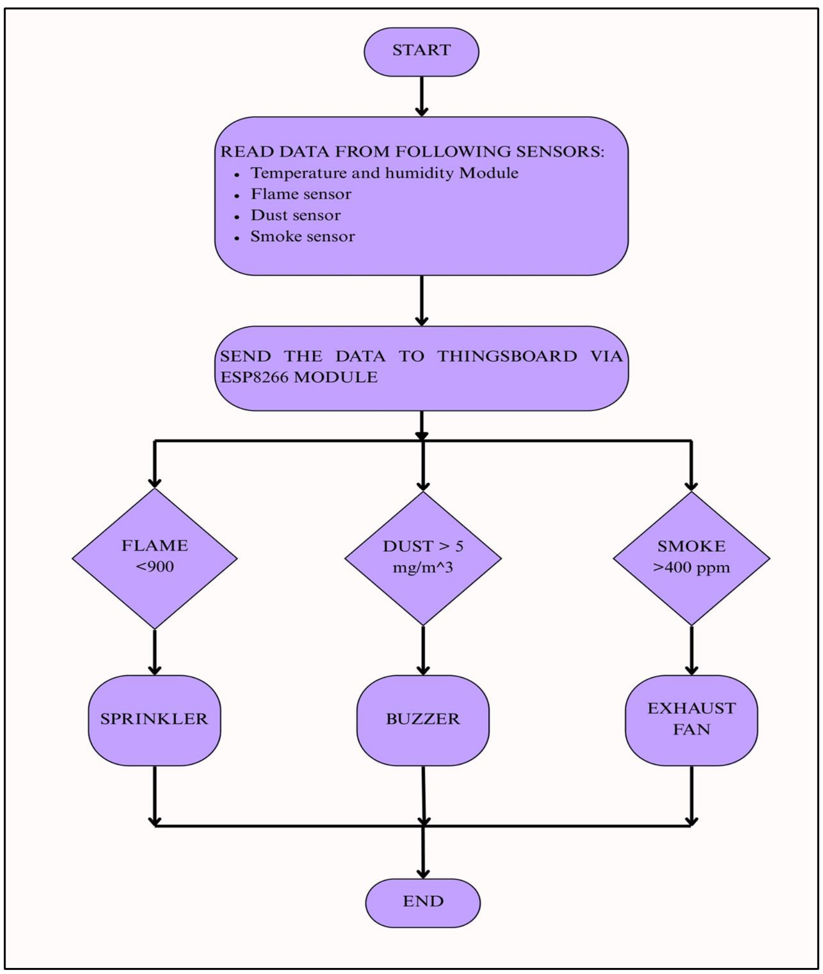

Fig.5 Flow Chart of Work Process

Table. 1 Permissible and Action Triggered Data Level

Parameter	Permissible Level	Action Triggered When
Temperature	20–40°C	> 60°C → Risk of combustion
Humidity	> 60%	> 70% - 80% → Damp Product
Smoke	< 350 PPM	> 400 → Health hazard
Flame	1023(Analog value)	< 900 → Fire hazard
Dust	< 5 mg/m³	> 50 mg/m³ → Health hazard

A. Temperature & Humidity Sensor Data

The temperature and humidity sensor data indicate consistent environmental conditions over the recorded period. The temperature readings are steady at 33.0°C, and the humidity remains constant at 70%. This uniformity suggests that the environment is stable, with no significant fluctuations in either parameter. A temperature of 33.0°C is relatively warm and could indicate a space without active cooling or one exposed to heat sources. The 70% humidity level is considered high, which might contribute to a humid and potentially uncomfortable atmosphere. In environments like storage rooms or husk warehouses, such high humidity levels may also pose risks such as mold growth or moisture-related damage, especially if ventilation is poor. Therefore, monitoring and possibly controlling these conditions is important for safety and material preservation.

B. Flame Sensor Data

The flame sensor data readings of 783, 784, and 780 indicate a high and consistent detection of infrared light or flame-like signals. These values are significantly above the typical baseline, which is usually much lower when no flame is present, suggesting the presence of a flame or a strong heat source within the sensor's detection range. The minimal variation between the three readings also implies that the flame or heat source is steady and not fluctuating. In a fire detection or safety monitoring system, such high readings would likely trigger an alert or alarm, signaling a potential fire hazard. It is crucial to verify these values in the context of the environment to determine whether the flame is intentional (e.g., part of a controlled process) or indicates a sign of danger requiring immediate response.

C. Smoke Sensor Data

The smoke sensor data readings of 160 PPM, 149 PPM, and 151 PPM indicate a consistent detection of smoke particles or gas concentration in the environment. These values suggest a low to moderate presence of smoke or combustible gases, which could potentially stem from light combustion activity, nearby machinery, or early signs of overheating.

While these readings are within a range that is not critically high, they are significant enough to warrant caution, especially in sensitive environments like husk storage warehouses, where the risk of combustion and fire is heightened. Continuous monitoring of these readings is essential. Should the sensor values start to increase, it may signify an emerging hazard that could necessitate interventions such as improved ventilation or activation of alarms to ensure the safety of personnel and stored materials. Proactive measures based on real-time data can help mitigate risks and maintain a safe operational environment.

D. Dust Sensor Data

The dust sensor data indicate a concerning upward trend in particulate concentrations, with measurements recorded at three different points: 0.10 mg/m³, 0.17 mg/m³, and 0.45 mg/m³. Initially, the dust level is relatively low at 0.10 mg/m³, which falls within the safe limits for most indoor environments. However, the final reading of 0.45 mg/m³ approaches levels that could pose health hazards, especially in enclosed or poorly ventilated spaces. In the context of a rice husk storage facility, increasing dust concentrations are particularly alarming. Fine husk particles not only present respiratory risks but also raise concerns regarding combustibility. This data underscores the urgent need for implementing effective dust control measures, such as enhancing ventilation systems or employing air filtration techniques. Such actions are essential to prevent potential safety hazards and to maintain air quality within acceptable exposure limits.

V. CONCLUSION

The IoT-based Hazard Detection system for husk storage warehouses addresses critical challenges associated with safety and operational efficiency in facilities handling highly combustible materials. By leveraging advanced IoT technologies, including sensors for temperature, humidity, smoke, flame, and dust detection, the system ensures real-time environmental monitoring and hazard detection. The integration of automated responses, such as triggering sprinklers and ventilation systems, significantly mitigates risks associated with fire, dust explosions, and gas emissions. This project demonstrates the capability of IoT to revolutionize traditional warehouse management by offering predictive analytics, remote monitoring, and enhanced compliance with safety standards. Despite challenges like connectivity issues in remote areas and initial setup costs, the proposed system provides a scalable, efficient, and sustainable solution. By ensuring the optimal storage of husks, the system not only protects valuable resources but also promotes environmental sustainability and operational resilience.

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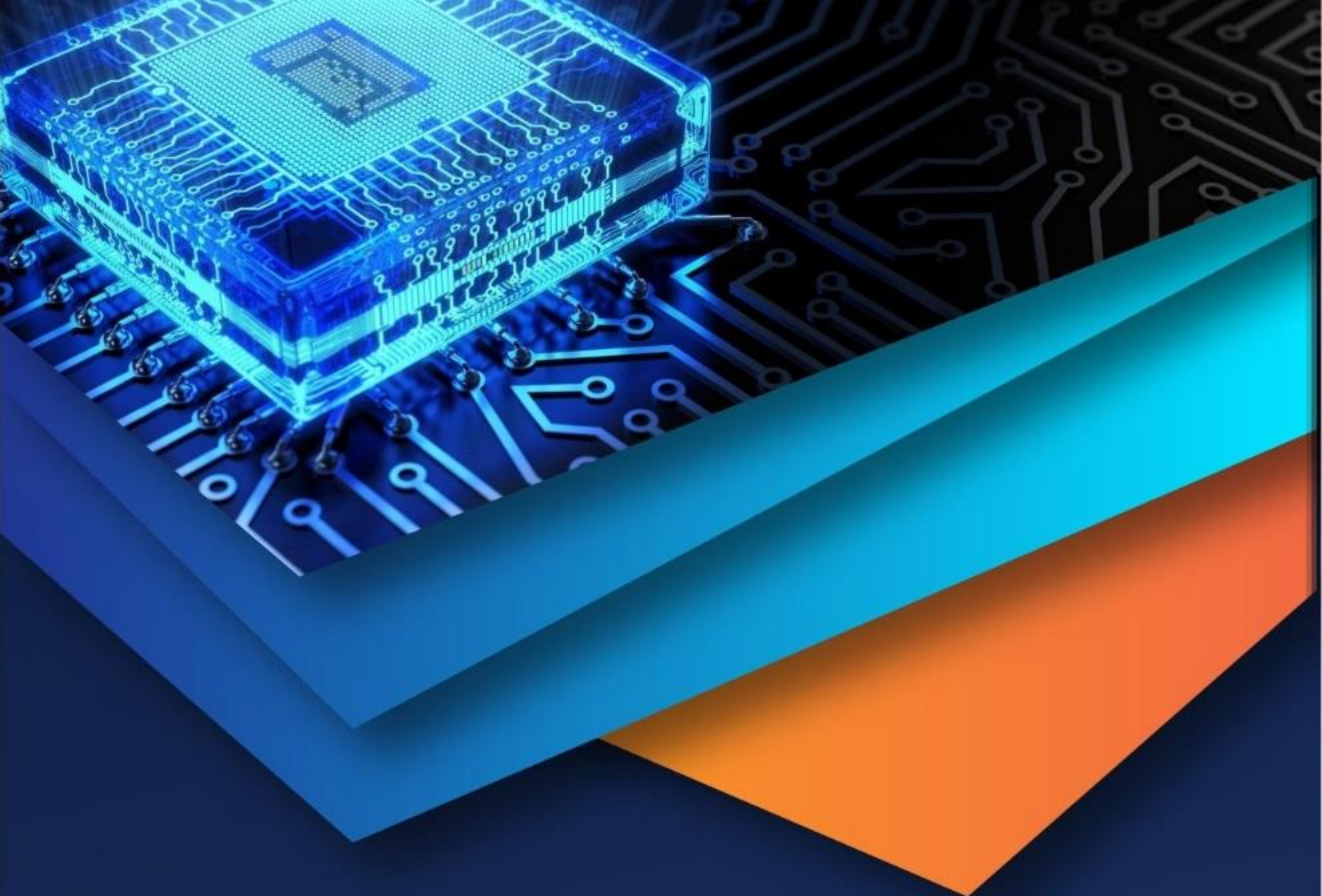

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