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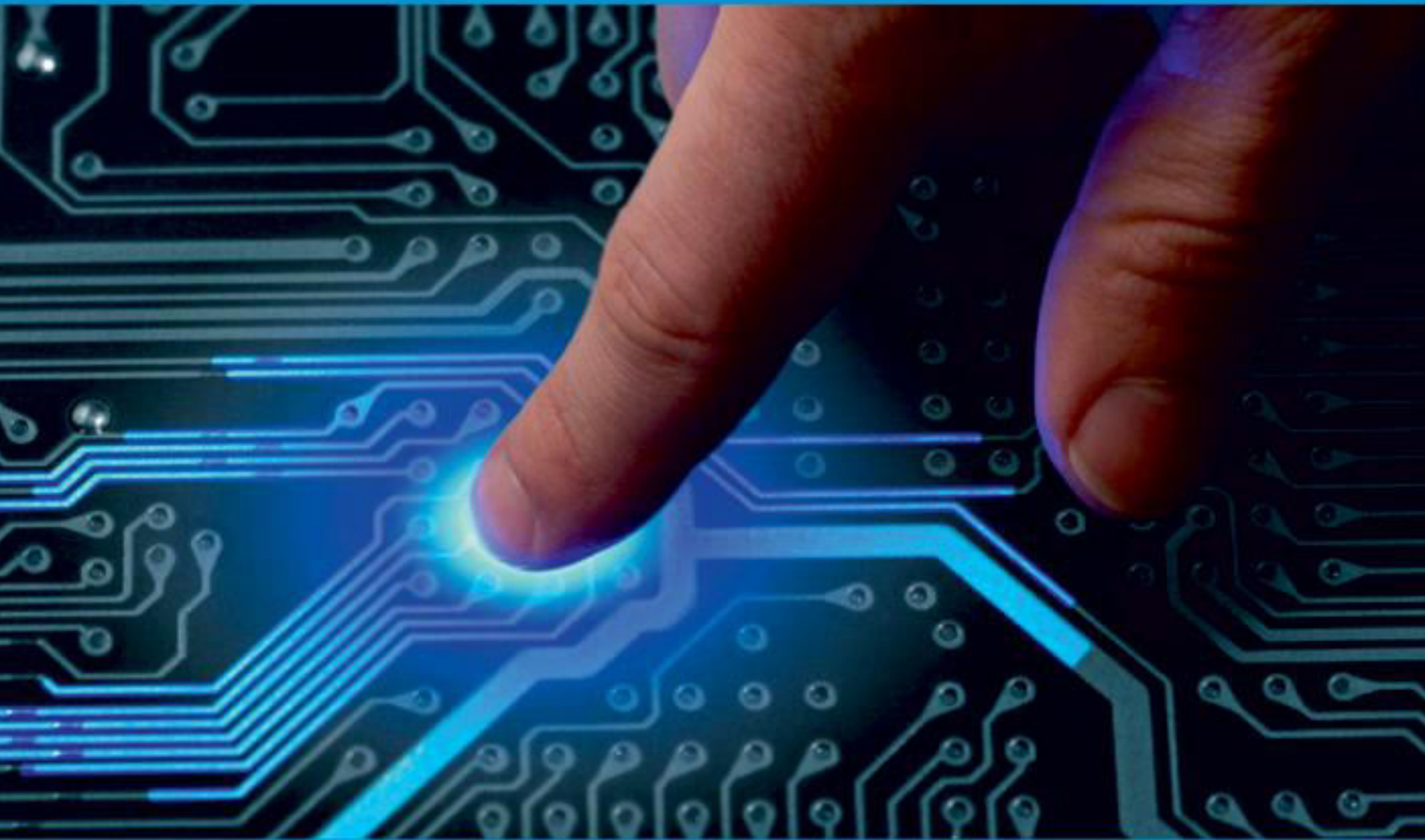

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Design of Intelligent Garment Warehouse Monitoring System Based on Internet of Things

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ABSTRACT: The quality and safety of items kept in warehouses depend a lot on how well they are managed, especially with the world's population growing and the demand for food rising along with it. In this way, it is important to deal with the problems of post-harvest losses, wasted food, and keeping storage conditions at their best. This paper shows how an Internet of Things (IoT)- based smart warehouse tracking system can help with these problems. By using IoT technology, the suggested system allows for real-time tracking and control of warehouse conditions like temperature, humidity, and pest infestation. This minimizes food grain waste and enhances storage efficiency ultimately. The system collects data from various sensors and transmits it to the IoT cloud using ESP32, a set of low-cost, low-power system- on-chip microcontrollers with built-in Wi-Fi and dual- mode Bluetooth, where warehouse owners or managers can access it through a mobile app. The paper talks about the importance of the Internet of Things (IoT) in warehouse management, describes the design of the system, and talks about the possible benefits of using such a system to reduce losses and improve food storage.

KEYWORDS*:* IoT, smart warehouse, monitoring system, post- harvest losses, storage condins

I. INTRODUCTION

The use of IoT in the management of warehouses has become increasingly popular in recent years. IoT-based warehouse monitoring systems have the ability to gather and analyze data in real time, which can help businesses optimize their operations and reduce costs. Recent information from the World Population Data Sheet shows that the world's population is expected to hit 9.9 billion by the year 2050. This is a big jump from the 7.8 billion people who lived on the planet in 2021 [1]. The growing number of people makes it hard to keep up with the rising demand for food. To solve this problem, food output must be doubled, new methods must be used, and grain waste must be kept to a minimum. Grain output and storage are highly significant to the business and social growth of a country.
The Food and Agriculture Organization (FAO) says that each year, a lot of food goes to waste. Cereals lose 30% of their value, while root crops, fruits, and veggies lose between 40% and 50%. Due to food waste and loss, 20 percent of oilseeds, 20 percent of meat, 20 per cent of dairy goods, and 35 percent of fish are lost. [2] At different points, like reaping, threshing, cleaning, packing, and transporting, these losses happen. Even though it might not be possible to stop these losses completely, it is very important to work together to cut them down.

Current warehouse monitoring systems present operational difficulties, such as ineffectual monitoring and administration in real time. These obstacles necessitate the installation of an IoT-based intelligent warehouse monitoring system. Ineffectiveinventory management is one of the primary issues, resulting in inventory discrepancies, stockouts, and overstocking. An Internet of Things solution can automate stock replenishment, provide real-time inventory visibility, and optimize warehouse space utilization. As traditional systems frequently have limitations, inadequate security and safety measures are also a concern. By monitoring key locations, detecting unauthorized entry, and addressing safety risks such as temperature, humidity, and vermin infestations, an IoT-based solution can improve security. Moreover, current warehouse operations are plagued by inefficient resource allocation, which wastes time and effort. Real-time insights into resource utilization are provided by an IoT-based system, enabling predictive maintenance, workflow enhancements, and optimal allocation of labor, apparatus, and vehicles. Existing systems also lack real-time monitoring and analytics, which hinders proactive decision-making. A smart warehouse monitoring system based on the Internet of Things can collect and analyze real-time data from multiple sensors, providing actionable insights and analytics for optimized operations and data-driven decisions. By addressing these concerns, the IoT-based system can significantly enhance operational efficiency, inventory management, security and safety measures, resource allocation, real-time monitoring, and analytical capabilities.

Post-harvest loss is a significant obstacle in the battle against food waste, affecting the economic prosperity of nations across the spectrum of development. Maintenance and storage of grains are essential for assuring food security.

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Nonetheless, warehouses encounter a number of obstacles during storage, such as sustaining optimal temperature and humidity levels and preventing rodent and insect infestations. Seasonal and climatic variations can exacerbate problems by encouraging microbial growth, insect activity, and the development of fungi that produce mycotoxins, thereby diminishing the nutritional value of stored cereals. fortunately technological advances have paved the way for the implementation of in-house remote surveillance systems, allowing for the convenient monitoring of storage conditions from any location. To minimize storage losses, it is essential to monitor temperature, humidity, grain security, bacterial and fungal infections, and insect, avian, and rodent activity. In addition, careful consideration must be given to the amount of cereals being stored. Modern and adaptable storage systems are currently being utilized to reduce grain losses and maintain total grain quantity, thereby contributing to enhanced food preservation efforts. The IoT-based system proposed for the warehouse incorporates several features for efficient data storage and rom the cloud. Real-time monitoring capabilities are achieved by leveraging IoT technology. The ESP32 device plays a crucial role in this system as it collects data from various sensors within the warehouse and transmits it to the IoT cloud utilizing its built-in Wi-Fi module. The collected data is securely stored in the IoT cloud, enabling convenient access for the warehouse owner or manager. Through a dedicated mobile application, the warehouse owner can directly monitor atmospheric conditions and promptly detect any signs of rodent or insect activities occurring within the warehouse. This real-time monitoring capability enhances the overall awareness and control of warehouse

II. LITERATURE REVIEW

The Internet of Things (IoT)-based warehouse monitoring systems have grown in popularity in recent years. These systems offer a variety of features designed to enhance effi- ciency and performance. They contain sensors that collect and analyze data in real time. This survey will investigate recent research work on IoT-based warehouse system advancements and innovations.

Z. Hao, Lin Zhao [3] proposed the design and imple- mentation of an Internet of Things (IoT)-based warehouse monitoring system. System components include an STM32 microcontroller, temperature and humidity sensor, Wi-Fi mod- ule, RFID skimmer, alarm circuit, OLED display, and Aliyun platform integration. Utilizing the sensor and an RFID skim- mer to trace the movement of objects, the authors demonstrate that the system effectively captures and monitors temperature data. This data is then transmitted to the Aliyun platform for additional analysis and management. Susmita Banerjee, A. Saini, Himanshu Nigam [4] proposed an initiative concentrating on monitoring warehouse param- eters that have a substantial effect on stored grains, such as temperature, humidity, CO levels, motion, vibration, and smoke. An ESP32 WiFi module collects information from various sensors to facilitate data collection. The collated data is then transmitted via a MQTT broker to a Node-red dashboard. Multiple IoT modules are strategically located throughout the warehouse to ensure complete coverage. These nodes perpetually collect environmental data and provide producers with real-time updates. Farmers receive alerts via Mobile SMS and Email, allowing them to remain abreast of the current warehouse conditions. This system enables producers to actively monitor and react to changes in the warehouse environment, thereby preserving the quality and condition of their stored cereals.

Wen-Tsai Sung, Chengsan Lu [5] proposed The Internet of Things (IoT) is utilized as the basis for the development of a smart storage system in this study. Arduino and LORA are the primary components of the remote transmitter and receiver, respectively. The system employs RFID devices attached to warehouse products to provide users with detailed information and location data regarding the goods. The system includes temperature sensors, humidity sensors, gas sensors, and in- frared sensors to ensure the safety of the products. These sensors actively monitor the warehouse's interior conditions, enabling real-time surveillance and detection of any potential problems.By incorporating Internet of Things (IoT) technolo- gies and a variety of sensors, this intelligent storage system provides users with enhanced visibility and control over their warehouse inventory. It improves warehouse safety measures and facilitates effective warehouse management.

K. Ananthi, R. Rajavel, S. Sabarikannan, A. Srisaran and C. Sridhar's [6] proposed paper presents a solution for the challenging task of locating products in large warehouses. It introduces an Internet of Things (IoT)-based inventory control system that provides real-time information on prod- uct locations and maintains accurate inventory details. By utilizing an IoT platform, extensive product data is stored for efficient monitoring and management. RFID card infor- mation is wirelessly transmitted to the receiver module via the internet. The central controller, Raspberry Pi, handles data administration tasks. The paper highlights the system's dynamic nature and cost-effectiveness. Overall, the developed system offers a practical and effective solution for product localization in large warehouses using IoT technologies and wireless communication.

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From all the above related works, we gathered RFID access to the system and IoT based approach for monitoring of the warehouse. We have incorporated ESP32 WiFi module to facilitate the data collection. These works however did not focus on detection of surrounding objects. For this, we have used ESP32CAM and pre-trained ML models to notify incase rats are detected inside a warehouse at any point.

III. METHODOLOGY

The primary goals of the proposed system are:-
I. To use the Internet of Things (IOT) to set up an automatic system to reduce the amount of food grain that goes to waste due to different weather conditions and rodent activity inside the building.

I. TO DEVELOP A MOBILE APPLICATION FOR REMOTE MONITORING AND VISUALIZATION

The proThe proposed system is intended to function as a Wireless Sensor Network (WSN)-based communication mechanism. [7] The Fig 1 demonstrates the proposed IoT-based monitoring system
The monitoring and control capabilities of the IoT-based warehouse monitoring system are provided by multiple components. A load cell is utilized to precisely measure the weight of each quantity transferred into the warehouse, thereby ensuring accurate inventory tracking. The system uses RFID technology to manage access, allowing the warehouse propri- etor and authorized users to interact securely with the system and mobile application.A DHT11 sensor continually updates the temperature and humidity readings to monitor the ware- house's environmental conditions. This information is vital for ensuring optimal storage conditions for various products. In addition, a gas sensor (MQ2) is incorporated into the system to detect smoke and fire, thereby e

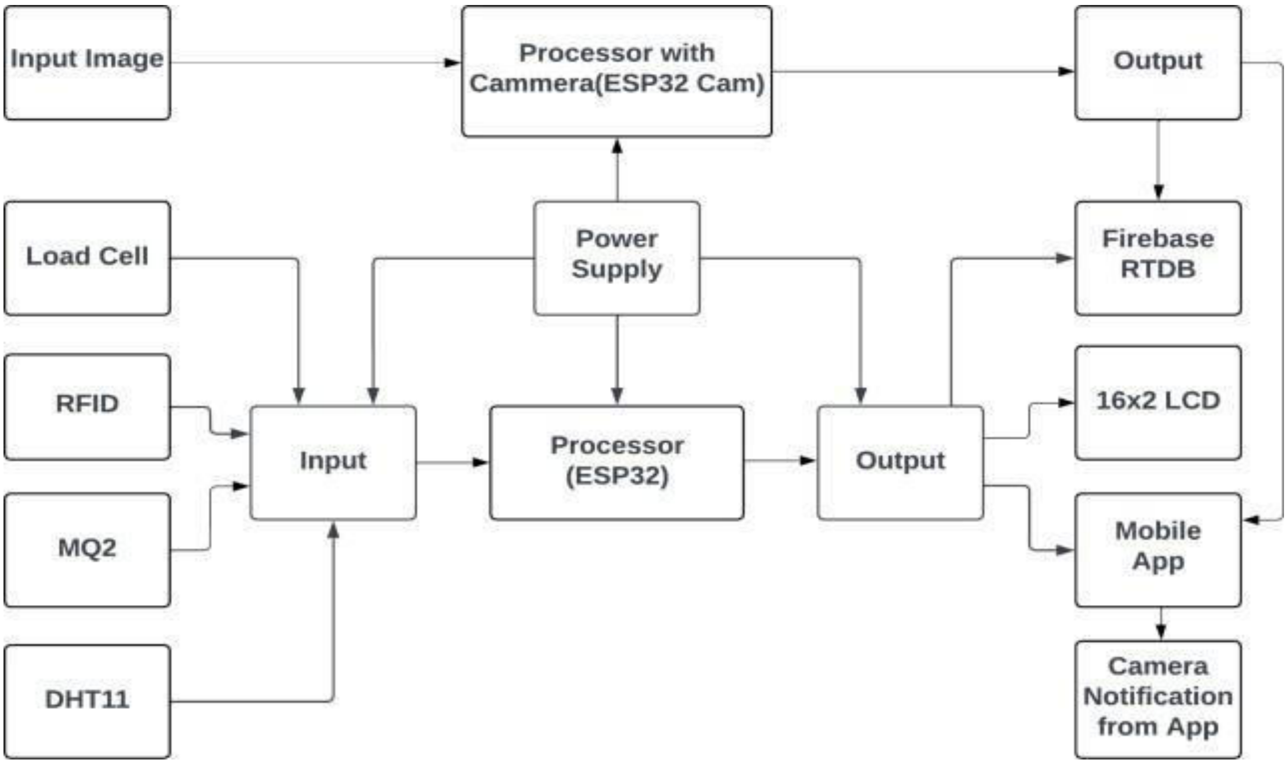

Fig.1 IOT Based Smart Warehouse Monitoring System

and allowing for prompt detection and response. The ESP32 functions as the system's primary processor, receiving input from all sensors and devices. It consolidates the data and sends it to Firebase, a cloud-based platform connected to a mobile application. The mobile application provides remote access to the system, enabling the warehouse proprietor to monitor real-time data, receive alerts, and take appropriate action from anywhere. A system-integrated LCD display presents changes in parameters and their corresponding values for warehouse personnel's on-site visibility and fast reference. In addition, an ESP 32 CAM module is used for video surveillance of the warehouse. The

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system is designed to detect the presence of rats, activating an alert in the mobile application and alerting the proprietor to take immediate action. The IoT- based warehouse monitoring system ensures accurate weight measurement, secure access control, continuous monitoring of temperature and humidity, early detection of smoke and fire, efficient data processing and storage in the cloud, remote accessibility via a mobile application, active area monitoring, and timely alerts for effective warehouse management and security.

This project aims to develop a warehouse monitoring system with various parameter sensors. The system allows the owner to access the system using login credentials and provides access to warehouse management information through a mo- bile application. The monitoring dashboard displays infor- mation such as load weight, gas concentration, temperature, humidity, and allows RFID access. Additionally, the system continuously monitors the warehouse area for unauthorized presence, promptly detecting intruders like rats and sending notifications to the owner. Overall, the system enables real- time data monitoring and effective warehouse management.

IV. DETAILED HARDWARE DESCRIPTION

The numerous hardware components utilized in the creation of the proposed IoT system are described in depth.

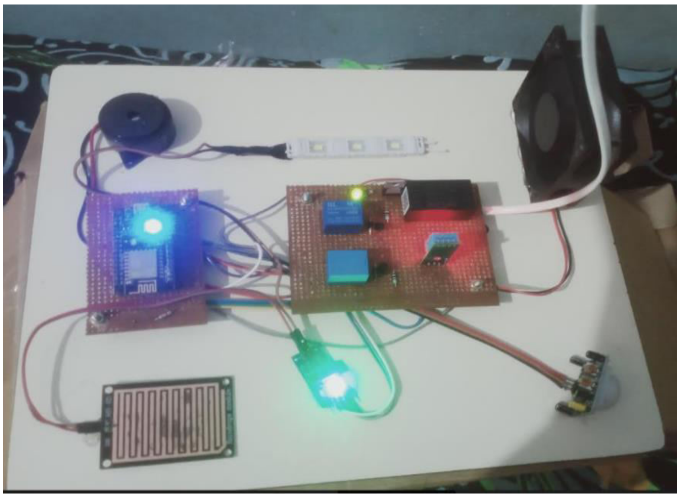

Fig. 2. **Proposed system**

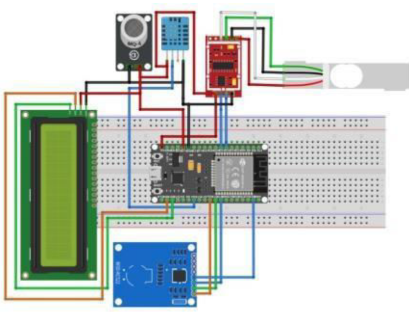

Fig. 3. **Simulation Diagram of Proposed System**

A. ESP 32

The ESP32 [8] microcontroller is a powerful and versatile hardware component for IoT-based warehouse monitoring sys- tems. It offers a dual-core processor for efficient multitasking and handling complex tasks. With built-in Wi-Fi and Blue- tooth capabilities, it enables seamless wireless connectivity for remote monitoring and data transmission. The

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availability of GPIO pins allows for easy integration with various sensors and devices, facilitating monitoring of warehouse conditions such as temperature, humidity, and gas levels. The ESP32 also supports analog sensor readings through its ADC, and SD card support provides local data storage options. The microcon- troller's multiple serial communication interfaces enhance its connectivity with other devices. With its onboard memory and flexible power supply options, the ESP32 is an excellent choice for building scalable and customizable warehouse monitoring systems.

B. ESP cam Module

The ESP-CAM module is a versatile hardware module designed for detection purposes. It is based on the ESP32 microcontroller, which offers built-in Wi-Fi, Bluetooth, and ample memory. The module features a camera sensor for image and video capture, with resolutions ranging from VGA to 2 megapixels. It provides GPIO pins for flexible interfacing with external devices and components. The module requires a power supply voltage of 5V to 12V and supports serial communication interfaces like UART and I2C. Some variants include an onboard SD card slot for local storage. The module offers convenient mounting options for easy integration into projects. Overall, the ESP-CAM module combines the power of the ESP32 microcontroller, camera sensor, GPIO pins, and serial communication, making it a comprehensive solution for detection applications. In our project, we have used it to detect various objects that might be seen in a warehouse. If the CAM detects a rat, a notification is sent to the owner on the app. For this detection, we use pre-trained yolo and coco models.

C. DHT11 sensor

The DHT11 sensor is a popular and inexpensive relative humidity sensor that measures both temperature and humidity [9]. It may be simply interfaced with an Arduino board to offer real-time humidity and temperature monitoring. The sensor provides a temperature range of from 0 to 50 degrees Celsius with a precision of 2 degrees and a moisture range of 20 to 80 percent with a precision of 5 percent. One reading is taken per second at a sampling rate of 1 Hz.
The DHT11 sensor is implemented in the suggested system to properly monitor temperature and humidity levels. The sensor's threshold values may be changed to meet the indi- vidual needs of the various types of food grains kept in the warehouse. This enables exact monitoring and management of storage conditions, ensuring the quality and safety of the stored commodities.

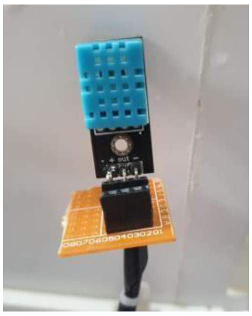

Fig. 4. **DHT11 sensor in the model**

D. Load cell

A 10Kg load cell is a transducer designed for measuring weight or force. It comprises the strain gauges arranged as a Wheatstone bridge.Strain sensors undergo deformation when a force is applied, resulting in a change in resistance and an output signal proportional to the applied force. The load cell requires an excitation voltage and produces a millivolt-level output signal. It offers sensitivity and accuracy in measuring weight or force and is mechanically mounted for easy integra- tion into weighing systems. The load cell may have overload protection and environmental protection features. Overall, the 10Kg load cell is a reliable and versatile component used in various industrial and commercial weighing applications. In our proposed system, the load cell is used to note every new entry of weight into the warehouse. This helps in keeping track of how much quantity of product is available inside the warehouse.

E. RFID sensor

The RC522 [10] RFID sensor is a compact module designed for RFID applications. It includes an RFID reader operating at

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13.56 MHz and an integrated antenna for RF signal transmis- sion and reception. The module supports communication via SPI interface and requires a power supply voltage of 2.5V to
3.3V. It offers GPIO pins for external device connectivity and control registers for customizing its behavior. Some modules may feature LED indicators and a reset pin. The RC522 RFID sensor is commonly used in access control systems, attendance systems, inventory management, and asset tracking due to its compact size, ease of integration, and reliable performance. In our system, the access to the system and the updated information of the warehouse environment is given by RFID. Unless the correct RFID is used to access the system, there will be no changes in the parameters. This ensures no unauthorized personnel can make changes to the system thereby avoiding any humanized error.

F. FTDI

The FTDI FT232 is a USB-to-serial converter chip widely used for establishing communication between computers and external devices. It features a USB interface compliant with USB standards, allowing easy connection to a computer or USB host device. The chip provides a serial interface, typ- ically UART, enabling bidirectional communication with the external device. It includes GPIO pins for additional digital I/O functionality and an integrated oscillator for generating clock signals. The FT232 also incorporates an EEPROM for storing configuration data. It operates with a power supply voltage ranging from 3.3V to 5V and is supported by FTDI's drivers for seamless integration with various operating systems. With its package options, the FT232 offers flexibility in PCB inte- gration. Overall, the FTDI FT232 chip is a reliable solution for USB-to-serial communication in applications such as micro- controller programming and embedded system configuration. In our proposed system, FTDI is used to supply voltage as well as to input code into the ESP32 CAM module.

MQ2 gas sensor for fire detection system

The MQ2 gas sensor [11] is a commonly used component in fire detection systems to detect flammable gasses such as LPG, butane, and propane etc. It utilizes a tin dioxide semiconductor as its sensitive material and includes an integrated heater to maintain a stable operating temperature. The sensor measures changes in electrical conductivity when exposed to flammable gasses. It provides an analog output voltage proportional to the gas concentration detected. The MQ2 gas sensor operates at a specific voltage, requires a warm-up time for stabilization, and can be calibrated for sensitivity adjustment. Proper mounting and consideration of environmental factors are important for accurate gas detection. Overall, the MQ2 gas sensor is a reliable and cost-effective solution for fire detection applica- tions, helping to identify potential fire hazards and activate appropriate safety measures.

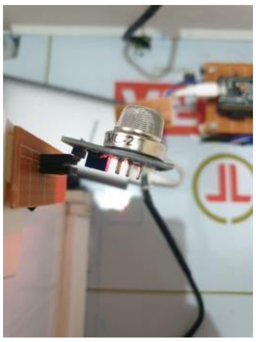

Fig. 5. **MQ2 sensor in model**

G. 16x2 LCD display

The 16x2 LCD display is a compact alphanumeric display module consisting of 16 columns and 2 rows of characters. It is controlled by a dedicated controller chip and features a backlight for improved visibility. The display module has connection pins for easy integration with microcontrollers and other devices. It allows for contrast adjustment and supports standard controller commands for controlling display behavior. With its parallel interface and compact size, the 16x2 LCD display is widely used for displaying textual information in various electronic projects. In our system, the on-site param- eters are displayed using the LCD display. As each parameter sensor acquires change in surrounding data, it is displayed beside the system for the operator.

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Fig. 6. **Output displayed on LCD**

H. EXPERIMENTAL SETUP AND RESULT DISCUSSION

In this system, ESP32 is the microcontroller which acts as a sensor node. All the parameters are monitored using sensors and the information is displayed in the mobile application as well as on LCD present in the model. We measure parameters like temperature, humidity, smoke, total weight of the incom- ing product. RFID access is the entry point to the system. Similarly, the mobile application can be accessed with correct credentials.

Another part of the system is Rat Detection. Here the process is carried out by ESP32CAM. We use a pre-trained ML model to detect rats. If a rat is detected, a notification is sent by the app and the user can click the notification to send message to person on-site.

Performance parameter	Value
Accuracy	62.5%
Loss	0.80
Inferencing time	328ms

Fig. 7.

Rat detection performance parameters

Fig. 8. **Mobile App Login for owner**

V. CONCLUSION AND FUTURE ENHANCEMENT

Thus, the IoT-based warehouse monitoring system that we have proposed has the potential to improve the efficiency and effectiveness of warehouse management. This system provides real-time data of products inside the warehouse system and also monitors the environment parameters of the warehouse such as temperature, humidity and gas concentration. It also has RFID based access control to ensure authorized approach to the system. We have also incorporated detection of rats in the warehouse using ESP 32 CAM module. However, there is scope of further development of the technical and logical aspects of the system not only for warehouses but also for further steps of Supply Chain Management. The existing system is based on monitoring aspects, it can further

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