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An IoT-based Real-time Intelligent Monitoring and Notification System of Cold Storage

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Abstract**:** Cold storage facilities play a critical role in preserving perishable goods, such as food and pharmaceuticals. However, ensuring optimal storage conditions, such as maintaining precise temperatures and humidity levels, is essential to prevent spoilage and maintain product quality. Traditional monitoring systems often lack real-time capabilities and intelligent decision-making, leading to inefficiencies and potential losses.In response to these challenges, this paper proposes an innovative IoT-based real-time intelligent monitoring and notification system for cold storage facilities. The system integrates various IoT sensors to continuously collect data on temperature, humidity, and other relevant parameters within the storage environment. These sensors transmit data to a central hub, where it is processed and analyzed using advanced algorithms and machine learning techniques.The intelligent system is capable of monitoring the storage conditions in real-time, identifying deviations from optimal parameters, and generating timely notifications/alerts to relevant stakeholders, such as facility managers or maintenance personnel. Moreover, the system employs predictive analytics to anticipate potential issues and recommend proactive measures to mitigate risks, thereby minimizing product losses and ensuring regulatory compliance.

Keywords: Temperature,Humidity,Light Intensity,Sensors,Random Forest.

I.INTRODUCTION

The current landscape of cold storage facilities faces several challenges in effectively monitoring and maintaining the quality of perishable commodities. Traditional approaches to monitoring environmental parameters in cold storage have been limited, typically focusing on temperature and humidity while neglecting other crucial factors such as CO2 concentration, light intensity, and gas levels. This oversight can lead to significant losses of perishable goods due to inadequate monitoring and lack of timely interventions. As a result, there is a pressing need for innovative solutions that can address these shortcomings and enhance the efficiency and effectiveness of cold storage operations.

Implementation of IoT technology in cold storage facilities have shown promise in revolutionizing the monitoring and management of environmental parameters. By leveraging IoT sensors and connectivity, real-time data collection and analysis become feasible, enabling proactive decision-making and interventions to maintain optimal storage conditions. However, existing IoT solutions in cold storage have often been limited in scope, focusing primarily on temperature monitoring and lacking comprehensive monitoring of all critical environmental parameters. This limitation underscores the necessity for a more holistic and intelligent monitoring system that can provide real-time insights into multiple environmental factors affecting the quality and shelf-life of perishable commodities.

The requirement for an advanced real-time monitoring and notification system in cold storage facilities is underscored by the critical impact of environmental parameters on the quality and safety of stored goods. Fluctuations in temperature, humidity, CO2 levels, and light intensity can accelerate the spoilage and deterioration of perishable commodities, leading to significant financial losses and food waste. Timely detection of unfavorable conditions and proactive interventions are essential to mitigate these risks and ensure the preservation of product quality throughout the storage period.

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Therefore, a comprehensive and intelligent monitoring system that can track and analyze all relevant environmental parameters in real-time is essential to address the challenges faced by cold storage facilities and optimize the storage conditions for perishable goods.

By developing an IoT-based real-time intelligent monitoring and notification system for cold storage, the project aims to bridge the existing gaps in monitoring capabilities and provide a proactive solution for enhancing the quality and shelf-life of
perishable commodities. The integration of advanced sensors, data analytics, and notification mechanisms in the proposed system will enable personnel to monitor environmental parameters remotely, receive alerts on critical conditions, and make informed decisions to prevent spoilage and minimize losses. This proactive approach to cold storage management aligns with the growing demand for efficient and sustainable practices in the food supply chain industry, emphasizing the importance of leveraging technology to optimize storage operations and reduce food waste.

II.LITERATURE SURVEY

Monteleone et al. [1] In this paper a conceptual model for a temperature monitoring system in the medicine Cold Chain is proposed to address temperature continuity issues and improve product quality and patient safety. The model comprises three components: identification, thermal packaging, and a sensor network. Variables affecting adoption include risk factors (temperature perturbations, weaknesses, disruption time) and complexity factors (chain density, node criticality, number of actors). Benefits extend beyond medicine to vaccine Cold Chain and temperature-controlled logistics in laboratory medicine, offering improved responsiveness, real-time monitoring, and better decision-making. The paper emphasizes the need for measures to enhance Cold Chain responsiveness, including risk mitigation, standardized monitoring tools, and stakeholder collaboration. Future work involves validating the model through studies.

Nagpal et al. [2] In this paper a design and development approach for a sensor node for cold storage systems in India is presented. This addresses the lack of proper cold storage facilities hindering fruit and vegetable production. The sensor node, integrated into a wireless sensor network, monitors temperature, humidity, toxic gases, and light intensity to improve the quality and longevity of stored commodities. The paper highlights the use of wireless sensor networks and presents the design, implementation, and experimental results, validating its stability, reliability, cost-effectiveness, and suitability for real-world cold storage systems deployment.

B.K et al. [3] This paper outlines the design and implementation of an automotive cold storage unit for potato crops utilizing GSM technology. The objective is to monitor and control the environmental conditions within the storage unit. The prototype continuously monitors temperature, humidity, light intensity, and detects rotting potatoes, sending SMS notifications to the owner if any parameters exceed the threshold. The system demonstrates a low error rate, offering an efficient method for preserving potatoes. Future enhancements include delay circuits, robotic arm integration, and a counter circuit for optimized potato management.

Sarmah et al. [4] This paper discusses a low-cost cold storage management system based on the Internet of Things (IoT) to tackle the challenges of tracking food quantity and quality. The proposed model stands out by focusing on both parameters and utilizing IoT devices, cloud services, and an Android application. It incorporates UV and gas sensors to measure food occupancy and detect deteriorating food. The experiment successfully demonstrated accurate detection and instant notifications, offering real-time updates and cost-effectiveness.

Lim et al. [5] This paper proposes a remote monitoring system for cold storage, ensuring optimal temperature for farm produce freshness. It features a temperature controller, freezing unit, data collector, and remote communication device. Temperature is monitored and adjusted automatically, with data transfer to a main server. Remote monitoring is enabled, improving efficiency, reducing costs, and simplifying cold storage management.

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Hussain et al. [6] In this paper a low-cost milk quality monitoring system using an ARM processor is proposed. It detects spoilage in raw milk by measuring VOC concentration changes in the headspace, indicating bacterial activity. Utilizing TGS gas sensors, the LPC 2148 processor, and Zigbee networks, the system offers real-time monitoring and early detection of spoilage, ensuring milk quality and consumer safety.

Sousa et al. [7] This paper introduces a novel monitoring system for cold storage facilities, employing microcontrollers and dedicated circuits. It tracks temperature and humidity, ensuring optimal storage conditions for perishable goods like food, medicines, and biological samples. The system boasts three independent modules: a central unit for user interaction, an electricity meter, and an internal sensor module. The intuitive graphical user interface facilitates data visualization, alarm management, and system configuration. Exported data enables further analysis using tools like Excel or MATLAB. The system's affordability and modularity make it a versatile and readily implementable solution for cold storage management.

Xu et al. [8] This paper delves into the automotive industry, exploring market trends, consumer behavior, and technological advancements. It focuses heavily on electric and hybrid vehicles, highlighting their benefits and challenges. Furthermore, it examines autonomous driving, safety regulations, and the environmental impact of the industry. Statistical data and graphs support the presented information, offering a comprehensive overview of the current automotive landscape.

Zhang et al. [9] This research paper presents a simulating-human intelligent control method for fruit and vegetable cold storage. The system utilizes an embedded microprocessor to gather data and control the storage environment's parameters, impacting food storage quality and energy conservation. By focusing on temperature and humidity, the system can extend the shelf-life of fruits and vegetables while reducing energy consumption. The system uses specific algorithms and is supported by the Linux operating system and a high-speed processor. In a small-scale refrigerator control system, the system achieved a temperature control precision of ±0.2°C & humidity control precision of ±0.5%.

Toranzo et al. [10] This paper explores the potential of technology in monitoring and controlling temperature for perishable goods throughout the cold chain. It identifies trends in RFID, WSN, IoT, and cloud computing, highlighting their use primarily during transport. The paper emphasizes the need for constant control across all stages and suggests distributed predictive control as a solution. Future work involves integrating these technologies with predictive models to optimize temperature and humidity. Temperature estimation methods, thermal imaging, and ANNs are also promising for real-time data. Challenges remain, but the strategic combination of RFID, WSN, and IoT offers significant business value.This research provides valuable insights into how technology can enhance cold chain processes and ensure product quality and safety.

III. SCOPE AND METHODOLOGY

Aim of the project

The aim of this project is to develop a sophisticated IoT-based system for real-time monitoring and management of environmental conditions in cold storage facilities, focusing on preserving perishable fruits and vegetables. By integrating sensors, wireless communication technology, predictive algorithms like Random Forest and Artificial Neural Networks, as well as an Android application, the system aims to continuously monitor key environmental parameters such as temperature, humidity, light intensity, and CO2 concentration. Through seamless data communication and analysis, the system predicts the status of stored produce and alerts personnel of any unsatisfactory or alarming conditions, enabling timely intervention to prevent spoilage. The Android app provides remote access to monitoring and decision support tools, empowering personnel to make informed decisions and ensure optimal storage conditions, ultimately minimizing losses and maximizing the quality and shelf life of perishable commodities.

Scope of the Project

The scope of this project encompasses the development and implementation of an advanced IoT-based system tailored

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for monitoring and managing environmental conditions within cold storage facilities, with a primary focus on preserving perishable fruits and vegetables. By leveraging a combination of sensors, wireless communication technology, predictive algorithms like Random Forest , and an Android application, the system aims to provide real-time monitoring, predictive analytics, and decision support capabilities. Key functionalities include continuous monitoring of ambient temperature, humidity, light intensity, and CO2 concentration, predictive classification of produce status, automatic notification of unsatisfactory or alarming conditions, and remote access to monitoring and decision-making tools via the Android app. The seamless integration and communication among the various modules ensure the efficient and effective operation of the system, ultimately reducing spoilage and maximizing the quality and shelf life of stored commodities.

Methodology

The solution automatically monitors real-time environmental parameters such as ambient temperature, relative humidity, light intensity, and concentration of CO2.These real-time values are stored on a Firebase database for easy access and analysis. An Random forest algorithm is applied to predict the status of perishable FVs, classifying them into three categories: good, unsatisfactory, or alarming. Automatic notifications are sent to personnel when the system detects unsatisfactory or alarming conditions to prompt timely action. An Android app is developed to monitor real-time environmental parameters from anywhere, offering decision support by predicting the status of commodities based on the gathered real-time data. The proposed system consists of several modules: sensing module, wireless communication technology, status prediction module, and Android App module. These modules communicate with each other using wireless technologies, ensuring the seamless operation of the real-time IoT monitoring system for cold storage. The sensing module includes sensors, a microcontroller, a power supply PCB, and a breadboard to measure environmental parameters such as temperature, relative humidity, light intensity, and CO2 concentration. The real-time environmental data collected by the sensing module is stored in a database , and this data is exported as a JSON file for further processing by the status prediction module. The status prediction module generates a file that is imported into the Android app, which performs inference to predict the status of the commodities. The Android app allows personnel to perform real-time monitoring of environmental parameters in the cold storage and check the predicted status of commodities as determined by the decision model. Automatic notifications are sent to personnel when dangerous limits of environmental parameters are detected, enabling timely intervention to mitigate the loss of perishable fruits and vegetables in cold storage. Additionally, the Android app provides graphical representations of the measured environmental parameters for monitoring purposes.

System Architecture

The system architecture of the proposed project comprises several interconnected modules to enable seamless real-time monitoring and management of environmental conditions in cold storage facilities. The sensing module includes sensors, a microcontroller, and associated hardware to measure ambient temperature, relative humidity, light intensity, and CO2 concentration. These measurements are transmitted wirelessly to the status prediction module, where a Random Forest algorithm is employed to classify perishable fruits and vegetables into categories of good, unsatisfactory, or alarming based on the collected data. Automatic notifications are triggered if unsatisfactory or alarming conditions are detected, prompting timely action. The real-time environmental data is stored in a database for easy access and analysis. An Android app provides personnel with remote access to monitor environmental parameters and check the predicted status of commodities, facilitating informed decision-making. This architecture ensures efficient communication and operation of the IoT monitoring system, enhancing the preservation and quality control of perishable produce in cold storage.

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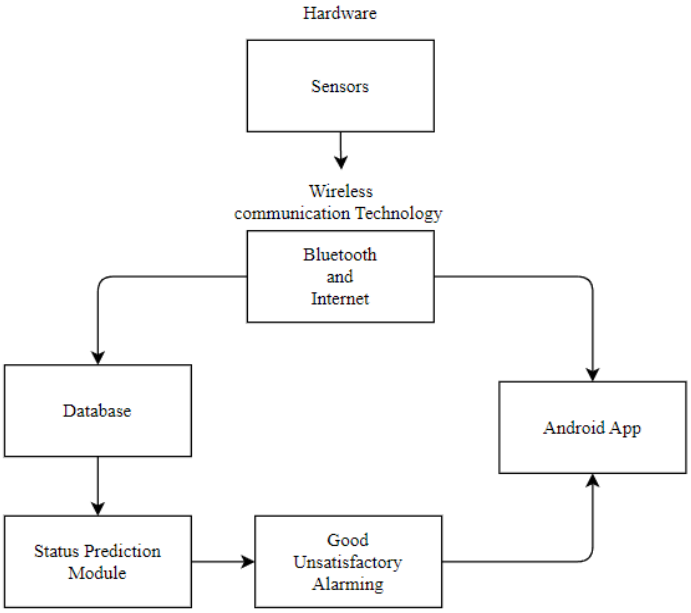

Fig 1. System Architecture

IV.CONCLUSION

The implementation of this advanced IoT-based system for monitoring and managing environmental conditions in cold storage facilities represents a significant step towards optimizing the preservation of perishable fruits and vegetables. By seamlessly integrating sensor technology, predictive algorithms, wireless communication, and a user-friendly Android application, the system offers real-time monitoring, predictive analytics, and decision support functionalities. The utilization of Random Forest enhances the accuracy of predicting produce status, while automatic notifications ensure timely intervention in case of unsatisfactory or alarming conditions. Through the collaboration of the sensing module, status prediction module, and Android app module, personnel can effectively monitor environmental parameters and make informed decisions to mitigate losses and maximize the quality of stored commodities. The Android app further enhance monitoring capabilities, ultimately improving the efficiency and sustainability of cold storage operations.

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