Iot Based Real Time Food Expiry Estimation and Alert Mechanism

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Abstract—Food spoilage is a significant challenge both in domestic and industrial settings, frequently resulting in health concerns and financial setbacks This research presents an IoT-driven system for real-time monitoring of food status and forecasting of its expiration. The proposed system utilizes environmental sensors to observe conditions like temperature, humidity, and gas concentration associated with food degradation. The gathered information is processed through a microcontroller and subsequently transferred to the cloud for analysis. Based on predefined threshold values and condition- using this method, the system determines the level of food and generates timely alerts to users. The proposed approach improves food safety and minimizes unnecessary waste, and supports smarter food management practices. Experimental observations indicate that the system provides consistent monitoring and efficient alert systems, making it suitable for real-world applications.

Index Terms—IoT, Food Expiry Detection, Smart Monitoring, Sensors, Food Safety, Real-Time Alert System

I. INTRODUCTION

Food spoilage is a natural and unavoidable process influenced by microbial activity, enzymatic reactions, and environmental factors such as temperature and humidity [1]. In conventional systems, expiry dates printed on food packaging are determined under controlled conditions and may not accurately reflect real-time storage environments [2]. As a result, food may spoil before the indicated date or remain consumable even after the expiry date, leading to either health risks or unnecessary wastage.

The increasing emphasis on ensuring food safety and maintaining quality has driven the integration of modern technological solutions. IoT technology delivers a reliable framework for acquiring real-time data and enabling remote monitoring, and informed decision-making [3]. Such systems incorporate linked sensors and devices that exchange data over the internet, enabling continuous monitoring of surrounding environmental conditions.

In the food industry, IoT applications are widely used in cold chain management, storage systems, and supply chain monitoring [8]. However, many existing solutions focus only on temperature monitoring and do not consider other critical factors such as humidity and gas emissions. These elements are essential in determining food freshness and spoilage levels.

This work is intended to develop an integrated A system based on IoT technology that monitors diverse environmental parameters and provides reliable food expiry predictions. It features an affordable and simple design appropriate for household and commercial use environments. By offering instant alerts along with useful insights, the proposed system supports proactive food management and contributes to reducing food waste.

Numerous studies have explored the development of intelligent food monitoring solutions utilizing IoT technologies. Systems that rely on temperature monitoring are widely implemented in cold storage facilities and transportation to preserve food quality [3]. By keeping products within safe temperature ranges, these systems help minimize spoilage during transit

In addition to temperature monitoring, gas sensor-based systems have been introduced to detect spoilage by measuring gases released during food decomposition, such as ammonia and methane [5]. These systems provide direct indicators of spoilage but often require precise calibration and are sensitive to environmental variations.

Recent advancements include the use of machine learning algorithms to predict food shelf life based on historical data and environmental conditions [14]. These models improve prediction accuracy but involve high computational complexity and require large datasets for training. Moreover, they may not be suitable for low-cost, real-time applications.

II. SYSTEM ARCHITECTURE

The architecture of the proposed system is designed to support reliable data gathering, processing, communication, and user interaction. It consists of four main layers: sensing layer, processing layer, communication layer, and application layer.

The sensing layer integrates devices to detect temperature, humidity, and gas concentrations that continuously monitor environmental conditions surrounding the food [5]. These sensors continuously output data describing the storage environment and potential spoilage indicators.

The processing layer consists of a microcontroller such as NodeMCU, which functions as the main control unit. It collects sensor data, performs initial filtering and handles data processing, ensuring it is prepared for transfer. The microcontroller also executes the decision-making algorithm based on predefined thresholds.

The communication module supports wireless transmission of data using Wi-Fi technology. The processed data is sent to a cloud-based system, where it is saved and examined [9]. This component ensures uninterrupted linkage between the hardware system and remote users.

This layer provides a user interface, for example, a mobile or web dashboard, which displays real-time data and alerts. Users can monitor food conditions remotely and receive notifications when spoilage is detected [8].

III. SYSTEM PROCESS MODEL

The methodology of the proposed system operates through constant monitoring, threshold analysis, and alert generation. The sensors are programmed to collect data at regular intervals, ensuring real-time observation of environmental conditions.

Each parameter is associated with predefined threshold values representing safe storage conditions. For example, temperature above a certain limit accelerates microbial growth, while high humidity promotes mold formation [7]. Gas sensors detect the presence of decomposition gases, providing direct evidence of spoilage [5].

The system employs a rule-based algorithm to analyze sensor data. The algorithm compares real-time values with threshold limits and assigns a freshness status to the food. It is commonly divided into three categories:

- Fresh: All parameters within safe limits
- Warning: Parameters approaching unsafe levels
- Spoiled: Parameters exceeding safe thresholds

When the system detects a transition from fresh to warning or spoiled condition, it generates alerts and notifies the user. The collected data is instantly transferred to the cloud platform for storage and visualization [9]. This approach ensures timely detection of spoilage and enables preventive action, thereby improving food safety and reducing waste.

IV. IMPLEMENTATION

The implementation of the proposed system is carried out using an integrated combination of hardware and software elements designed to support real-time monitoring and data transfer. The NodeMCU (ESP8266) microcontroller forms the core of the system, acting as the primary processing unit and enables wireless communication through its built-in Wi-Fi capability [12]. Environmental parameters are measured using a DHT11 alternatively, a DHT22 sensor is used to monitor temperature and humidity, as these factors significantly influence food spoilage rates [5]. Along with this, an MQ-135 gas sensor is implemented used to detect gases such as ammonia and carbon dioxide that are released during the decomposition process, providing a direct indication of food degradation [5]. The components are integrated through a breadboard setup and interfaced through appropriate wiring, while a stable 5V power supply ensures continuous operation of the system.

The microcontroller is coded using the Arduino IDE, in which embedded C code is written to read sensor record data at scheduled intervals, evaluate the inputs, and transmit the information to a cloud platform such as ThingSpeak or Firebase [9]. The system maintains continuous surveillance of environmental factors and compares sensor readings with predefined threshold values to determine the freshness status of the food. Using this evaluation as a basis, the system determines the category of food condition into categories such as fresh, warning, or spoiled. Whenever the sensed values exceed safe limits, indicating potential spoilage, the system automatically generates alerts and provides alerts to the user using the connected interface [8]. Data is maintained and visualized on the cloud, permitting users to monitor live and previous changes in food conditions.

The overall system is compact and can be easily installed in food storage environments such as refrigerators or storage containers. The merging of sensing, analysis, and communication modules ensures continuous and reliable operation without manual intervention. Experimental testing under different environmental conditions confirms that the system effectively detects variations in temperature, humidity, and gas concentration, thereby providing an efficient solution for real-time food expiry estimation.

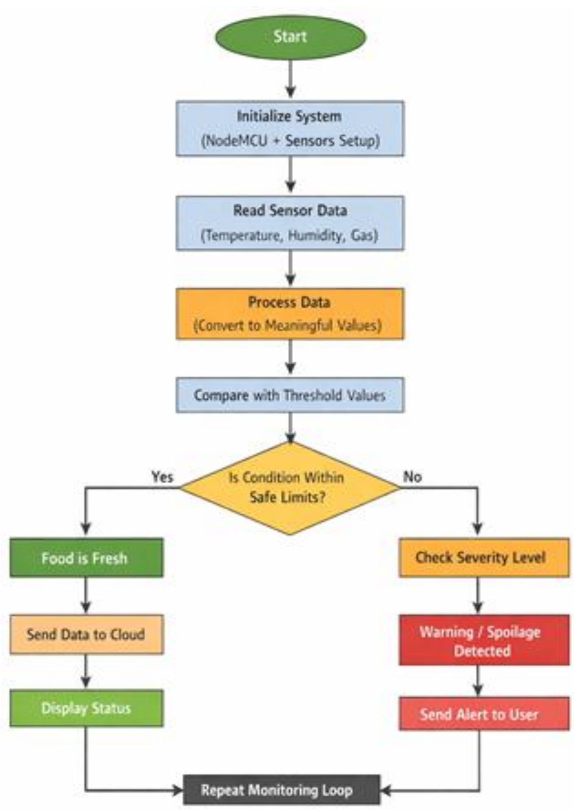

Figure 1 Flowchart Representation Of Working Model

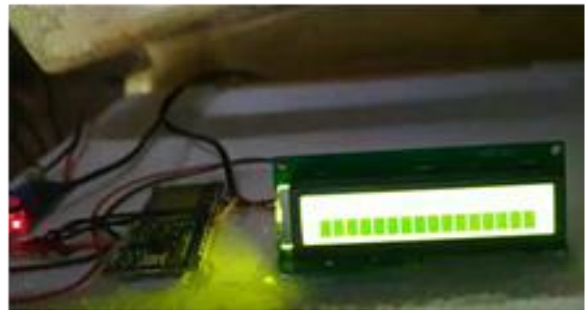

Figure 2 Display module

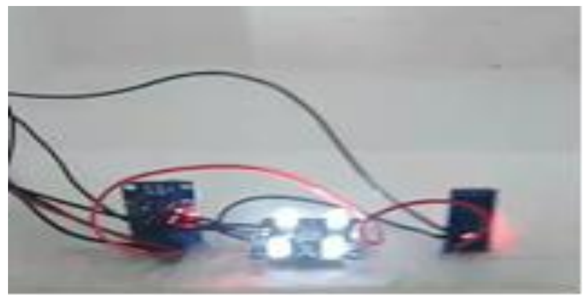

Figure 3 Sensor modules

Figure 4 Working Model

The collected raw data is then processed by the microcontroller. This procedure entails changing analog signals into digital format and filtering noise to obtain accurate measurements. The processed data is then compared with predefined threshold values that represent safe storage conditions for food. The threshold values are determined according to standard food safety guidelines and experimental observations

V. INPUT TO OUTPUT MODULE

The working of the proposed IoT-based food expiry estimation system commences by initializing the microcontroller and connected sensors. Once the system is activated, the NodeMCU establishes connections with the temperature, humidity, and gas sensors and configures the Wi-Fi module for internet communication. Once the setup process is finished, the system moves into a continuous monitoring loop.

At the beginning, the sensors initiate the collection of real-time environmental data. The temperature and humidity sensor measures the surrounding conditions, which directly affect microbial growth and food degradation. Simultaneously, the gas sensor detects the presence comprising gases like ammonia and carbon dioxide that are typically released during food spoilage. These sensor readings are captured at regular intervals to ensure continuous monitoring.

According to the comparison, the system analyzes the condition of the food. If all values fall within safe boundaries, the system classifies the food as fresh, and the system continues monitoring without interruption. If any parameter begins to approach unsafe levels, the system labels the condition as a warning stage, indicating a potential risk of spoilage. When the sensor values exceed critical limits, the system detects spoilage in the food. Once the status is established, the system communicates the data to a cloud platform using the Wi-Fi module. Data is securely held on the cloud platform and provides visualization through graphs and dashboards, allowing users to monitor changes over time. Meanwhile, upon detecting warning signs or spoilage, the system issues alerts and communicates notifications to the user through a connected application or interface.

The system then repeats the entire process in a loop, ensuring continuous real-time monitoring. This automated cycle allows early detection of spoilage and enables users to take preventive actions such as adjusting storage conditions or discarding unsafe food. The overall process ensures efficient food quality monitoring with minimal human intervention and improved reliability.

VI. RESULTS AND DISCUSSION

The IoT-driven food expiry prediction system was implemented under different environmental conditions using various perishable food samples. The system regularly monitored environmental parameters such as temperature, humidity, and gas levels, while sending the recorded data to the cloud for immediate visualization and analysis. The experimental results indicate that the system is capable of effectively tracking environmental variations and identifying early signs of food spoilage.

During the initial testing phase, when food samples were held under monitored conditions, the sensor observations remained within predefined safe thresholds. The system correctly classified the food status as fresh and displayed stable readings on the cloud dashboard. As time elapsed, incremental changes in environmental factors were detected, especially an elevation in humidity and slight fluctuations in temperature. These fluctuations were successfully monitored by the DHT sensor, reflecting the robustness of the sensing system [5].

A significant observation was made when the food samples began to deteriorate. The MQ-135 gas sensor detected an increase in gas concentration, indicating the release of volatile compounds associated with spoilage [5]. This change was reflected in the system as a transition from fresh to warning condition. The system successfully identified this intermediate stage, providing early alerts to the user before complete spoilage occurred. This capability is highly useful in limiting food waste and ensuring safety.

When the environmental parameters exceeded critical threshold values, the system classified the food as spoiled and generated real-time alerts. Notifications were sent to the user interface without noticeable delay, demonstrating efficient communication between the hardware and cloud platform [9]. The alert mechanism proved to be reliable and responsive, allowing users to take immediate action.

The cloud platform provided continuous data logging and graphical representation of sensor readings. This enabled analysis of trends over time, helping to understand the rate of food degradation under different conditions. The integration of cloud technology improved accessibility and allowed remote monitoring, which is a key advantage of IoT-based systems [9].

Despite the overall effectiveness, certain limitations were identified. Sensor readings may be affected by environmental noise and external factors such as air flow and ambient contamination. Additionally, the predefined threshold values may vary according to the category of food being tracked. Calibration of sensors and customization of threshold values are necessary to improve accuracy and adaptability [10].

Overall, the system demonstrated consistent performance, accurate detection of spoilage conditions, and reliable alert generation. The combination of multiple sensors and cloud-based monitoring makes the system suitable for practical applications in both domestic and commercial environments.

VII. CONCLUSION

This paper presented an IoT-based real-time food expiry estimation and alert mechanism designed to improve food safety and reduce wastage. The design connects temperature, humidity, and gas sensors incorporated with a microcontroller and cloud system to continuously monitor food storage conditions. By examining environmental conditions and identifying spoilage patterns, the system generates precise and timely insights about food freshness [3].

The experimental results confirm that the system is equipped to sense initial spoilage conditions and trigger alerts before the food becomes unsuitable for consumption. This proactive mechanism helps users act early, decreasing health risks and preventing unnecessary food disposal. The inclusion of cloud technology contributes to further enhancement of the system by enabling remote monitoring and data visualization [9].

One of the key advantages of the proposed system is its simplicity and cost-effectiveness. The use of readily available sensors and microcontroller platforms makes it accessible for widespread adoption. Furthermore, the system requires minimal human involvement, making it appropriate for smart homes, restaurants, and food storage facilities.

Even so, some modifications could further enhance system performance. The system's performance in terms of accuracy can be refined by incorporating advanced calibration techniques and adaptive threshold values based on different food types. Future work may also include the integration of machine learning algorithms to predict shelf life with greater precision and deliver tailored recommendations [14].

In summary, the proposed system provides a dependable and efficient solution for real-time food monitoring. It plays a role in strengthening food safety, cutting down waste, and advancing intelligent food management systems. As improvements are made, the system may potential to be implemented on a larger scale within the field of the food industry and supply chain logistics.

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