International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 03, March 2026)

A Software-Centric Intelligent System for Monitoring Grain Level, Moisture, and Temperature to Prevent Spoilage

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***Abstract*—Grain storage is a very important stage in agriculture because it directly affects food quality and economic value. During storage, grains are exposed to environmental conditions such as temperature, humidity, and moisture. If these parameters are not properly controlled, they can lead to fungal growth, spoilage, and loss of quality. In this work, a software-based intelligent grain monitoring system is developed. The system continuously monitors temperature, humidity, and grain level, and based on these parameters, it provides suggestions to maintain proper storage conditions. It also estimates how long the grain can remain in safe condition. The main focus of this project is on software intelligence rather than only hardware, which makes the system more flexible and cost-effective. The system was tested using simulated real-time data, and the results showed that it can effectively detect unsafe conditions and provide useful recommendations.**

***Keywords*—Agriculture monitoring, Grain storage, Humidity control, IoT, Temperature monitoring**

I. INTRODUCTION

Agriculture is one of the most important sectors, and proper storage of grains is necessary to reduce losses after harvesting[1]. In many cases, grains are stored for a long period, and environmental conditions play a major role in determining their quality. From our observation, it is seen that temperature and humidity changes are the main reasons for grain spoilage.

When temperature increases, microbial activity also increases, which leads to faster deterioration[2]. Similarly, high humidity causes moisture absorption, which promotes fungal growth. Traditional storage methods mainly depend on manual checking, which is not sufficient because changes in environmental conditions can happen quickly. Therefore, there is a need for a system that can continuously monitor these conditions and provide early warnings[3]. In this project, a software-based monitoring and decision system is developed.

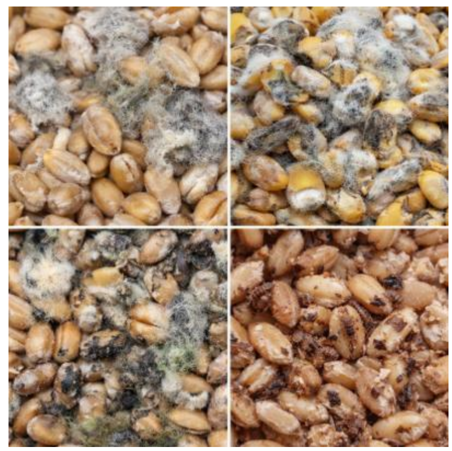

Fig. 1. Grain deterioration due to moisture and fungal growth

II. THEORETICAL BACKGROUND

The quality of stored grain mainly depends on temperature, humidity, and moisture content. These parameters are interconnected and influence each other.When temperature increases, biochemical reactions inside the grain also increase[4], leading to heat generation and faster spoilage. $Q = m \times Cp \times (dT/dt)$ Moisture content is another critical factor. When surrounding humidity is high, grains absorb moisture, which promotes fungal growth. $M = f(T, RH)$ A combined risk factor is defined as: $R = w_1T + w_2RH + w_3M$ Shelf-life estimation is given by: $S = K / (T + RH + M)$ These equations form the theoretical basis for predicting grain condition and decision-making in the system

III. HARDWARE IMPLEMENTATION

For real-time implementation, the proposed system consists of multiple sensors, a processing unit[5], communication modules, and control components.

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In the designed circuit, environmental parameters such as temperature and humidity are measured using a DHT22 sensor, while grain moisture is detected using a soil or grain moisture sensor. Gas sensors such as MQ-2 or MQ-135 are used to detect gases released during grain spoilage, enabling early identification of deterioration. Grain level inside the storage unit is measured using an ultrasonic sensor, which calculates the distance between the sensor and grain surface. All these sensors are interfaced with the ESP32 microcontroller through GPIO pins using analog and digital connections.

The ESP32 acts as the central processing unit, collecting and processing sensor data. For long-range wireless communication, a LoRa module (SX1278) is connected to the ESP32 using SPI/UART interface, allowing data transmission to remote monitoring systems. A voltage regulator (AMS1117) is used to provide a stable 3.3V and 5V power supply to the ESP32 and associated components. The system also includes relay driver circuits (ULN2003), which are used to control output devices such as fans, heaters, dehumidifiers, and buzzer alarms based on system decisions. This hardware configuration ensures reliable sensing, processing, communication, and control, making the system suitable for real-time agricultural applications.

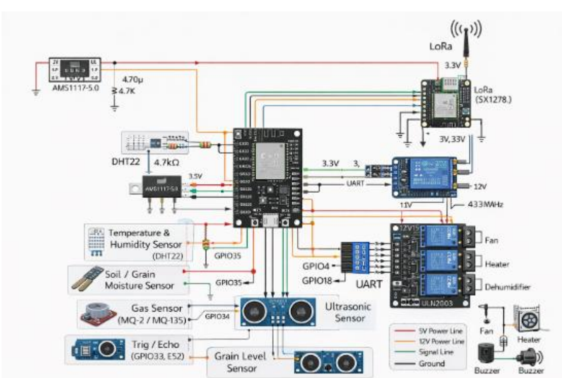

Fig. 2. Hardware circuit diagram

IV. Software System And Working

The main part of this project is the software system. It is developed using Python, and the dashboard is created using Streamlet. In our system, data can either come from sensors or be simulated. We mainly used simulated data to test different conditions like high temperature and humidity. The software processes the data and shows it in the form of graphs[6]. It also checks whether the values are within safe limits. If not, it generates alerts and suggestions.

For example:

- If temperature is high → it suggests cooling
- If humidity is high → it suggests drying

The system also calculates the estimated shelf life of the grain based on current conditions.

V. Intelligent Decision System

The most important part of this project is that it does not just monitor data, but also **gives solutions**.From our testing, we observed that just showing values is not enough. So, we added a system that analyzes the data and suggests what should be done.

For example:

- If humidity increases → system suggests using a dehumidifier
- If temperature increases → system suggests ventilation

In addition, the system predicts how long the grain will remain in good condition. This is very useful for farmers because they can plan storage and selling accordingly [7].This makes our system a **Decision Support System (DSS)** rather than just a monitoring system. The system also predicts how long the grain will remain safe, helping farmers in decision-making.[8]

TABLE I
INTELLIGENT DECISION RULES

Condition	System Detection	Suggested Action
High Temperature	T > Threshold	Cooling
High Humidity	RH > Threshold	Dehumidifier
High Moisture	M > Threshold	Drying
Gas Detection	MQ Trigger	Alert
Low Grain Level	Distance ↑	Refill

VI. Dashboard

The dashboard is designed to be simple and easy to use. It shows real-time graphs of temperature, humidity, and grain level.

We also included:

- Alerts (like high humidity warning)
- Suggestions (what action to take)
- Shelf-life estimation (for example: 6–12 months)

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From our testing, the dashboard made it easy to understand the condition of grain without needing technical knowledge.

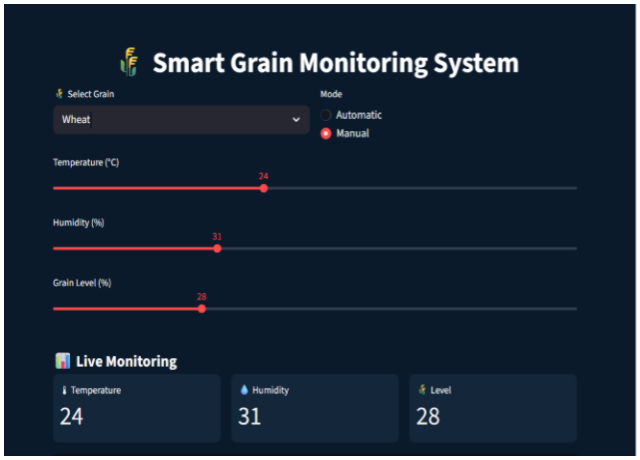

Fig. 3. Monitoring dashboard

VII. Results And Observations

The system was tested using simulated data. It successfully detected unsafe conditions and generated alerts.

Observations:

- Fast response
- Accurate suggestions
- Dynamic shelf-life prediction

Fig. 4. Health index

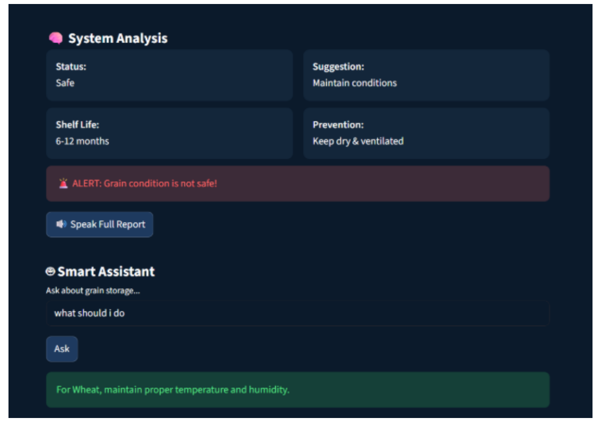

Fig. 5. Decision output

VIII. Novelty Of The Project

The main difference in our project is that we focused more on software intelligence[9]. Most systems only monitor data, but our system also analyzes and predicts.

The key features of our system are:

- Suggesting solutions
- Predicting shelf life
- Detecting spoilage conditions early
- Supporting crop-based monitoring

IX. Conclusion

In this project, we developed a smart grain monitoring system that can observe environmental conditions and provide useful suggestions. The system also predicts how long the grain will remain safe, which helps in better decision-making. The software-based approach makes the system simple and cost-effective, while still allowing real-world implementation using hardware. Overall, the system can help reduce grain losses and improve storage management.

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