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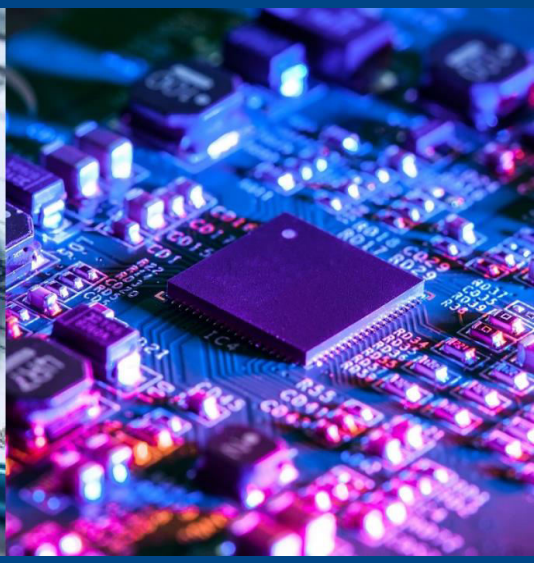

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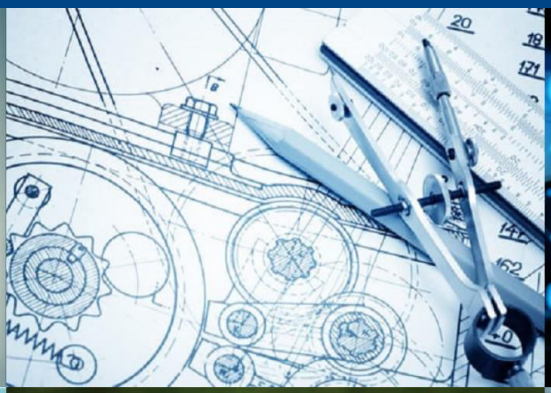

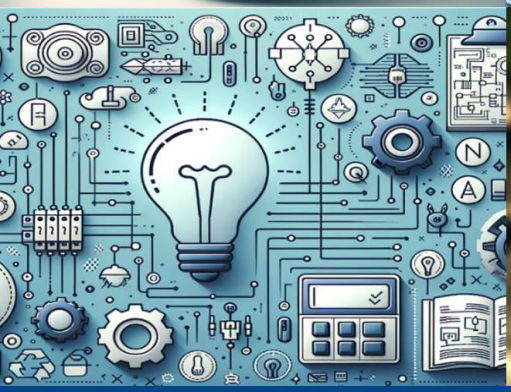

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Smart Rice Storage Humidity Monitoring System to Prevent Mold and Crop Damag

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ABSTRACT: This study developed a Smart Rice Storage Humidity Monitoring System to Prevent Mold and Crop Damage. The system uses a DHT11 sensor to measure temperature and humidity, an ESP32 microcontroller to process sensor data, a GSM module to send SMS alerts, and an ESP32-CAM to provide visual monitoring of the storage area. When readings exceed predefined thresholds, the system automatically sends notifications to responsible personnel for immediate corrective action. The system was developed using the Agile Model and evaluated based on ISO/IEC 25010 standards. Results showed that the system was highly acceptable in terms of functional suitability, reliability, usability, and performance efficiency. By automating monitoring and alerting, the system helps farmers improve storage practices, preserve grain quality, and minimize losses caused by mold growth and crop deterioration.

KEYWORDS: Smart Rice Storage, Humidity Monitoring, Temperature Monitoring, ESP32, GSM Alert System, Mold Prevention, Crop Damage Prevention, Rice Storage Management.

I. INTRODUCTION

The study began with the common problem many farmers faced when storing rice mold growth caused by high humidity and improper drying. In many areas, rice spoiled quickly because it was stored while still damp or kept in places with little airflow, leading to wasted crops and financial loss. Traditional drying and storage methods were not always reliable, especially during rainy seasons, the study proposed developing a Smart Rice Humidity Monitoring System to help farmers monitor moister levels and prevent damage before it happens.

Rice storage is important for protecting harvested grains, especially in places where rice is a major food source, so good monitoring systems are needed (Islam et al., 2024). Many farmers lose part of their harvest because poor humidity control and weak post-harvest practices lead to mold and grain damage (Nebrida, 2024). Mold often appears when rice is not fully dried or kept in storage areas with little airflow, making the grains spoil faster (Sharmeela, 2020; Viviane et al., 2023). Traditional drying and storage methods make the problem worse, especially when mechanical dryers do not remove enough moisture compared to sun-drying. Because of these challenges, experts suggest using real-time monitoring systems to help prevent spoilage and improve storage conditions for farmers.

There were still gaps about how farmers could monitor rice humidity in real time using simple and affordable technology. Most existing solutions focused only on traditional drying methods and did not include continuous monitoring after storage, which left farmers unaware of rising moisture levels. There was also limited research on systems that combined sensors and alerts specifically designed to prevent mold in small local storage setups. This study introduced a unique feature by creating a Small Rice Humidity Monitoring System that provided real-time readings and early warnings to help farmers protect their rice more effectively.

This study was important because it aimed to help farmers reduce rice spoilage by using IoT-based sensors that monitored humidity and temperature inside the storage area in real time. These Iot sensors also sent automatic SMS alerts to the farmer whenever moisture levels became too high, allowing them to respond immediately before mold and damage occurred. With continuous data and instant notifications, farmers could make quick decisions and keep their stored rice

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safe from spoilage. The study offered a practical and affordable solution that improved rice storage management through simple but effective IoT technology combined with SMS Monitoring.

II. LITERATURE SURVEY

Reviewed the use of IoT in smart agriculture in the Philippines, Mastul et al. (2023) highlighting its potential to improve farming practices. The study discussed various IoT applications, such as monitoring soil moisture, weather conditions, and crop health, to optimize farming operations. It emphasized how IoT technologies could help address challenges like inefficient resource use and climate change. The authors concluded that IoT adoption in Philippine agriculture could lead to more sustainable and efficient farming practices.

Explored the use of scalable sensor technology for managing moisture levels in agriculture to enhance food security. Their study focused on how sensors can effectively monitor soil moisture, helping farmers optimize irrigation and reduce water waste. The technology aims to improve crop yields and ensure food security by maintaining ideal moisture conditions for different crops. The authors highlighted the potential of scalable sensor systems to support sustainable farming practices and address challenges in agricultural resource management. Neyra et al. (2025)

III. METHODOLOGY / APPROACH

The system was tested only in selected rice storage areas in Cantilan, so it was not tested in larger or industrial storage facilities. The device depends on stable power sources and mobile network signals for sending SMS alerts, which may not work well in areas with weak network coverage. The system only tracks humidity and temperature and does not consider other factors like pests, storage cleanliness, or grain quality. The study focused mainly on the technical aspects of the IoT system and did not look into long-term financial impacts or the overall success of the harvests for farmers.

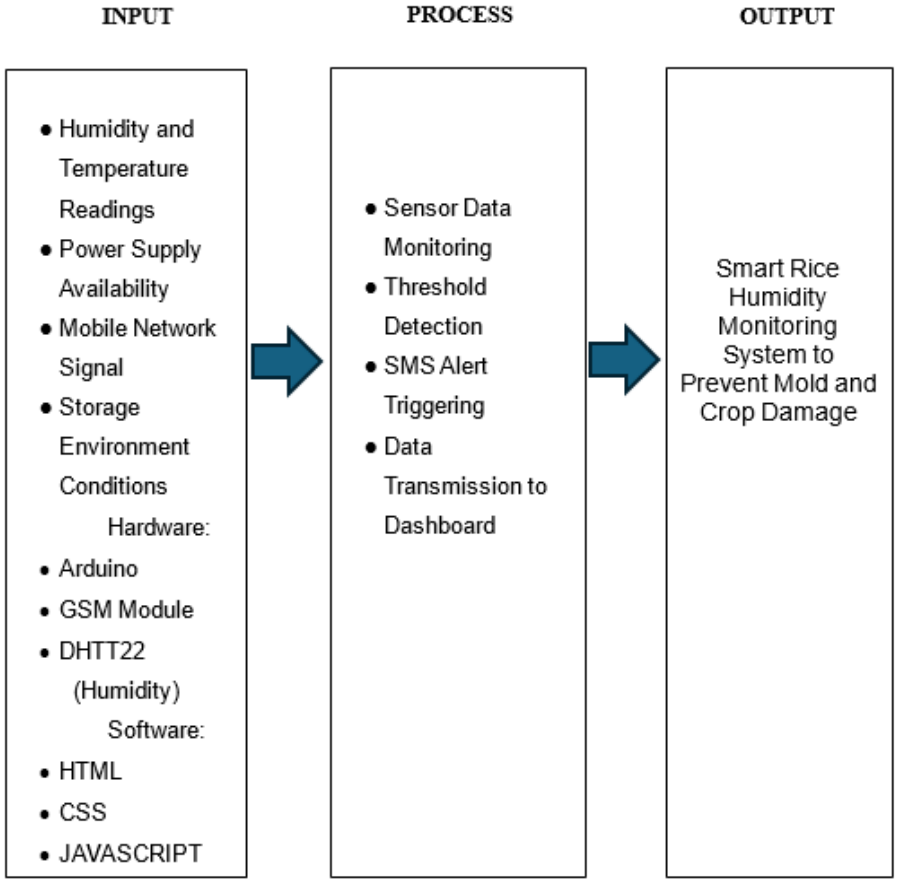

Figure 1 IPO Diagram

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Figure 1 presents the overall flow of Smart Rice Humidity Monitoring System to Prevent Mold and Crop Damage for each IPO section. These inputs included the temperature and humidity readings from IoT sensors inside the rice storage. It also depends on stable power and mobile network signals for real-time monitoring and SMS alerts. These inputs ensure the system can accurately assess the rice storage conditions.

Process The system continuously monitors the humidity and temperature, comparing them against safe storage thresholds. If the readings exceed these limits, the system triggers an SMS alert. The process involves analyzing the data and responding appropriately to avoid mold and crop damage.

Output the system provides real-time humidity and temperature data on the dashboard, allowing farmers to monitor their rice storage. It also sends SMS alerts when humidity levels are too high, enabling farmers to act quickly and reduce the risk of spoilage.

Research design

The researchers conducted a quantitative research design to evaluate the effectiveness, reliability, and usability of the proposed Smart Rice Storage Humidity Monitoring System. The study aims to develop and test a humidity monitoring device equipped with a humidity sensor, microcontroller, and IoT integration to monitor and record humidity levels in real time.

The researchers assembled the necessary hardware components, including humidity sensors, microcontroller boards, and communication modules, and integrated them with software for monitoring and data visualization. The prototype was installed in a rice storage environment to measure humidity levels continuously and determine whether the system can effectively detect humidity changes that may cause mold growth and crop damage.

System development approach

The researchers adopted the **Agile Model**, a flexible approach within the Software Development Life Cycle (SDLC), to guide the system development process. Unlike a strictly sequential method, Agile allows development to occur in iterative cycles, enabling continuous improvement at each stage. The researchers gathered user requirements, designed, developed, and tested the system in repeated iterations, incorporating feedback to refine the system progressively. This approach allowed early detection of issues, faster adjustments, and continuous quality enhancement. As a result, the process ensured the development of a reliable, efficient, and high-quality humidity monitoring system.

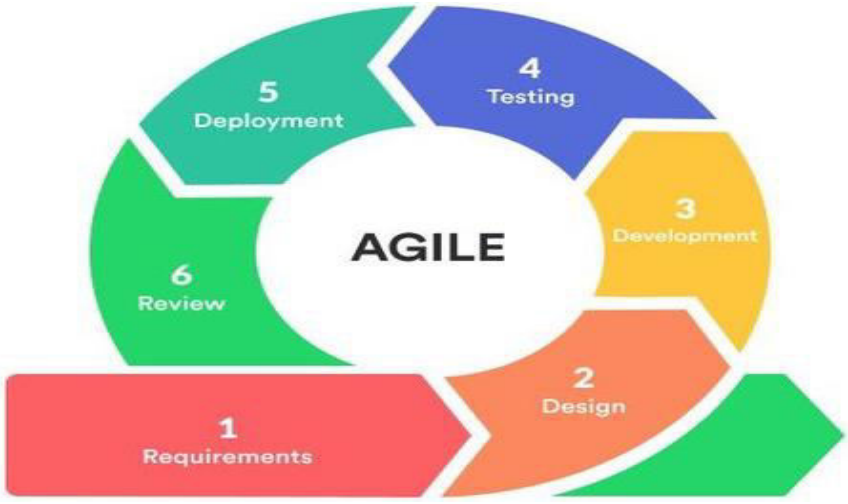

Figure 2 Agile Method

The researcher decided to use the Agile Method as one of the types of SDLC methods; it is suitable because the project is feedback-dependent on improving the system.

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IV. RESULTS AND DISCUSSION

Overall Feedback Result

The established Smart Rice Storage Humidity Monitoring Device has been constructed to fulfil specified criteria that permit for the development of functions to monitor storage temperature and humidity, provide real-time photographic images of the stored item(s), and generate automatic short message service (SMS) notification alerts to appointed staff members. Verification of the performance of the system was conducted through staff testing of the user interface verifying the correct functionality of the system dashboard displaying current sensor readings and capturing environmental data (i.e., humidity, temperature) to provide monitoring data for post data review and analysis. Survey responses from the participants rating the satisfaction of the system showed a high level of satisfaction across each quality characteristic outlined in ISO/IEC 25010, with Functional Suitability and Usability receiving the highest ratings from users based on ease of operation of the device and the effectiveness of the device to provide timely alerts when the environmental conditions were not acceptable for storage. The DHT11 sensor and the GSM module were evaluated under multiple environmental conditions that supported the validity of the system measuring accurately and producing reliable notification alerts for environmental conditions. Therefore, it can be concluded that the performance of this device provides a reliable and efficient tool for monitoring the environmental conditions of stored rice to aid in the prevention of mold formation, reduce yield losses, and/or reduce postharvest losses to the farmers and/or storage managers.

Table 4.7 Overall Results

Table	Quality Characteristic	Mean	Verbal Interpretation
1	Functionality	4.20	Moderately Agree
2	Reliability	4.29	Moderately Agree
3	Usability	4.17	Moderately Agree
4	Efficiency	4.26	Moderately Agree
5	Maintainability	4.22	Moderately Agree
6	Portability	4.29	Moderately Agree
	Overall Mean	**4.24**	Moderately Agree

overall performance based on different quality characteristics. The results indicate that the system received high mean scores in all criteria, which means that the respondents generally had a very positive evaluation of the system.

Among the quality characteristics, Reliability and Portability obtained the highest mean score of 4.29, interpreted as Moderately Agree. This suggests that the respondents believe the system is dependable and can work effectively in different environments. Efficiency also received a high mean score of 4.26, showing that the system can perform its tasks quickly and efficiently.

On the other hand, Maintainability obtained a mean score of 4.22, indicating that respondents think the system can be easily maintained and improved when needed. Functionality followed with a mean score of 4.20, which shows that the system can perform its intended functions. Meanwhile, Usability received the lowest mean score of 4.17, but it is still interpreted as Moderately Agree, meaning that users still find the system easy to use and understand.

Overall, the system achieved an overall mean score of 4.2, which is interpreted as Moderately Agree. This means that the respondents are highly satisfied with the system's performance and believe that it effectively meets their needs.

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V. CONCLUSION

Based on the findings of the study, the Smart Rice Storage Humidity Monitoring System to Prevent Mold and Crop Damage proved to be an effective and reliable tool for monitoring humidity levels in rice storage environments. The system addresses the common problem of unnoticed humidity buildup, which can lead to mold growth and spoilage of stored rice. Through real-time monitoring and automatic alerts, the system allows users to respond quickly when humidity levels become unsafe. This early warning feature helps protect the quality of stored rice and reduces the possibility of crop loss.

The high acceptability rating given by the respondents also shows that the system is easy to use and performs its intended functions well. The integration of sensor technology and a monitoring interface demonstrates how smart technologies can be applied to improve agricultural storage practices. In general, the system can serve as a useful tool in improving rice storage management and helping prevent crop damage caused by excessive humidity.

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