

IOT Based Smart Maize Crop Storage System by monitoring real time environmental parameters

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Abstract: The agricultural sector in KAMONYI District, Rwanda, faces significant post-harvest losses, particularly in maize storage, due to inadequate monitoring and management of storage conditions. This project aims to develop and implement an intelligent maize crop storage system using the Blynk cloud platform to address these challenges. The system utilizes NodeMcu, DHT11 sensors and gas detectors to monitor crucial storage parameters such as temperature, humidity, CO2 levels and Light detector. During our research, we visited a store called Rumbuka Seeds in Kamonyi District, where the current system fills maize into slots. To enhance this system, we propose adding DHT11 sensors, LDR sensor and MQ2 and different actuators like lamp, heater and fan in order to maintain optimal storage conditions. Additionally, the system will be integrated with Blynk to monitor and control the collected data, enabling more effective management of storage conditions. NodeMcu, a microcontroller with Wi-Fi capability, serves as the core unit, collecting data from sensors. These data are then transmitted to the Blynk cloud server, where they are processed and stored in real-time. Farmers can access this data through a user-friendly mobile interface provided by the Blynk application. This interface allows them to view real-time data, analyze historical trends, and receive alerts, facilitating timely interventions without needing to be physically present at the storage site. By continuously monitoring storage conditions and offering actionable insights, the smart maize storage system seeks to reduce spoilage and post-harvest losses, promote sustainable storage practices, and ultimately enhance the productivity and profitability of maize farming in Kamonyi District. The inclusion of alert systems within the Blynk app ensures that farmers are promptly informed of any adverse conditions, allowing for swift corrective actions. This innovative approach leverages IoT technology and the Blynk cloud to provide a more efficient and reliable maize storage solution, addressing a critical need in the region's agricultural sector.

Keywords: NodeMcu, Blynk, sensor.

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1. Introduction

In Rwanda and similar agricultural environments, traditional maize storage methods often struggle with several significant challenges. Pest infestations, for example, are a major concern, with insects and rodents infiltrating storage facilities and causing substantial damage. Additionally, maintaining proper moisture levels is difficult, as fluctuations in humidity can lead to mold growth and spoilage. Temperature control is another critical issue, particularly in areas with variable climate conditions, where poor ventilation or insulation

can speed up deterioration. To overcome these ongoing challenges in maize storage in Kamonyi District, Rwanda, we have developed an IOT based Smart Maize Crop Storage System. This innovative system leverages modern technology, including advanced sensors and IoT devices, to provide real-time monitoring and management of storage conditions. Implemented in rural farming communities across Kamonyi District, our project empowers local farmers by allowing them to remotely monitor temperature, humidity, light and pest activity through a user-friendly interface accessible on their mobile phones. During our research, we visited Rumbuka Seeds, a

store in Kamonyi District, where the current system involves filling maize into slots and monitoring only humidity and temperature.

To enhance this system, we propose adding DHT11 sensors and incorporating a fan and heater to maintain optimal storage conditions. Additionally, the system will be integrated with Blynk to monitor and control the collected data, enabling more effective management of storage conditions. By providing timely alerts and actionable insights, our IOT based Maize Crop Storage System enables farmers in Kamonyi District to take proactive steps to protect their maize harvests from pest damage and spoilage. This initiative not only improves storage efficiency but also helps reduce post-harvest losses, supporting food security and promoting sustainable agricultural development in the region.

2. Literature review

Agriculture is a cornerstone of many economies, especially in regions where maize is a primary food source. Despite the critical importance of this crop, post-harvest losses due to inadequate storage conditions remain a pervasive issue. Traditional storage facilities often lack the necessary mechanisms to control environmental factors such as temperature and humidity, which are crucial for maintaining grain quality. Consequently, farmers face significant losses due to spoilage and pest infestations, which undermine food security and economic stability. Many farmers rely on outdated and ineffective storage solutions. The lack of real-time monitoring and precise control over storage environments exacerbates the problem, leading to diminished grain quality and economic losses. The integration of modern technologies such as the Internet of Things (IoT) and advanced sensor systems presents an unprecedented opportunity to revolutionize crop storage practices. [1] In Rwanda, maize is a crucial crop within the Crop Intensification Program (CIP), aimed at maximizing harvest yields on small land areas. To achieve this, farmers need to adopt modern agricultural practices such as soil testing for optimal maize productivity, proper cornfield planting techniques, efficient fertilizer usage, effective irrigation methods, and robust disease and pest management strategies. Furthermore, they must employ appropriate harvesting, filtering, and storage techniques to ensure the quality of their maize crops. [2] Despite the importance and availability of maize, farmers continue to face significant post-harvest losses due to inadequate storage facilities. For instance, when farmers harvest 2 tonnes of maize, they sell a portion and store the rest. However, within just three months, the stored maize often starts to deteriorate due to factors such as moisture content, temperature (grain and air), relative humidity, storage conditions, fungal growth, and insect pests. This forces farmers to sell their remaining maize at a lower price to avoid total loss. [3] The importance of this project is designed to address these critical challenges by providing a reliable solution for monitoring and managing storage conditions, thereby reducing post-harvest losses, enhancing food security, economic impact, sustainability, and technological advancement. Maize is a vital staple crop, but improper storage can lead to significant losses due to moisture, temperature fluctuations, and gas buildup, which contribute to mold growth, insect infestations, and mycotoxin contamination. Traditional storage methods often fall short in maintaining optimal conditions, making it necessary to explore advanced solutions. The advent of the Internet of Things (IoT) has revolutionized agricultural practices, including crop storage management. [4] IoT systems enable continuous monitoring of environmental conditions within

storage facilities, allowing proactive measures to be taken to preserve maize quality. Monitoring gas levels, particularly CO₂, is crucial as elevated levels can indicate grain respiration or pest presence. Humidity control is equally important, as high humidity can lead to moisture absorption, increasing the risk of fungal contamination and spoilage. IoT-based systems can regulate humidity by activating dehumidifiers or ventilation systems. [5] Temperature management is another key aspect, as fluctuations can accelerate spoilage and reduce the shelf life of stored maize. IoT systems help maintain a stable temperature by controlling cooling or heating systems. [6] Case studies, such as smart silo and Wireless Sensor Networks (WSNs), demonstrate the effectiveness of these technologies in reducing post-harvest losses. [7] However, challenges in implementing IoT-based systems, particularly in rural or resource-limited settings, include power supply, sensor maintenance, data transmission, and initial setup costs. Despite these challenges, IoT integration in maize storage presents a promising solution to reducing losses and ensuring food security by maintaining optimal storage conditions, extending shelf life, and preventing spoilage. [8]

3. Contribution of the paper

In our country modernization in agriculture domain is still under, especially in when we are keeping the harvest of different crops, therefore as many researchers they were focused on how the new technology of IOT can be introduced in agriculture domain including storing the harvest some they were looking forward only for monitoring the gas and humidity sensors and provide notification to the user which allows the user to take other measures in order to reduce these parameters. However, our system including an addition parameter of sensing light because a good store should receive enough light and also, we added features of monitoring light, heat and temperature by activating the actuators automatically if the corresponding parameter is exceeding.

4. Proposed solution

This system is designed to develop a very cost-effective solution to protect maize crops from post-harvest loss. It consists of different types of sensors like DHT11, MQ2, and LDR sensors, DC power supply is used to provide current to the entire system. All these sensors are connected to the ESP8266 Wi-Fi module. The system is monitored continuously using these sensors and modules. All the data such as temperature, humidity, gas leakage are collected from the sensors by the Wi-Fi module and it is uploaded to the Blynk Cloud where all these data processed. Ac lamps, fan are used as actuator one lamp is used to provide the necessary light in the stock once darkness is exceeded, another is used to monitor the necessary heat once the degree of coldness is low while fan is activated once heat is exceeding. The user will get a notification of all these parameters to the phone through the Blynk application. By implementing this system, we can prevent huge loss of crops in warehouse which will contribute a major part to help feed the empty stomach of needy.

5. Hardware component

- **DHT11:** The DHT11 sensor's humidity sensing component consists of a moisture-holding substrate with electrodes applied to its surface. When water vapor is absorbed by the substrate, ions are released, increasing the conductivity between the

electrodes. The change in resistance between these electrodes is proportional to the relative humidity: higher humidity decreases the resistance, while lower humidity increases it. The DHT11 sensor converts this resistance measurement to relative humidity using a chip mounted on the back of the unit, and then transmits both humidity and temperature readings directly to an ESP2866 [9].



Figure 1: DHT11 Temperature detector

- **LDR (Light depending resistance):** LDR (Light Dependent Resistor) as the name states is a special type of resistor that works on the photo- conductivity principle means that resistance changes according to the intensity of light. Its resistance decreases with an increase in the intensity of light. This is used to activate automatically the lamps during dark period [10].



Figure 2: LDR

- **Gas sensor (MQ2):** Monitoring gases such as carbon dioxide (CO₂) and oxygen (O₂) can help in detecting spoilage and respiration rates of stored maize. Sensors like MQ135 and O₂ sensors are employed for this purpose [11].



Figure 3: MQ2

- **NodeMcu 2866:** Based on the ESP8266 Wi-Fi transceiver module and the CH340 USB converter chip, this compact (Open Source) development and prototyping board is ideal for IoT applications. The Wi-Fi module is compatible with the 802.11 b/g/n standard at 2.4 GHz, has an integrated TCP/IP stack, 19.5 dBm output power, data interface (UART / HSPI / I2C / I2S / Ir Remote Control GPIO / PWM) and PCB antenna [12].

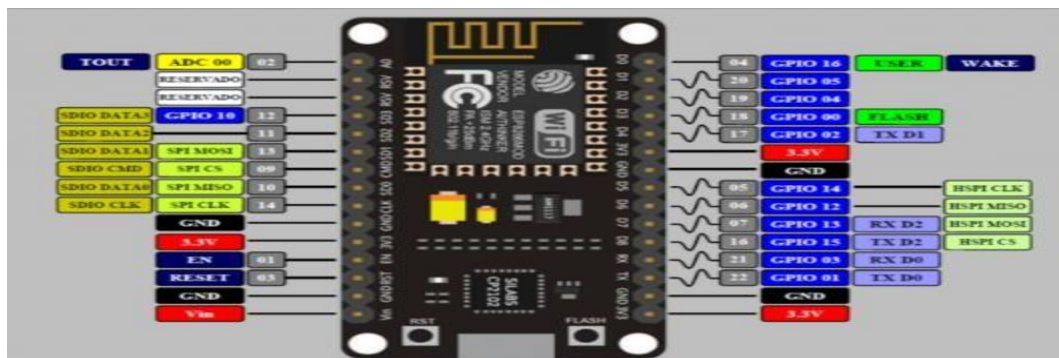


Figure 4: ESP2866

6. Design and implementation of proposed system

6.1. System architecture

The following block diagram shows the architectural design of our project; we have three sensors (LDR, MQ2 and DHT11). LDR is used to detect light and darkness in the store, once there is an exceed darkness the lamp presented by light will on. DHT11 is available for

detector two parameters temperature and humidity same as light depending resistor once the temperature is excessive in the room fan will be activated automatically. In addition, the gas sensor MQ2 is used in order to help the user to monitor the quantity of CO₂ available in the store. Furthermore, all these parameters the user will be able to view all data using mobile phone through the interface of cloud blynk application installed in the phone.

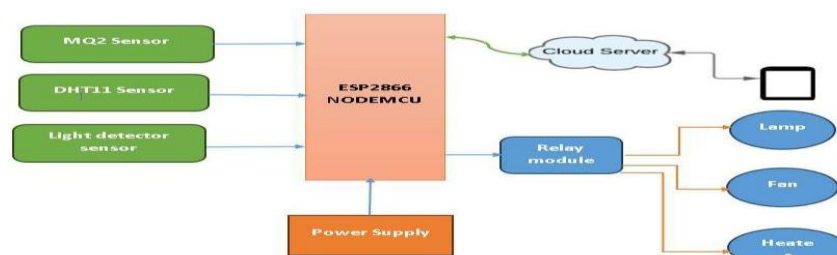


Figure 5: System architecture of proposed system

6.2. Circuit diagram

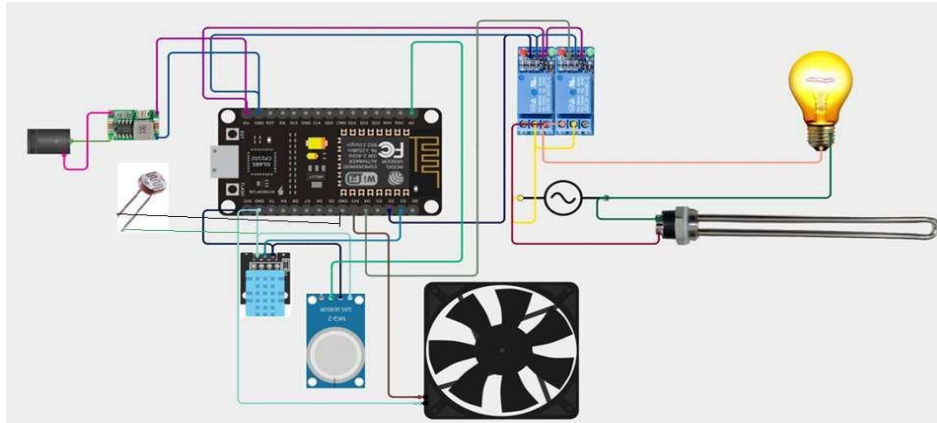


Figure 6: Circuit diagram

Working Principle of circuit

The IoT based Maize Crop Storage System operates by continuously monitoring key environmental parameters gas levels, humidity, and temperature within the storage facility to ensure the maize remains in optimal conditions. The system uses sensors to collect real-time data on these parameters, which are then transmitted to a microcontroller for processing and analysis. If the data indicates that any parameter exceeds predefined safe thresholds, the system automatically triggers corrective actions, such as activating ventilation fans to reduce gas and temperature concentration, turning on dehumidifiers to lower humidity, or adjusting cooling systems to

stabilize the temperature. This data is also sent to the Blynk cloud platform, allowing users to monitor the storage environment remotely through a mobile app. The Blynk platform provides real-time alerts if any issues arise, enabling quick responses to potential problems. The system continuously monitors the storage environment, logging historical data for further analysis and optimization. By integrating IoT technology and Blynk, this system provides an efficient, scalable solution to maintain optimal storage conditions, reducing the risk of maize spoilage and ensuring quality preservation. We can say that our hypothesis has been achieved where this system enabled the user to view all data collected by sensors through their phones.

6.3. Flow chart

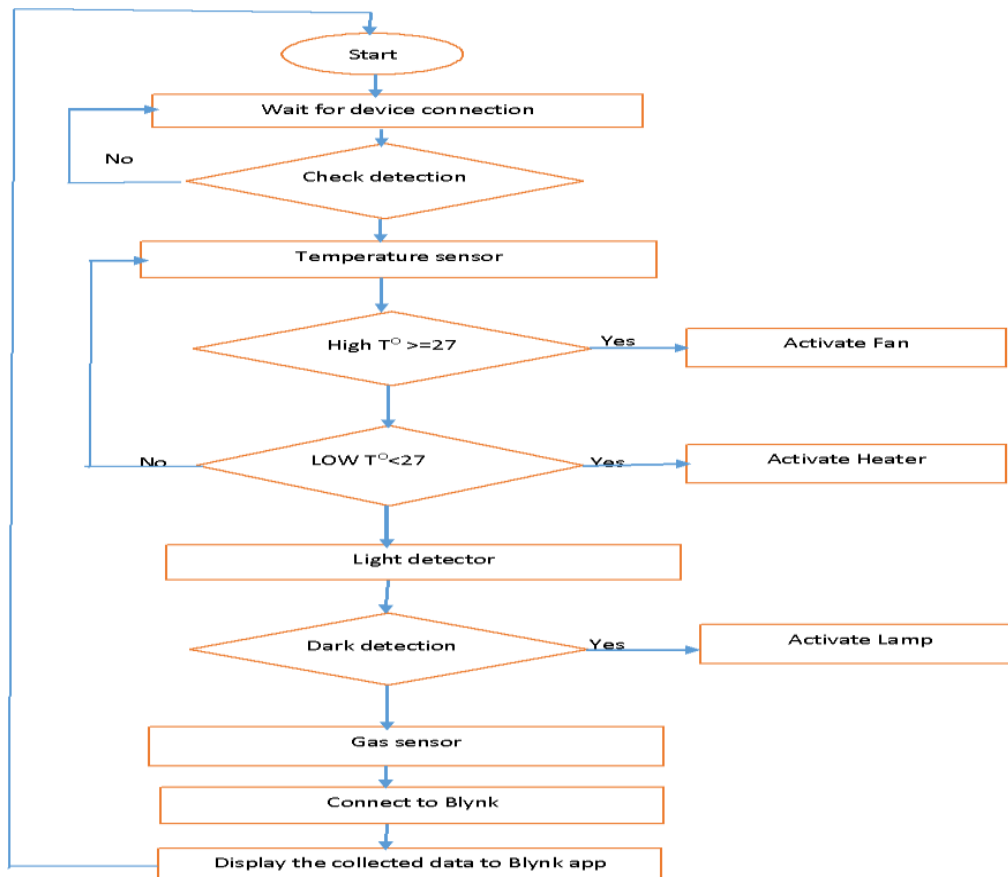


Figure 7: Flow chart

This flowchart shows all sequences according to the environmental condition available to the maize store and take the decision in order to monitor these conditions. At the starting point the ESP2866 detect and connect to the connection, after that the sensors starts to detect the 3 environment parameters (temperature, humidity, light and Gas). Therefore, the actuators (fan, lamp and heater) are activated by respecting the condition provided in the code.

7. Hardware Assembling

- **DHT11 connection:** As it is observed on circuit diagram the DHT11 is used as temperature sensor and humidity, once temperature becomes high (above 27 oc) the fan will be activated in order to reduce the degree of hotness in the store. When the temperature is below 27oc the heater will be activated in order to reduce the humidity in the store



Figure 8: DHT11 connection

- **Light depending resistor (LDR) connection:** LDR is a sensor that detects light or darkness, in our system we used LDR in order to be able to monitor the darkness in the store, when the light intensity is below 50% the lamp will be activated.



Figure 9: Connection of LDR

- **Gas detector connection:** gas detector (MQ2) is used to help the user to monitor the quantity of CO2 available in the store.



Figure 10: Gas detector connection

Connection of power supply to the ESP8266: The actuators we were using use 220VAC, we designed a regulated DC power supply that converts AC to DC in order to be able to connect ESP8266 to the power supply. In addition, relay module has been introduced in the system in order allow us to activate our actuators



Figure 11: Power

- **Actuators connection:** As we described before the actuators are working by respecting the condition determined in program and available condition in environment.



Figure 12: Actuator connection

8. Results of the Platform

A platform for the design and implementation of IOT based maize storage system serves as a critical interface to monitor key parameters such as gas levels, humidity, temperature and light within the storage facility. The platform enables users to stay informed about potential issues, track data specific to each storage unit, and engage in discussions, ultimately fostering a collaborative environment that promotes effective storage management and enhanced maize preservation. In addition our system has three actuators that are activated automatically in order to monitor all those parameters we stated above for better preservation of maize crop.

- Reading result using blynk cloud platform (web)

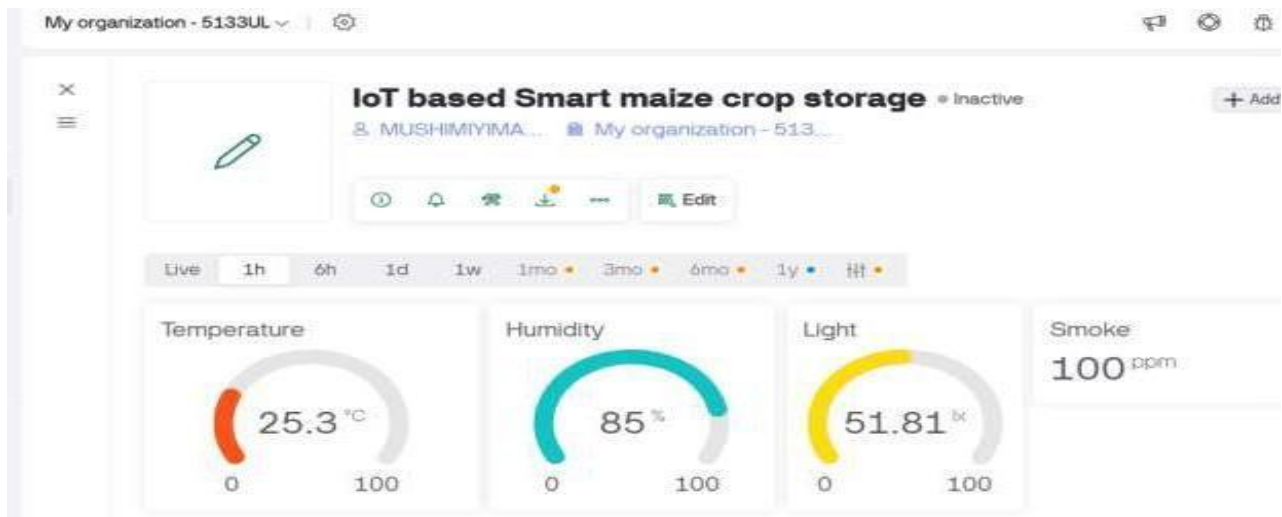


Figure 15: Reading Results on blynk cloud platform

Reading results using mobile phone



Figure 16: Viewing results using mobile phone

9. Future Enhancement

The warehouse of the future will take advantage of automated capacity management by leveraging technology for better data driven capacity planning. The result is fewer capacity planning errors that can lead to lost revenue and improved space utilization, which translates to a healthier bottom line. In current system we have shown only three sensors. In future, we can add two more sensors and system parameters. We can use web camera to capture live images or video and integration of GSM technology. It will help to see the actual condition of the product. Currently, the system is monitoring only three parameters and controlling two parameters but in future system it is possible to monitor and control more parameters and users can view the results through the GSM technology.

10. Conclusion

This project completes the design and implementation of IOT based smart maize crops warehouse. It also alerts the abnormal parameter variations, if any in the crop warehouse by a providing notification. It finishes the wireless communication between three sensors and ESP8266 and successfully, uploading the sensing data into Blynk Cloud. This is a more cost-efficient system which can be very beneficial, useful and can save time and labour. This will help us eradicate the hunger of people and aid in better economic value of crops. With the implementation of user-friendly user interface, the users can easily monitor the crops in the Warehouse without much effort. In future, this innovation can be used in several areas in different applications and many enhancements can be done so that it can be made available to all the sectors.

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