MAIS: An Architectural Design for Optimizing Corn Agriculture

Lee Carlo F. Simon

University of the Cordilleras, College of Information Technology and Computer Science, lcsimon@mmsu.edu.ph

This study aims to revolutionize corn agriculture by enhancing the monitoring and management of corn crops through the Internet of Things (IoT) and intelligent tools. The goal is to develop a comprehensive, farmer-centered architectural design that leverages IoT technologies. Using the design thinking methodology, the researcher engaged directly with corn farmers to understand their unique requirements. Through brainstorming and iterative prototyping, concepts were developed and tested to evaluate their effectiveness in real-world conditions. The findings indicated that farmer input is crucial for creating practical and effective IoT solutions. The study concludes with developing an architectural framework for a Monitoring and Analytics Integrated System (MAIS) device to help farmers understand the workflow and the relationships between different components. Once implemented, this device promises to significantly enhance agricultural operations by automating monitoring activities, increasing efficiency, and reducing labor costs, thereby improving crop management and productivity.

Keywords: Optimize, System modeling, System architecture, Block diagram, IoT, MAIS.

1. Introduction

The Internet of Things (IoT) has made it possible to access and link smart devices with each other online. By sending measured data from a wireless sensor network, various devices may be remotely monitored and controlled in response to the analysis performed in real-time [1]. This technology is particularly relevant in the context of smart agriculture, where it is used in seven key categories: smart monitoring, smart water management, agrochemical applications, disease management, innovative harvesting, supply chain management, and smart agricultural practices [2].

IoT devices and machine learning algorithms are being applied in precision agriculture, and the effectiveness of such equipment and algorithms on different spatial scales is discussed [3]. The GSM module can also provide real-time farm protection by notifying the farmer through an SMS in any alarming situation [4].

Though smart farming has an excellent scope in the future, it faces certain limitations related to implementation cost, data security, and the lack of sufficient digital knowledge among farmers [5], conducted tests on various IoT platforms, evaluating different studies in IoT designs to confirm data processing and display variations. Able to compare the platforms, considering attributes like cost, flexibility, and services, as well as aspects like price and convenience of connection and analysis and using the temperature sensor as an example explains how to configure these platforms for data collection and analysis and determine which is more suitable for a specific task or set of requirements [6].

The earlier work developed a wide range of intelligent agricultural systems. The research focuses on IoT technology, smart farming, and machine learning. Related works incorporate hybrid power supplies, IoT devices, cloud technology, and web and mobile applications. Table 1 summarizes some of these current systems for comparison.

Table 1. Previous Research Works in Terms of Purpose and Used Technologies

Reference	Research Purpose	Used Technologies
[7]	Creating a reliable hybrid power supply system for irrigation by integrating multiple renewable energy sources	Reliable hybrid power supply systems like solar photovoltaic (PV) panels, wind turbines, battery storage systems, grid connection, power management systems, smart sensors, and IoT integration
[8]	To develop an IoT-based smart crop-field monitoring and automated irrigation system to optimize agricultural practices.	Sensors – soil moisture, temperature, humidity, and other environmental factors. Wireless Sensor Networks (WSN), Microcontrollers (Arduino and Raspberry Pi), Cloud Computing and Automation Systems
[9]	To design and implement an IoT-based monitoring system that enhances agricultural practices by providing real-time data on various environmental parameters crucial for crop growth.	Sensors – soil moisture, temperature, humidity, and light intensity. Microcontrollers, Wireless Communication, and Cloud Computing.
[10]	utilizing Internet of Things (IoT) technology to create an effective system for automating water conservation in irrigation.	Sensors – soil moisture, temperature, and humidity. Power sources (like batteries or solar panels). Cloud computing and automated control systems are like a mobile app or a web-based dashboard.
[11]	Integrating Internet of Things (IoT) and Unmanned Aerial Vehicles (UAVs) in smart farming.	Sensors – soil moisture, temperature, humidity, and nutrient levels. Unmanned Aerial Vehicles (UAVs), Data Analytics and Machine Learning, LPWAN (Low Power Wide Area Network), and 5G

[12]	Developing and implementing an Internet of Things (IoT)-based monitoring system tailored for agricultural applications. The primary objective is to enhance farm productivity and efficiency through real-time data collection and predictive analysis.	Sensors – soil moisture, temperature, humidity, and light intensity. Wireless Communication (Wi-Fi) Cloud storage and machine learning
[13]	Integrating the Internet of Things (IoT) and machine learning (ML) to enhance agricultural practices.	Sensor – soil moisture, temperature, and humidity Hybrid Machine Learning Model Algorithm Usage like Extreme Learning Machine (ELM) and the modified Butterfly Optimization Algorithm (BOA)
[14]	Introduces an innovative approach to smart agriculture by leveraging IoT and cloud computing technologies and developing the CLAY-MIST system, which stands for Cloud-enabled Measurement and Monitoring.	Sensors – temperature, humidity, and soil moisture Cloud Storage Comfort Measurement and Monitoring (CMM) index
[15]	Integration of artificial intelligence (AI) and machine learning (ML) within the Internet of Things (IoT) framework to promote sustainable agricultural practices.	Sensors – soil moisture, temperature, humidity, and light levels Artificial Intelligence and Machine Learning
[16]	The advancements in Agriculture 4.0 integrate modern technologies to improve agricultural practices.	Sensors – soil moisture, temperature, and humidity AI (Artificial Intelligence), Drones and UAVs (Unmanned Aerial Vehicles)

Intelligent agriculture systems leverage various technologies to enhance corn yield, optimize resource use, and improve farm management. Devices are integral to these systems and play a crucial role in improving the efficiency and productivity of modern farming practices.

2. Methods

Design Thinking Methodology

The study employed a design thinking methodology to address issues specific to agriculture. Fig. 1 illustrates the process involving empathy, definition, ideation, prototype, and testing.

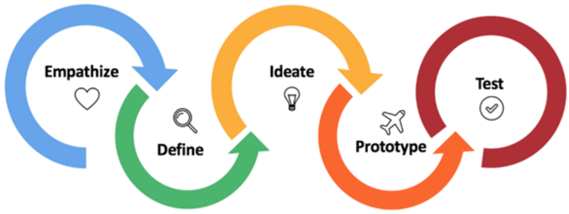

Figure 1. Design thinking development process

The study was conducted in the City of Batac, Ilocos Norte, to elicit the respondents' knowledge and practices of corn farming. The researcher selected Barangay Palongpong as the pilot barangay, and the researcher's farmer resided there.

1. Empathize

Through interaction with essential figures in the field, this method establishes a platform for listening to different needs and wants. It facilitates the development of creative, all-encompassing solutions to satisfy the intended corn farmer's needs. It aids in providing a solution that is accessible, inexpensive, and long-lasting [17]. The research utilized both formal and semi-structured interviews in addition to observations. The main goal was to understand corn farmers' experiences thoroughly. Additionally, the aim was to gather data regarding the challenges faced by corn farmers in managing and overseeing their farms.

As someone who has experienced the challenges firsthand, I understand the highs and lows of farming. I have observed and experienced various issues that impact corn yield, including pest management, weather conditions, soil quality, and resource access.

2. Define

In this phase, I have combined the knowledge I gathered during the empathy stage. I have collected and examined information to focus on the key issues that needed resolution [18]. As shown in Fig. 2, the research divided the issues corn farmers faced into three main categories. Information revealed that biotic and abiotic stress conditions and low-yield farming system approaches are only a few difficulties local corn farmer's encounter. The results above corroborate the research, which showed that several variables, including input, an unmechanized production process, insect infestation, and more, make up the difficulties that corn farming faces.

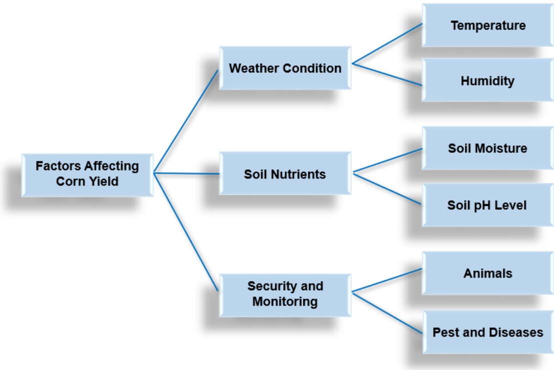

Figure 2. Categorization of Factors Affecting Corn Farming

3. Ideate

This phase involved generating ideas using defined problems. Paper sketches, scenarios, and mini-prototypes helped illustrate and visualize ideas [17]. The study optimizes corn agriculture by applying various diagrammatic techniques, including system modeling, architecture, and block diagrams. The study delves into system modeling concepts, detailing the agricultural system's logical relationships, processes, and interactions. The system architecture provides a conceptual blueprint outlining the structural and behavioral aspects of the monitoring system, highlighting key components and their interactions. Block diagrams simplify complex systems into manageable modules, illustrating the connections between the various sensors used to monitor the corn crop.

4. Prototype development

The ideas in the previous sections were prototypes for proper investigation, evaluation, and improvement. They were re-examined or rejected based on user experiences [18]. The aim was to understand better the constraints inherent to the solution and the problems at hand. The system modeling for optimizing corn agriculture shown in Fig. 3 generally identifies the different processes to improve agricultural techniques.

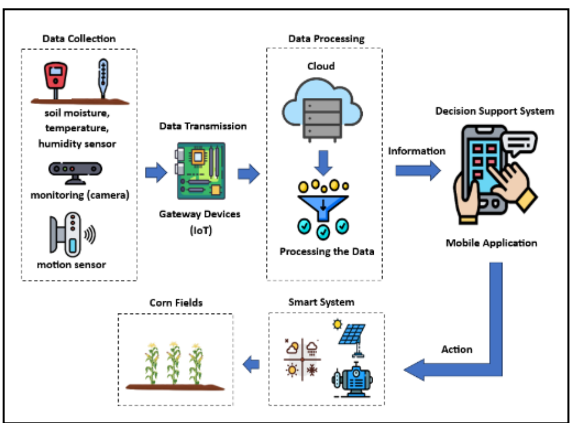

Figure 3. System Modelling for Optimizing Corn Agriculture

Software development for data collection and processing

Establish a network of interconnected sensors to monitor environmental conditions such as soil moisture, temperature, humidity, and light. This network should be capable of real-time data acquisition. Use IoT-tagged sensors to gather real-time data, providing farmers and researchers valuable insights for intelligent crop management. Implement innovative systems to analyze the vast amounts of data IoT devices generate. This helps identify patterns and make informed decisions. Develop a tailor-made IoT data platform that can handle the specific needs of agricultural data, overcoming the limitations of various IoT device vendors.

3. Findings

System architecture design

The integrated solution enables farmers to solve the challenges by utilizing cutting-edge technologies like the Internet of Things (IoT), mobile applications, and cloud storage. Through user-friendly mobile applications and a secure cloud database, the system architecture shown in Fig. 4. The system architecture implemented with a generated database offers helpful insights and recommendations to farmers, including animal and pest monitoring, temperature, humidity, soil moisture, and watering control.

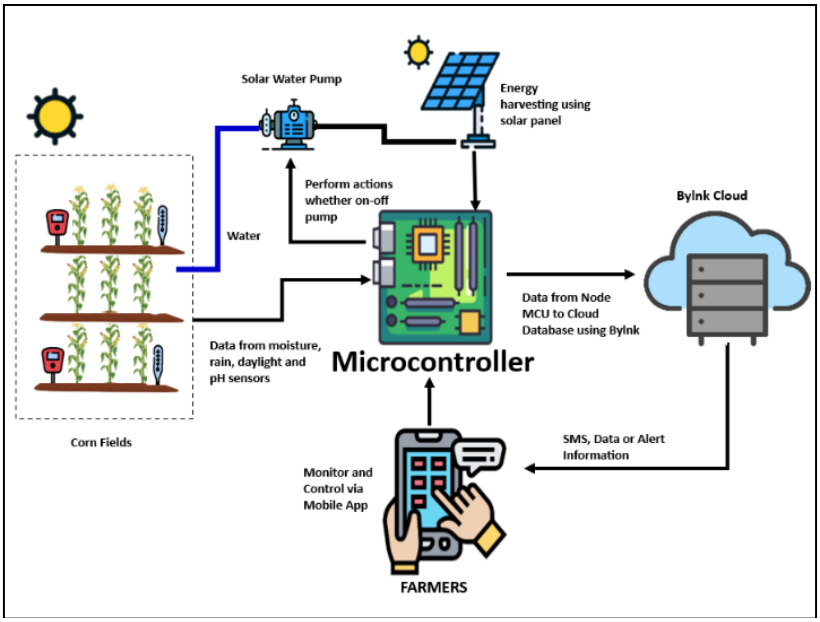

Figure 4. System Architecture for Optimizing Corn Agriculture

Real-time monitoring and data collection are possible, enabling accurate decision-making and ensuring optimal resource allocation. Farmers may gain from higher productivity, decreased expenses, and enhanced general agricultural management by implementing the model. Farmers can obtain up-to-date, accurate information and make decisions to increase productivity, reduce waste, and improve their farming techniques.

Block Diagram

This block diagram represents the systematic approach to optimizing corn agriculture through data collection, processing, analysis, decision-making, monitoring, and evaluation. Each stage ensures corn crops' most efficient and sustainable growth. It helps identify and focus on the key components and stages of the study, such as environmental sensors, data storage, analysis models, and automated systems. This guarantees the inclusion of all crucial elements.

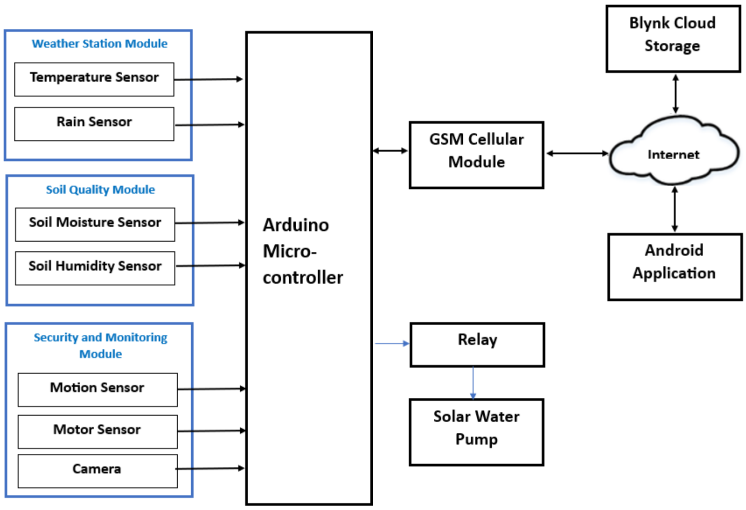

Figure 5. Block Diagram for Optimizing Corn Agriculture

It provides a clear and concise visual representation of the entire process, from data collection to outcome evaluation. This helps farmers understand the workflow and the relationships between different components.

Hardware requirements.

Table 1 of earlier research efforts highlights a variety of technologies often used to improve agricultural practices, with a particular emphasis on the Internet of Things (IoT). First, the sensors play a crucial role across multiple studies. Second, this data will be processed, and automation systems will be managed using microcontrollers. Cloud computing is the third technology, offering strong processing and storage capacity for the enormous data that sensors gather. Fourth, the power management systems provide a reliable power source for these IoT devices. Lastly, automation systems, often controlled via mobile apps or web-based dashboards, streamline agricultural operations by leveraging real-time data to automate processes like irrigation.

Hardware requirements

In the current related work on intelligent agriculture systems, standard devices include:

1. Sensors

Temperature Sensor

A temperature sensor measures the degree of hotness or coldness in an environment. These analog or digital sensors are widely used in various applications, including weather monitoring, HVAC systems, and industrial processes [8].

Motion Sensor

A motion sensor detects physical movement in a given area. These sensors are often used in security systems, automatic lighting, and various smart home applications. They can detect motion using infrared, ultrasonic, or microwave technologies [16].

Soil Moisture Sensor

A soil moisture sensor measures the volumetric water content in the soil. These sensors are essential in agriculture for monitoring soil moisture levels to optimize irrigation and ensure proper plant growth [9].

Humidity Sensor

A humidity sensor measures the amount of water vapor in the air. These sensors are used in weather stations, HVAC systems, and various industrial applications to monitor and control humidity levels [8].

Soil pH Level Sensor

A soil pH level sensor measures the acidity or alkalinity of the soil. This information is crucial for agricultural purposes, as different plants require specific pH levels for optimal growth. Maintaining proper pH levels helps in nutrient absorption and overall plant health [11].

2. Microcontrollers

Arduino

With IoT integration, Arduino allows farmers to remotely monitor and control various agricultural systems using smartphones or computers, enhancing convenience and efficiency [9].

3. Cloud computing

Blynk Cloud Platform

Blynk Cloud Platform remotely monitors, controls, and automates processes [8].

4. Power Management Systems

Solar Panel

Solar panels provide a continuous power supply to sensors and IoT devices deployed in fields, ensuring uninterrupted monitoring of soil moisture, temperature, humidity, and other environmental factors [7].

Battery

Batteries store excess energy generated by solar panels during the day. This stored energy can be used at night or on cloudy days, ensuring the continuous operation of agricultural devices and systems [10].

5. Additional Device

Camera

Cameras capture high-resolution images and videos of crops to monitor their growth, health, and development. This helps identify issues such as pests, diseases, and nutrient deficiencies early on [18].

Buzzer

Buzzers are used as auditory alert systems to notify farmers and workers about various conditions and events [8].

4. Conclusion

The architectural design for optimizing corn agriculture through IoT sensors presents a transformative approach to modern farming practices. Corn farmers in Batac, Ilocos Norte, can significantly improve crop yield, resource efficiency, and sustainability by harnessing real-time environmental monitoring. Integrating advanced sensor technology allows for precise data collection on soil moisture, temperature, humidity, and other critical factors, enabling timely and informed decision-making. The Monitoring and Analytics Integrated System (MAIS) device addresses the specific needs of corn crops in the region and sets a precedent for the broader application of IoT in agriculture. This innovative approach can ultimately enhance agricultural productivity, promote sustainable farming practices, and contribute to the region's economic growth.

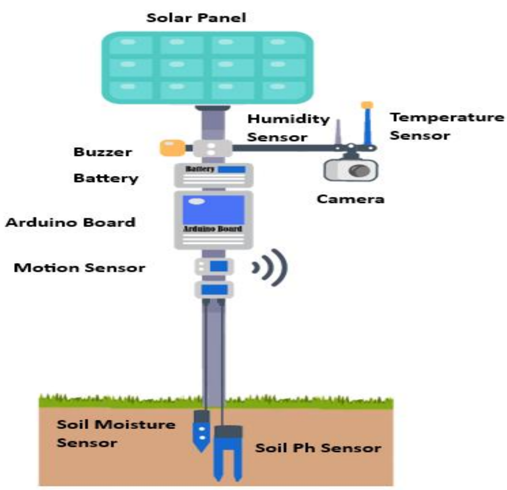

Figure 6. Monitoring and Analytics Integrated System (MAIS) device.

The depicted Monitoring and Analytics Integrated System (MAIS) device showcases a sophisticated device designed to enhance agricultural operations' efficiency for corn farmers significantly. This device provides real-time environmental monitoring by integrating various sensors such as soil moisture, pH, humidity, temperature, motion sensors, camera, Arduino board, and solar panel for sustainable energy. This innovative device allows corn farmers to precisely monitor critical parameters affecting crop growth, thereby optimizing water usage, ensuring ideal soil conditions, and detecting potential crop threats. The automation of these monitoring activities reduces the need for manual labor, leading to lower operational costs and increased productivity. Consequently, adopting the MAIS device is poised to revolutionize traditional farming practices, offering a more sustainable and efficient approach to agriculture.

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