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DEVELOPMENT OF AN IoT-BASED PEST SURVEILLANCE AND CONTROL SYSTEM

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ABSTRACT

Management of pests in rice farms is an important task in agriculture; birds are known to be a serious pest to rice farms as this has greatly affected and prevented the high yield of this plant at the end of the planting season. While the Internet of Things (IoT) seamlessly integrates into our daily lives by allowing network-based control of electronics, its impact on agriculture is truly transformative. This research presents a solution: an efficient agricultural monitoring and control system designed to repel and chase birds from rice fields while offering a live stream for real-time farm observation. The system uses a sensor, ESP32 camera, IoTs and a buzzer in which the sensor senses the bird's path and sends the information to IoTs for processing; the processed information turns the buzzer on to scare the birds away and sends a message to the farmer through WIFI technology. The farmer receives the message through the Android mobile app and views the farm's stream using an IoT IP address through the webpage. This work analyses the existing systems for bird's surveillance and control in rice farm and develop a system using IoTs integrated with an android based application with an in-built mobile module for providing automatic monitoring and control of the presence of pest in rice farm.
Keywords: Intelligent System, Internet of Things, WiFi technology, Monitoring, Firebase

1. INTRODUCTION

Internet of things (IoTs) is a recent technology that has experienced a lot of applications in various fields because of its application, it plays vital roles in health care, education, engineering and agriculture to monitor the growth of plant, to generate farm report, weather report station [1]. Also useful in controlling various farm equipment such as water irrigation system, rice planting and to control birds in rice farm and Beyond birds, the Internet of Things (IoT) offers solutions to deter a wider range of animals that can disrupt crops and livestock. In essence, IoT connects physical objects embedded with Wi-Fi, networking, and computing capabilities, allowing them to communicate with each other and access services over the internet. However, the application of IoTs is major concern in agriculture, more technology has been intensified on agriculture for proper development, growth and increase in farm product.

Rooted in the earliest civilizations, agriculture has undergone a continuous transformation to enhance crop yields and quality. The introduction of machinery and innovative tools, such as irrigation systems, harvesters, and land clearing equipment, marked a significant leap forward from the dawn of agriculture, which relied primarily on human and animal labour [3]. The rate at which technology are used in agriculture today for proper control, monitoring in order to have large turnout of production beyond expectation. Recent technology has contributed a lot to development of major equipment used in the country, most especially in agriculture environment such as farm equipment, fertilizer and chemical [4]. Rice has been the major food many country depends on, the demand for rice is higher than any other farm product because of its consumption, most especially in Nigeria where the citizen depends on it more than any other food. The production of rice in Nigeria is low owning to some difficulties the farmer face in term of pest such as birds. Birds are dangerous pest to rice production because of their activities during the milky stage in rice production. The birds are highly motivated during this stage which often cause loss to the farmers, primitive methods have been adopted to curb the situation but it faces different challenges in term of stress and also difficult to practice. To solve this problem, this paper proposes an efficient agriculture monitoring and control system using internet of things (IoTs).

The Internet of Things (IoT) is revolutionizing agriculture, offering farmers a multitude of benefits. By implementing IoT-based monitoring systems, farmers can optimize resource use, leading to reduced costs and increased crop yields. This intelligent approach leverages information and communication technology to manage all aspects of agricultural operations. Several studies have been investigated on monitoring and controlling of rice farm. The work considered in [5] developed and tested a solar-powered bird deterrent that uses predator sounds. Their design included a solar panel, battery backup, sound player, amplifier, and speaker. They found that the effectiveness depended on choosing the right predator call, high-quality sound, and even the camouflage of the device itself. Interestingly, tests showed that birds would try to locate the speaker to verify if it was a real threat. Among the 22 sounds tested, falcon calls proved most effective, particularly for crows. Additionally, the scarer's performance was influenced by weather conditions, with better results on sunny days.

Another study [3] explored a bird detection and repellent system using an Arduino Uno and an Android app. This system relied on a PIR sensor to detect bird movement, triggering an ultrasonic repeller controlled by the Arduino. The repeller's frequency could be adjusted by modifying a capacitor value. This research highlights the ongoing evolution of the agricultural sector, continuously adapting to advancements in automation for improved efficiency. The repeller utilizes a Piezo Ultrasonic Transducer, acting as both a transmitter and buzzer. This component generates ultrasonic waves using an LC oscillator circuit. The study identified a frequency range of 28 kHz to 60 kHz as effective in deterring birds, with the prototype set at the higher end of this spectrum (60 kHz). Building on the concept of using sound as a deterrent, another study [6] developed a solar-powered bird repeller system. This system features a solar panel for charging, a battery for backup power, and an MP3 player loaded with predator calls and distress sounds. An Arduino Uno microcontroller controls the system, triggering speakers to play these sounds upon bird detection by PIR or sonar sensors. The researchers propose further exploration of image processing for even more sophisticated bird identification.

The work of [7] explored a novel ultrasonic bird repeller using variable frequencies (15 kHz to 25 kHz) inaudible to humans. This solar-powered device successfully generated and broadcasted ultrasonic waves, creating an unpleasant environment that repelled targeted birds like weaver birds and blackbirds. The effectiveness increased with device power, covering larger areas (up to 429.53 m^2 for the most powerful version). Notably, the repeller did not affect quelea birds. While the range was limited, the study suggests ultrasonic waves can be a viable option for bird control, particularly when combined with other methods. In another study considered by [8], an embedded intelligence was proposed Embedded intelligence in agriculture sector includes smart farming, smart crop management, smart irrigation and smart greenhouses. The author in [9] delves into the breakdown of IoT gateways in agriculture. They identify key components like sensors, actuators, interfaces, and wireless links that facilitate communication within the system. This emphasis on communication frequency and bandwidth requirements is crucial for optimizing automation in agricultural applications.

Building on the concept of automation, another study ([10]) proposes a multi-functional agricultural robot. This robot, equipped with GPS and remote control, can perform various tasks including weeding, spraying, moisture sensing, and deterring birds and animals. Additionally, it offers smart irrigation features, automatically adjusting water delivery based on real-time field data. Finally, the system incorporates smart warehouse management, regulating temperature and humidity while ensuring security through theft detection. All operations are controlled remotely via a smartphone or computer connected to the internet. The robot itself utilizes sensors, Wi-Fi or ZigBee modules, a camera, and actuators interfaced with a microcontroller and Raspberry Pi for functionality.

2. MATERIALS AND METHOD

The material and methods used for the implementation of the design are discussed in this section.

2.1 System Design

The system design for the intelligent agriculture system consist of software and hardware module separately. The design system seems complex hence, a modularity method was adopted to break the large system into sub-system according to function each module performs. The stipulated objectives was used to achieve the aim of this research work for target expected result. When the system is powered on, the regulated 5V supplies power to the ESP8266, ESP32 and pest sensor. The written program code executes to initialize the whole system and operation commenced.

The compiled hex file embedded in ESP8266 initialized and established Wi-Fi and Firebase to gain proper access to internet service, ESP8266 configured as base station which access all other mobile phone to connect. It connects to the internet through a shared hotspot. When the pest sensor senses the birds, it transfers pulse generated to the ESP8266 for processing, after the signal has been processed then the buzzer produce heavy sound to scare the birds away and notification message is sent to the rice farm owner through internet on its mobile phone app. However, the farmer receives the message which inform him to enter camera IP address to view the stream video of the whole farm, that is, farm surveillance. The ESP8266 was linked to the Firebase database through its address. The mobile application is connected to the Firebase database through the database address.

2.2 Software Module

The software implementation includes the development of the user interface. The user interface is a graphical interface where the system user interacts with the system. This development was done using MIT Inventor for development. MIT Inventor is online android application development that assist in designing android app, it consists of difference component which aid in the design. It contains block of codes which are drag and drop arrangement block of code as shown in Figure 1. For seamless communication between the hardware module and user devices, a software application was developed using MIT App Inventor. This app leverages Firebase, a cloud-hosted real-time database, enabling secure two-way communication. The user interface allows receiving messages transmitted directly from the hardware module.

2.3 System architecture

This system architecture is sub divided into different functional components, which are processing unit, connectivity unit and communication unit.

2.3.1 Processing Unit

The ESPMCU8266, a microcontroller unit acting as the system's central processing unit (CPU), receives sensor data and performs the required calculations to make decisions and control the system's activities.

2.3.2 Sensor Unit

The pest sensor is the major component is this unit, it is responsible to take input from approach birds and send the pulse generated inform of information to microcontroller for execution.

2.3.3 Connectivity unit

The connectivity unit is used for the transmission of user command between the mobile device and the automated system. Real time database known as firebase establish communication between the two devices, it receives data from NODEMCU8266 through internet and mobile retrieve message from firebase database to alert the farmer.

2.4 Hardware Module

Figure 1: Application Software for the Proposed system

To obtain +5V from the mains 220V A.C, 12V step down transformer was used and convert it from alternating current to pulsating direct current with aid of diodes arranged in square form. A capacitor is placed across the positive and negative terminals of the 12V input to potentially reduce voltage ripple. The positive terminal of the capacitor was connected to the input terminal of the LM7805 voltage regulator. The positive output terminal of the LM7805 (supplying the regulated 5V) was connected to the positive terminal (VCC) of both the ESP8266 and ESP32. The ground (GND) pins of the ESP microcontrollers are both connected to the ground (GND) of the power supply. The output from sensor was interfaced with D6 of ESP82266 while Vcc pin is connected to output +5v power supply and GND pin is connected zero voltage of power supply. The pest sensor output was connected to the D2 of ESP8266 while both Vcc and GND pin were connected to their respective source. The buzzer was connected to the D2 for audible sound to be heard while ESP32 camera was connected separately to Vcc and ground for video stream.

3.5 *Experimental Setup*

The NodeMCU (ESP8266) is a selected microcontroller for this system owing to its size and compatibility with other sensors. The NodeMCU was connected to the GPIO pins of the NodeMCU as input to denote input signal. This input signal set flag in NodeMCU to send message to the cloud since is using Local Wi-Fi and shared host spot which is capable of receiving and sending signal via the internet. The developed mobile application software was installed on the mobile device which is capable of receiving message from cloud server. The ESP32 was accessed by typing IP address on Uniform Resource Locator (URL) with internet access which enable the camera interface to commence, the platform allow various operation to take place such video stream.

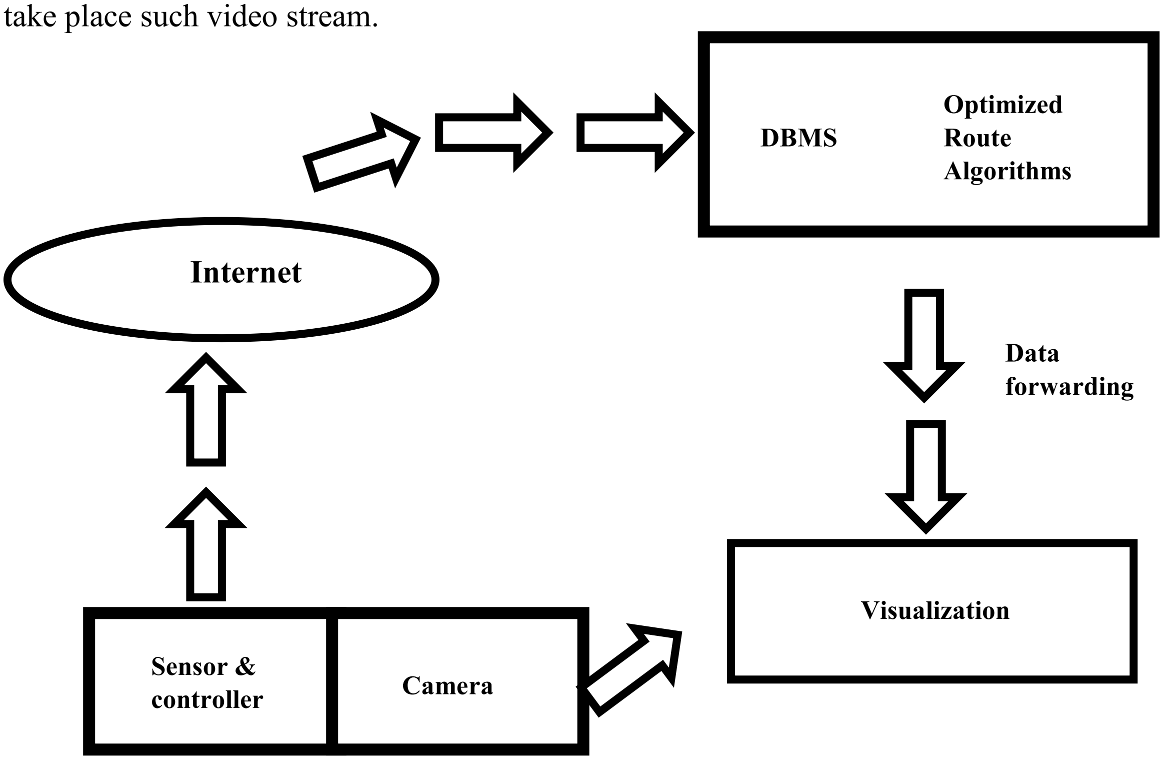

Figure 2: System Architecture

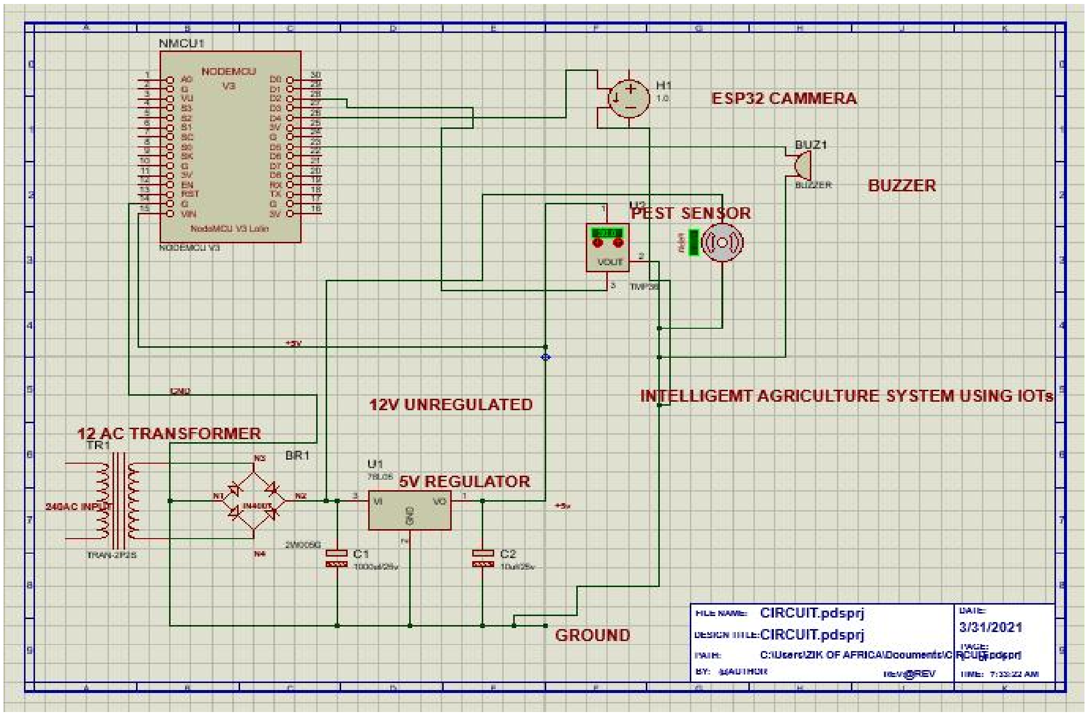

Figure 3: Circuit Diagram of the IoTs-based Control System

4. RESULTS AND DISCUSSION

The system performance was tested using rice farm area where the system was mounted at the edge of the farm at least 3 feet above level ground. Figure 4 shows the system buzzer where the sound comes out to scare birds. Figure 5 shows mobile application where farmer receive messages. Figure 6 shows camera where farmer watch video stream online, shows the interface for video stream and Figure 7 shows the breadboard developed circuit. The system uses PIR sensor to sense the presence of birds. The system design was evaluated based on the response time, that is, the time PIR sensor response to detect birds and the time taken for the farmer to receive massage. Average time of the whole system process iteration process was taking as the system response time as at when the system is connected to the internet. Response time in Table 1 depicts the system's time response that evaluates the efficiency of the system. The data were collected for four days viz morning, afternoon and evening with stop watch, Table 1 shows the data collected in the morning of the four days (1ms, 1ms, 1.1ms and 1ms) and also for afternoon and evening respectively. The mean value of morning, afternoon and evening were calculated to validate the reliability of values collected for the system using Equation 1. However, the same process was used to calculate the mean value of afternoon and evening respectively. The result in Table 1 were plotted using dot response time graph for day1, day2, day3 and day4 to correlate the changes that take place in response to time of the system. The calculated mean value in figure 6 also plotted using dot graph to correlate the value with the value in response time in Table 1. Figure 8 shows the result output of the system in terms of response time. The results show that the margin in between the response time of the system is relatively small which indicates that the efficiency and functionality of the system at any particular weather still prove good and can be trusted for the purpose the system is designed for.

$$Mean = \frac{\text{sum of morning values in ms}}{\text{sum of days}} \quad (1)$$

Table 1: Response Time Mean value for the system

Time	Mean value
Morning	1.025ms
Afternoon	1.325ms
Evening	1.15ms

Table 2: Response Time of the System

Time	Day1	Day2	Day3	Day4	Mean
Morning	1ms	1ms	1.1ms	1ms	1.05ms
Afternoon	1.4ms	1.3ms	1.4ms	1.2ms	1.33ms
Evening	1.2ms	1.1ms	1.1ms	1.2ms	1.15ms


Fig. 4: Bird Repeller used for the system

Fig. 5: Mobile Application of the

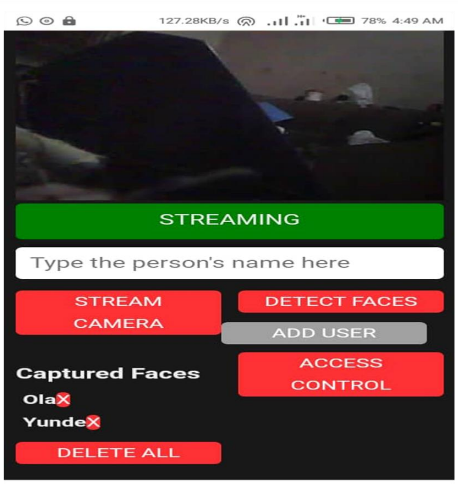

Fig. 6: Video Streaming

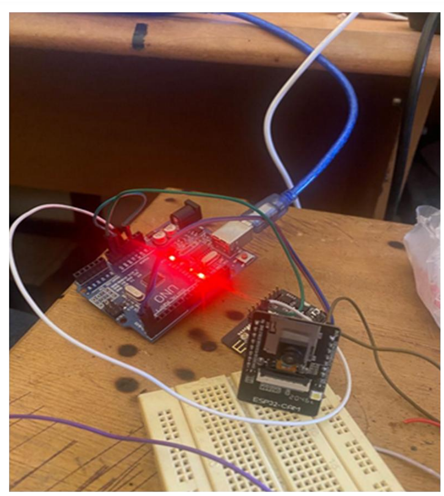
Fig. 7: Breadboard Circuit Design

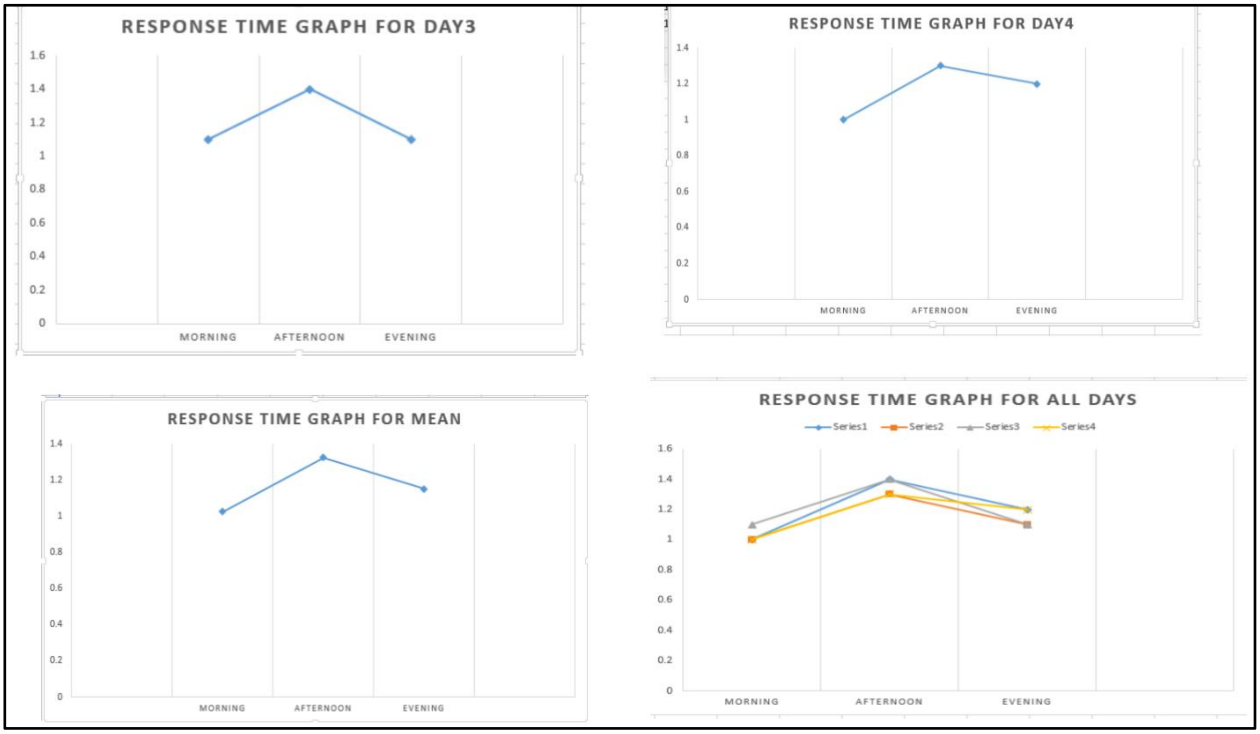

Figure 8: Result Output of the System for Response Time

5. CONCLUSION

In this study, the mobile cell phone has been successfully used to receive farm report from the system device placed in the farm and the esp32 camera send clear video stream to the farmer. The farmer can watch the video stream using IP address enter in URL and receives message from farm with mobile app developed with MIT inventor which serve as interface that connect the farmer to the device. Cloud server play vital role in the design, is a repository that connect both hardware and mobile cell phone. The esp8266 was used because of it capability to utilize Wi-Fi needed by the system and has availability of resource to lunch to internet through share hotspot. The developed NODEMCU contains TCP/IP protocol stack that allows connection through commands. The IoTs intelligent agriculture system was developed and connected to real time database popularly known as firebase which saves data from hardware and create measure for software application developed to retrieve it. The developed system was tested and evaluated using the response time.

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