DESIGN AND IMPLEMENTATION OF SMART FARM IRRIGATION WITH INTRUDER DETECTION SYSTEM

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ABSTRACT: Agriculture has been one of the significant sectors in the Nigerian economy due to its contribution to the development of the country; however, there is a need for a more efficient way of Irrigation and security. Traditional ways of irrigating the farmland are not efficient, as it leads to wastage of water resources, and some fungi crop diseases due to excess soil moisture content. Security is also crucial in agricultural practices, the security of crops against the attack of pests and diseases as well as that of the farmers during agricultural operations. The application of the Internet of Things can solve the problem regarding irrigation and security in agriculture thereby securing more productive and safe agricultural operations on the farm. A functional smart Irrigation system with Intruder detection which gives farmers access to remotely check soil moisture values on the farm, automatically control the irrigation process, and monitor movement around the farm through images captured on the farm to detect an intruder has been developed in this study. The developed prototype is a blend of various hardware modules and software programs controlled using the Internet of Things (IoT). The system is made up of a DC pump, capacitive soil moisture sensors, ESP32 cam, PIR sensors, and the ESP32 microcontroller. The soil moisture level determines when the pump will be turned ON or OFF automatically for irrigation to occur. The images captured by the ESP32 cam are saved on a memory card and also displayed on the IoT platform. This prototype behaves in an intelligent way which is sufficient for modern smart farming, by eliminating manual labour involved in the irrigation process and also detecting intruders on the farm, thereby reducing the time and cost involved in the manual monitoring and irrigation of the farm.

KEYWORDS: ESP32, Internet of Things, Intruder Detection, Irrigation, Microcontroller Sensor.

INTRODUCTION

Irrigation is a vital process that involves the artificial way of getting the soil watered for proper and improved growth of the plant (Venkateshkumar *et al.*, 2022). It has been determined that one of the best methods to increase crop yield and food security is through adequate irrigation. The plant must be provided with the correct amount of Water at all times, it must not be excess or insufficient as this not only wastes the available water resources, but it also inhibits the plant growth. Proper and adequate Irrigation is necessary for improved growth of crops, increased soil fertility and improved yield of crops (Olaniran & Ojo, 2019). Traditional ways of irrigating the farm include the use of sprinklers, drip or furrow methods of irrigation or manual labour. However, all these aforementioned methods are not accurate as the crops might be over-irrigated or under-irrigated due to human error and inaccurate weather prediction by farmers (Pradeep *et al.*, 2019). Due to this reason, creative strategies to enhance irrigation in Nigeria are required, which can be achieved through the implementation of a smart Irrigation system. This will not only allow the accurate monitoring of the soil content but also the supply of sufficient water to the plant. Several sensors can be used to measure soil moisture, light intensity, temperature, and humidity, then the measured values can be connected to systems to start alarms or automate tasks like air and water control. By utilizing the Internet of Things (IoT) to monitor temperature, humidity, rainfall, and soil efficiency, we may anticipate a low-cost rise in production, through the effectiveness of fertilizers, monitoring water tanks' storage capacity, and detecting theft in agricultural areas. Using soil monitoring devices, farmers can forecast crop yields, and carry out easy and automated irrigation (Fernado *et al.,* 2021). The IoT-based irrigation system ensures that water is properly managed, as the irrigation of the farmland is carried out with the minimum amount of water (Halit *et al.,* 2022). With the Internet of Things (IoT), agricultural practices such as planting, weeding, and harvesting are made modern and simple, leading to increased productivity, driving new revenue streams, increased safety, time-saving, improved farming efficiency and agricultural sustainability. Over the years, farmers have different ways of detecting intruders on the farm some of which include the use of traps, electric fencing of the farm, and the use of poison, chemicals (Panda *et al.,* 2022). But as good as these methods are, they have their drawbacks, for instance, the electric fence might lead to the death of anyone including those working on the farm, these methods are not reliable, which gives rise to the need for a more effective and smart devices for the control and detection of Intruders on the farm (Shaikh *et al.*, 2021). Research has explored various sensors, including motion sensors, vibration sensors, infrared sensors, and magnetic sensors. These sensors are used to detect unauthorized activities or intrusions in different areas of the farm. The integration of multiple sensors, and cameras allows for enhanced detection accuracy and reduced false alarms (Huang, 2014). As security is becoming a major concern in Nigeria, Motion sensors, cameras, Internet of Things can be incorporated into the farm to monitor movement and activity. The farmer is alerted every time someone visits the farm, this makes the farmers feel secure knowing that their crops will yield an abundant crop through the security monitoring system. This project is aimed at solving the drawbacks involved in the traditional ways of Intruders detection and also providing a smart and reliable irrigation system on the farm. This paper focuses on the development and implementation of a smart Irrigation system coupled with an intruder detection system using IoT technology. Many researchers have adopted the use of the Internet of Things (IoT), for accurate and precise control and smart monitoring of farm irrigation. Also, some have incorporated the same technology in the development of smart security systems on the farm. Some related research work has been carried out successfully some of which include the following: Mohammed *et al*. (2021) proposed an autonomous irrigation system using IoT and artificial intelligence. Different sensors were used to collect air humidity, air temperature, and soil moisture, then the values were sent to the NODEMCU microcontroller. These data values use machine learning algorithms to determine those that are accurate, before comparing them to another set of data obtained from the cloud, after the comparison, the microcontroller determines if the farm will be irrigated or not. The real-time monitoring report will be sent to the cloud for farmers to monitor the condition of their farmlands. Godsent *et al.*(2023) developed a Smart Irrigation System with Integrated GSM and Wifi Control which monitors and controls the level of moisture in the soil using a moisture sensor, GSM module, water pump and the NODEMCU IoT module. The moisture of the soil provides a means of automatically controlling the water pump, a pre-set value of 20% was used whenever the moisture level reached this percentage (20%). The pump turns on automatically, to irrigate the farm the user can control the device using the SMS feature. The SMS received by the user corresponds to the irrigation status. Ogedengbe *et al. (2020)* developed a model and sensor-based smart irrigation system. In the study, the system makes use of the feedback from sensors and a predicted rainfall model to control the irrigation process. The data obtained from temperature, soil moisture and humidity sensors are integrated with the controller to monitor the predicted rainfall which are communicated to the controller via the SIM module, located in the controller. The data from the sensors are also displayed on a Liquid Crystal display when the soil moisture content drops below 30% and the rainfall status shows that rainfall is null, that is rainfall is not expected, the pump for the system is activated and irrigation occurs with water gaining entrance into the farm through the sprinkler, this goes on until the maximum value of the moisture content is reached. When the upper limit is reached, the Pump is deactivated. Suma *et al.* (2017) worked on an IoT-based Smart Agriculture Monitoring System, the project includes various features like GPS-based remote-controlled monitoring, moisture & temperature sensing, intruder scaring, security, leaf wetness and proper irrigation facilities. It uses wireless sensor networks to detect soil properties and other environmental factors continuously. These sensors are located at different locations on the farm. The measured parameters are monitored through any remote device or internet services, and controlled by the PIC microcontroller 16F877A. The project has an android application where farmers have access to monitor, the temperature, humidity, soil moisture, and animal detection. Also, the farmer can control the irrigation of the farm via the Android application. Panda *et al*. (2022) designed a smart intruder control system that utilizes IoT technology, the system has an electric fence, an alarm system, a dead zone and a real-time system for monitoring movement and detecting Intruders, which enables farmers to remotely monitor the ongoing activities on the farm. The system has cameras attached at strategic places and an IoT Wi-fi module which behaves intelligently. The farmer makes a decision based on the feedback from the attached IP camera. Whenever motion is detected, the farmer gets notified on his smartphone, and he has the opportunity to properly view what is going on the farm, the farmer can issue a warning sound via the alarm system, and whenever the Intruder refuses to desert the farm, the electric fence is triggered, this stay on for 20 seconds. Although the system can detect intruders, it is unable to state the type of Intruder detected via the notification, unless the farmer checks the IP camera. Baranwal *et al*. (2016) proposed an IoT-based smart security and monitoring device for agriculture, the proposed work will provide complete security for the storage area of the farm. The system will be capable of detecting fire outbreaks and, the movement of Intruders on the farm and take appropriate actions before notifying the user. The data collected by the sensors is transferred to the cloud through the Raspberry Pi which is accessible to the user.

MATERIALS AND METHOD

Materials

The developed smart farm irrigation with Intruder detection system prototype essentially demonstrates the application of IoT and it entails the use of appropriate sensors to obtain the moisture level of soil to automate the irrigation process and also to monitor motion on the farm to detect Intruder. The prototype was designed to be efficient and must be able to show the application of IoT techniques in the irrigation process and motion monitoring on a farm. The prototype was also considered to be easy to use and maintain. The prototype is a blend of hardware modules and software. The system was developed using embedded C on the Arduino Integrated Development Environment.

Hardware used

The system consists of a DC pump, PIR sensor, Capacitive moisture sensor, ESP 32 cam, Buzzer, 5V valve, and the ESP microcontroller.

ESP32

This is a board of low-cost, low-power system-on-a-chip microcontroller as shown in Figure 1. It is capable of dual-mode Bluetooth and integrated Wi-Fi communication. It is the ESP8266 microcontroller's replacement. The specification of the microcontroller is shown in Table 1.

Table 1 - Features of ESP32

Feature	Description
Function	Microcontroller with Wi-Fi and Bluetooth
Processor	Tensilica Xtensa LX6
Connectivity	Wi-Fi, Bluetooth
Memory	Memory: 520 KB RAM, 448 KB ROM
Power Consumption	Low-power design

Figure 1: ESP 32

ESP 32 cam

ESP 32 cam as shown in Figure 2, is a camera module with low power consumption which is suitable for mobile devices, wearable electronics, and Internet of Things applications such as; wireless positioning system signals, Industrial wireless control, wireless monitoring, and smart home applications. The specification of the module is presented in Table 2.

Table 2 - Features of ESP32 Cam

Feature	Description
Function	Microcontroller with Wi-Fi, Bluetooth, and camera
Processor	ESP32
Connectivity	Wi-Fi, Bluetooth
Camera	Built-in OV2640 sensor
Storage	MicroSD card slot
Power Consumption	Low-power design

Figure 2: ESP32-CAM

DC Pump

The DC pump as shown in Figure 3, is a low-cost submersible pump motor which can be operated from a 12v power supply. In this project, the motor pump is connected to the outlet of a relay so that when the microcontrollers change the state of the relay, the motor pump can then either be switched ON or OFF.

Figure 3: DC pump

PIR Sensor

As shown in Figure 4, a passive infrared sensor is used to detect motion on the farm by any warm-blooded animal that produces infrared radiation. A PIR sensor has a thin pyroelectric film material that responds to infrared radiation by emitting electricity.

Figure 4: PIR Sensor

Soil Moisture Sensor

A Capacitive moisture sensor is a sensor that measures the moisture content of soil through capacitive and resistive methods. An analog capacitive soil moisture sensor is depicted in Figure 5. This sensor module is compatible with all of the major microcontrollers because it has an integrated voltage regulator that allows it to operate at voltages between 3.3 and 5.5 V. The three pins on the sensor are GND, VCC, and Aout. The sensor senses the moisture in the field and transfers it to the microcontroller to take the controlling action of switching the water pump ON/OFF.

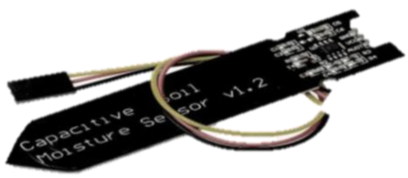

Figure 5: Capacitive soil moisture sensor

5V Valve

As shown in Figure 6, a 5v valve is an electromechanically operated valve which has two or more different ports to allow the flow of liquid in and out. It is open when the electricity is off and closes when it is on.

Figure 6: 5V valve

Buzzer

As shown in Figure 7, a buzzer produces a loud sound whenever it is connected to a power source. It operates on 5V. It makes a sound whenever the motion of a man or animal is detected on the farm.

Figure 7: Buzzer

Software Design

The hardware components of the project were interfaced with the Blynk app, and this was achieved through Arduino codes. All sensors and controllers interact with the app via the microcontroller. When the app receives the required commands through the program uploaded to the microcontroller, then the pump, ESP 32 cam and the alarm system are triggered to carry out appropriate actions.

Block diagram, Circuit diagram and Flowchart

A smart farm irrigation and Intruder detection system is designed. The design is divided into four different compartments for easy positioning of sensors, for efficiency of the overall system as shown in Figure 8. The block diagram for the system is shown in Figure 9. The interconnection of the different hardware components is shown in the circuit diagrams for the sub-units of the design which are shown in Figure 10.

Figure 8: Project Design

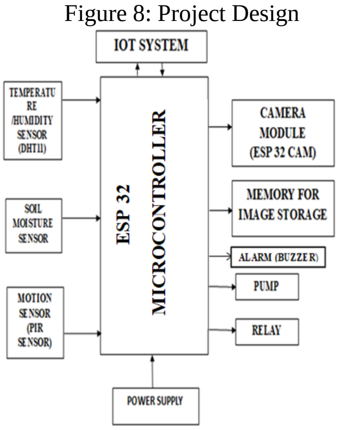

Figure 9: Block Diagram

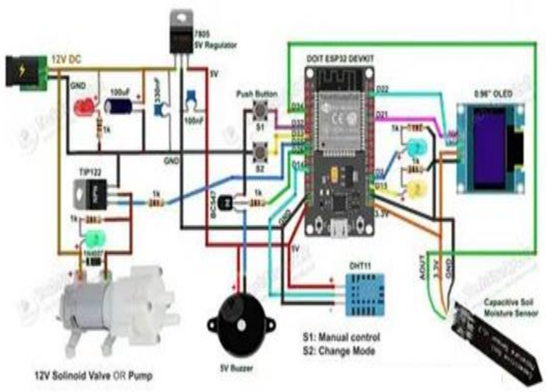

Figure 10: Circuit diagram

HOW THE SYSTEM WORKS

First, the soil moisture sensor and PIR sensor are activated to measure the moisture content of the soil and detect motion respectively. The measured value is compared to the threshold value on the microcontroller, whenever the value is less than the lower threshold value (30%), the DC pump is activated and the valve opens to allow the water into the field of the farm for irrigation. The soil moisture value continually reads the moisture content, when the reading matches up to the upper threshold value (80%), the DC Pump is deactivated. As this process is ongoing the soil moisture content is updated on the Blynk app, whenever motion is detected by the PIR sensors, the ESP 32 takes a picture of the image and sends it to the Blynk app. The principle of operation of the system for smart Irrigation and Intruder detection is shown in Figures 11 and 12.

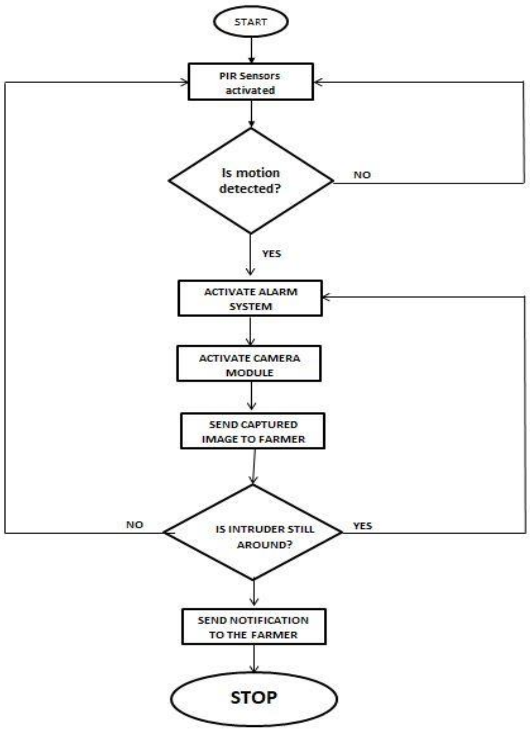

Figure 11: System Flow chat For the Smart Irrigation

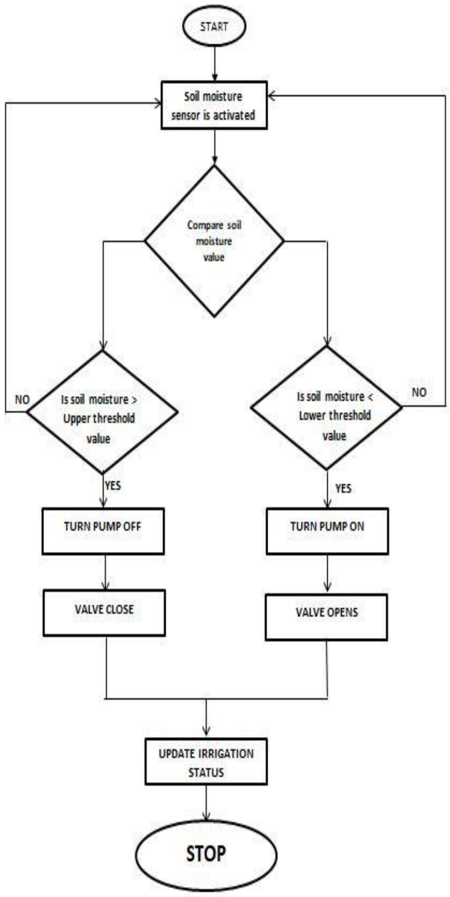

Figure 12: System Flow chat For the Intruder detection system

RESULTS AND DISCUSSION

The complete system which consisted of the various components integrated was tested, to determine if the specific objectives were fulfilled under this model's conditions. The subunits were tested individually to ascertain their functionality, the results from the testing are discussed in the following sections.

Testing the Smart Irrigation System

The four compartments of the system were tested rigorously with six different soil moisture contents via the Blynk app and the corresponding irrigation status was noted as follows, the graph in the figure, shows the soil conditions at different moisture contents. As shown in Figure 14 at 3%, the soil was very dry, the pump was turned on and the field was automatically irrigated. The irrigation status displayed on the Blynk app was ON. At 10%, the soil was still dry, the pump was also turned on and the field was automatically irrigated. The irrigation status displayed on the Blynk app displayed was ON. As shown in Figure 14, at 20%, the soil was slightly wet, the pump remained on and the automatic irrigation of the field continued. The irrigation status displayed on the Blynk app was ON. At 30%, the soil was still slightly wet, and the pump was still on, which made the automatic irrigation remain in process. The irrigation status displayed on the Blynk app was ON. At 55%, the soil had become very wet, the pump was turned on and the field was automatically irrigated. The irrigation status displayed on the Blynk app displayed was ON. At 80%, the soil had become waterlogged, and the moisture content at this level is now sufficient for the plant, immediately the soil moisture content reads this percentage (80%), the pump was turned off and the automatic irrigation ended. The irrigation status displayed on the Blynk app displayed was OFF. These results are summarized in Table 3. The Irrigation resumes automatically whenever the soil moisture content reads a value lesser than the lower threshold value (30%) because at this point the moisture content in the soil is not sufficient for the plant. The total time taken for the complete irrigation of the farmland from a soil moisture content lower than 10% to the upper threshold value (80%) is approximately 30 minutes.

Table 3: Soil conditions with their corresponding moisture content.

S/N	Soil conditions	Moisture content (%)	Irrigation status	The time interval between the soil moisture content (minutes)
1	Dry	0 -10	ON	3
2	Dry	11-20	ON	3
3	Slightly wet	21-30	ON	3
4	Slightly wet	31-45	ON	7
5	Wet	46-80	ON	14
6	Extremely wet (Waterlogged)	81-100	OFF	

Figure 13: Soil moisture content (Blynk app)

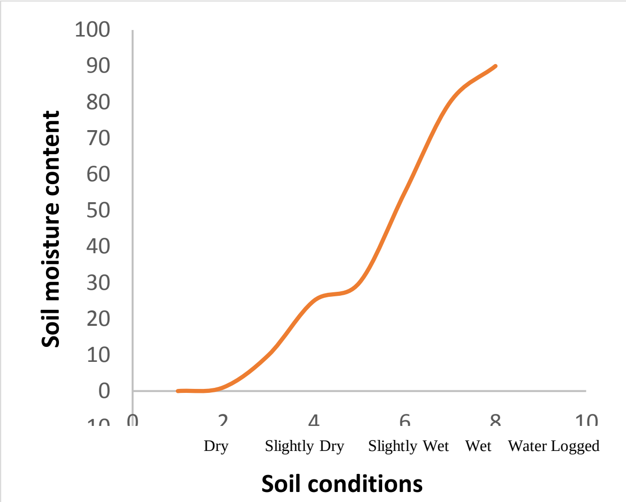

Figure 14: Soil conditions at different soil moisture content

Testing the Intruder Detection System

The PIR sensors attached at the corners of the farm were tested at different distances, and it was observed that the maximum detection range of the sensors is 4m. When an animal or person is on the farm the PIR sensor located directly opposite where the animal or person is standing detects the motion. Immediately the motion is detected the alarm system is activated to scare the Intruder, when the Intruder hears the sound, the ESP 32 cam captures him and the farmer gets notified that there is an intruder on the farm from the image displayed the farm intruder unit of the Blynk app as shown in figure 15. The PIR sensor detection time is in sync with the alarm system as shown in the figure where the two graphs overlap. The average detection time is the time taken for the sensor to detect changes in physical properties (i.e. motion). The capturing time (detection time) of the camera module (ESP32 cam) was more than that of the motion sensor and alarm system because the camera module is activated after 3 seconds of motion detection. There is a significant change in the detection time of the two ESP32-Cams because of their positional distance.

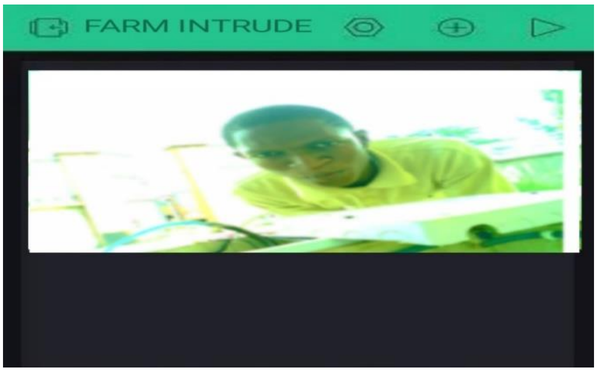

Figure 15: Farm Intruder detection (Blynk app)

Table 4: Average detection time for Intruder Detection system components within a range of 4 metres

Farm intruder detection system components	Average response time for Compartment 1 (s)	Average response time for Compartment 2 (s)
PIR Sensor	1.39	1.40
ESP32 Cam	5.5	6.0
Alarm system	1.41	1.41

Discussions

From the results obtained from the sub-unit testing (irrigation and farm intruder detection units), the overall system performed as expected. The result obtained from the components that make up our system was accurate and suitable for our design.

Conclusions

As proposed, the Smart Farm Irrigation with Intruder Detection System has been designed, tested and verified as being functional. It demonstrated that with the use of sensors, actuators, Internet of Things, irrigation of a farmland can be automated which increases the effectiveness of irrigation and motion on the farm can be remotely monitored to detect intruders on the farm to free up labourers to focus on other crucial farming duties.

The entire system was tested and controlled by the Blynk app and it worked perfectly well. The design has been made to simplify the following aspects:

- How soil conditions can be monitored in real-time
- How motion on the farm can be monitored in real-time
- The possibility of automated Irrigation on the farm

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