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DEVELOPMENT OF SMART IRRIGATION SYSTEM BASED ON INTERNET OF THINGS (IoT)

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Abstract:

The seasonal nature of water resources for agricultural activities has been a problem for increased production especially during the dry seasons. To sustain an all-year round farming system with optimal management of water resources with less human intervention requires the application of modern technology in irrigation systems, which is successfully implemented in a small potato farm in Abia State Polytechnic, Aba Nigeria based on Internet of Things (IoT) technology. The system which uses a circuit combination of soil moisture, temperature/humidity sensors connected to a Microcontroller Arduino Uno with a GSM/Wi-Fi module and an electromagnetic relay switch for energizing a connected water pump. The system operation requires the sensors sensing the soil conditions and transmitting same to the Microcontroller which in turn gives command to the switching relay to ON/OFF the water pump automatically while the generated farm condition data are transmitted to the farmer via the GSM/Wi-Fi module. The real time data as obtained by the sensors can also be viewed in thingspeak cloud in graphical form. The device which is cost effective, easy to operate and maintain has the advantage of making irrigation farming system enjoyable, less burden and increases productivity with lesser manpower management

Key Words: IoT, Smart Irrigation, Farm Automation, Microcontroller, Sensors.

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I. INTRODUCTION:

Agriculture is unquestionably the largest livelihood provider in West Africa and Nigeria in particular. With rising population and rise in the number of unemployed, there is the need for increased agricultural production. In order to boost agricultural productions especially, in crop farming, there is need for all year round requirement of fresh water amount in commensurate proportions which can only be achieved through a controlled irrigation system. Currently, agriculture accounts for about 80% of the total water consumption globally [1]. Unplanned use of water inadvertently results in wastage of water resources and thus suggesting the urgent need to develop systems that prevent water wastage without imposing undue pressure on farmers.

Over the past decade, many commercial farmers started adopting modern technology such as computers and software systems to monitor more effectively, the progress of their crops development and the activities of third parties for the overall productivity of farm activities [2]. The recorded success has increased over the years and diversified into multiplicity of applications. Today, information technology plays a key role in people's lives and agriculture which is the basis of human sustenance is increasingly becoming a data intensive industry where farmers need to collect and analyze a huge amount of information from diverse number of devices like sensors, farming machinery etc in order to improve their production base [3, 1].

The advent of Arduino boards and cheap moisture sensors, are increasingly viable to design devices and systems that can monitor effectively, the soil moisture conditions and automatically irrigate the fields as at when needed. This would require the use of microcontroller ATMEGA328P on Arduino Uno platform and IoTby farmers to remotely monitor the status of sprinklers installed on the farm thereby, making the farmers' work much easier as they can concentrate on other farm activities.

A conventional irrigation system requires human efforts and is time consuming but Internet of Things is able to provide the needed smart solution to the problems of conventional irrigation system. The technology of Internet of Things (IoT) is a fast-growing network of physical objects grafted into an Internet Protocol (IP) address for internet connectivity and the communication occurring between these objects and other internet-enabled devices and systems [4]. This technology of automated irrigation system would overcome the problem of over irrigation and under irrigation which are usually counterproductive and therefore, lead to effective use of available water resources for increased productivity.

Over irrigation occurs because of poor distribution or management of waste water, chemical which leads to water pollution. Under irrigation leads to increased soil salinity with consequent buildup of toxic salts on the soil surface in areas with high evaporation. To overcome these problems and to reduce the man power requirement for the conventional irrigation system requires the integration of smart irrigation system in the farming system which is the focus of this research work.

Problem statement/ Justification:

In Nigeria as in most developing nations, agriculture is the primary occupation and presently facing lots of problems due to lack of water resources especially during dry seasons. In this era of internet, where information plays a key role in people's lives, agriculture is rapidly becoming a very data intensive industry where farmers need to collect and evaluate a huge amount of information from diverse number of devices which can be used to determine the irrigation process schedule. To improve water efficiency and utilization system, there must be a proper irrigation scheduling strategy.

Currently, most of the irrigation systems in Nigeria are operated manually resulting in over/under irrigation of farms and associated man power management issues. In order to help the farmers to overcome these difficulties, smart irrigation system, utilizing the technology of Internet of Things (IoT) is an ideal option. Therefore, this study is set to address the identified problems militating against increased productivity in farming activities as regards to use of water resources.

Objective of the study

The aim of this research is to develop a smart irrigation system which measures the moisture content of the soil and automatically turns on or off the water supply system and alternatively alert the user to perform the switching remotely. To achieve this, the following sub-objectives were set:

(i) To study existing academic literatures relating to smart irrigation systems
(ii) To characterize soil parameters in order to maintain the various key performance indicators for better output
(iii) To design a smart irrigation system that is IoT based
(iv) To implement the designed system as a prototype.

II. THEORITICAL FRAMEWORK:

CONVENTIONAL IRRIGATION SYSTEM

Irrigation, the artificial system of watering of farmland to sustain plant growth apart from the conventional rainfall has been practiced in all parts of the world where rainfall does not provide enough ground moisture. In dry areas, especially during dry periods of the year, irrigation must be maintained from the time a crop is planted until maturity. In areas of irregular rainfall, the system is used during dry spells to ensure harvests and to increase crop yields and this has greatly expanded the amount of arable land and the production of food throughout the world.

Conventionally, irrigation can be classified into five major methods such as:

a) The traditional or manual system where watering cans are used by the farmers to deliver water from canals or wells to the plants.
b) Flood irrigation which is used for close-grown crops such as rice and where fields are level and water availability is abundant.
c) Furrow irrigation which is employed with row crops such as cotton and vegetables. Here parallel furrows, called corrugations, are used to spread water over fields that are too irregular to flood.
d) Sprinkler irrigation uses less water and provides better control as each sprinkler, spaced along a pipe, sprays droplets of water in a continuous circle until the moisture reaches the root level of the crop. Center-pivot irrigation which is a modernized type of sprinkler uses long lines of sprinklers that move around a circular field like the large hand of a clock.
e) Drip, or trickle, irrigation delivers small but frequent amounts of water to the root area of each plant by means of narrow, network of small plastic pipes to drip water mainly for crops that do not require too much water.

These conventional methods of irrigation have associated problems such as accumulation of salt on the soil, stunting plant growth and soil erosion, which are limitations to their applications and could result to poor productivity. The major issues with the identified methods of irrigation are as summed below:

i. Labour intensive to control as applicable to drip irrigation
ii. Wastage of water applicable to the use of sprinklers
iii. Time consuming and stressful especially with the traditional use of watering cans
iv. As a breeding site for mosquitoes around water logged areas of the farm due to over irrigation

SMART IRRIGATION SYSTEM

Smart irrigation systems offer a variety of advantages over conventional irrigation systems. Smart irrigation systems can optimize water levels based on certain conditions such as soil moisture and weather predictions. This can be achieved with wireless devices (moisture sensors) that communicate with the smart irrigation controls. Additionally, the smart system controllers receive local weather data that help in determining soil structure and thus decide when watering is required. The Smart Irrigation System is an IoT based device which is capable of automating the irrigation process by analyzing the moisture of soil and the climate condition (like raining).

Smart irrigation systems have a wide comparative advantage over the conventional systems such that it gives a better control of soil water management as well as peace of mind that the smart system can make decisions independently if the farmer is not within the area. Significant amount of money will be saved on water bills through intelligent control and automation of farming activities as the system will optimize resources such that every crop gets the optimal quantity of water at every point in time during the cropping season without wastages.

Smart Irrigation System uses valves which are automated by using controllers and solenoids to turn irrigation ON and OFF. Automating farm or nursery irrigation allows farmers to apply the right amount of water at the right time, regardless of the availability of labour to operate the valves. In summary, smart irrigation saves water and money; makes maintaining farm land easy and convenient; minimizes the infrastructure need to store and carry water as well as protecting the water resources for future generations.

III. REVIEW OF RELATED WORKS:

The technology of smart irrigation has progressed over the years with new inventions aimed at developing a friendlier and convenient system of applying artificial rain to farmlands putting into consideration, various soil characteristics for improved agricultural productivity. Soil sensor devices that monitor the humidity, soil pH, temperature and soil moisture when placed in the root zone of the plant according to [5, 6 and 1] were able to sense soil conditions based on the parameters and values sent to a microcontroller control system that initiated the supply of water to the field by switching ON/OFF of water pumping machine. One drawback to this design was that the system does not have the facility to communicate the farmer on the status of farmland. However, their system has the advantage of energy management as the devices were powered from the sunlight using solar cells.

In addressing the limitations of the farmer not knowing the status of the farmland, the use of GSM was incorporated into the microcontroller system such that short message services (SMS) are sent to the farm owner at intervals on the status of the farm. This smart irrigation technology was able to send information on soil moisture, temperature and humidity to a programmed GSM device when these parameters exceed the threshold value set in the programme [7]. The use of mobile phones as an integral part of human existence, serving multiple needs cannot be over emphasized. This application makes use of the GPRS feature of mobile phone as a solution for irrigation control system but coverage range of agricultural land is limited and therefore not economically viable.

An improved system of smart irrigation using IoT in which humidity, temperature and pH sensors were achieved using a microcontroller combined with a server is discussed in this article. Irrigation status is updated to the server or local host using personal computer and can be accessed everywhere at every point in time so long as there is availability of internet services [3, 8]. According to [9], this system uses wireless sensor networks in which various sensors are employed to monitor and measure soil parameters and thus provides web interface to the user to monitor and control the system remotely. However, without internet services, the farmer cannot be able to access the information about the current status of the farmland.

IV. THE DESIGN COMPONENTS

There are five functional components in this project:

The Sensors (Soil Moisture and Temperature/Humidity Sensors), Microcontroller (Arduino Uno), Wireless Frequency (WiFi) Module Esp8266, Electromagnetic Relay Switch and the Motor/Water pump.

1. **Soil Moisture Sensor:** The soil moisture sensor is used to measure the quantity of water content in the soil. In this project, the sensor measures loss of moisture over time due to evaporation and plant intake. It is made-up of two probes which are used to measure the volumetric content of water. The probes allow the current to pass through the soil and then it gets the resistance value to measure the moisture value. When more water available, the soil conducts more electricity which implies that there will be less resistance, thus the moisture level will be higher and vice- versa for dry soil condition. The digital pins or probes of the sensor directly reads the current soil moisture value and compares if it is above, within or below a set threshold. The threshold set point is regulated with help of potentiometer.

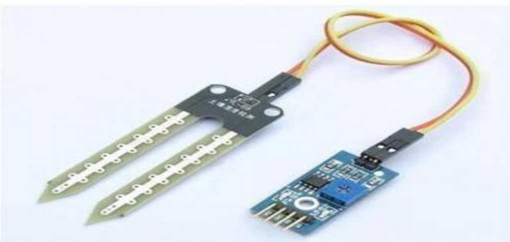

Figure 1. A Soil Moisture Sensor

2. Temperature and Humidity (DHT11) Sensor: Is used for measuring temperature and humidity of the soil. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air thereby providing a digital signal on the data pin (no analog input pins

needed). It is simple to use, but requires careful timing to collect data. This sensor is cost effective, provides low power consumption and up-to 20meters signal transmission

Figure 2. DHT11 Sensor

3. *Relay Module:* A relay is an electrically operated switch that can be turned on or off, letting the current go through or not, and can be controlled with low voltages, like the 5V provided by the Arduino pins. It acts a major switch to power ON/OFF the water pump based on signal from the microcontroller.

Figure 3. A Relay Module

4. **The Microcontroller (Arduino Uno):** The microcontroller board used in this design is the *Node MCU (ESP8266) Wifi Module which is an* advanced Application Programming Interface for hardware input/output device. It uses a code like Arduino Uno and be described as an interactive script and an open source IoT platform. It is implemented on a firmware of ESP8266 WiFi Soc (system on chip) produced by Espressif systems. NodeMCU designed with 16 input/output pins and hence 16 nodes can be connected to a single node. ESP8266 is an inbuilt WiFi module which in this project is the major interface between the various sensors, the switching relay and the wireless accessories such as the GSM module and the internet-based systems [8].

Figure 4. Microcontroller Arduino Uno

5. **GSM (Global System for Mobile Communication) Module:** is a standard developed by the European Telecommunication Standards Institute (ETSI) to describe protocols for second-generations (2G) digital cellular networks used by mobile phones. GSM describes a digital, circuit-switched network optimized for full duplex voice telephony

and also expanded to include data communications, packet data transport via GPRS (General Packet Radio Services).

Figure 5. A GSM/WiFi Module

V. ENGINEERING DESIGN AND SYSTEM OPERATION

The smart irrigation system is a combination of hardware and software components. The hardware part consists of embedded system while the software component is a webpage designed using Hypertext Preprocessor (PHP), an open source server-side scripting language commonly used to develop static or dynamic and interactive web sites. The webpage shall be hosted online and will consist of a database in which readings from sensors are inserted using the hardware. The overall system design is as shown on the block diagram of figure 6 while the prototype diagram is as shown in figure 8.

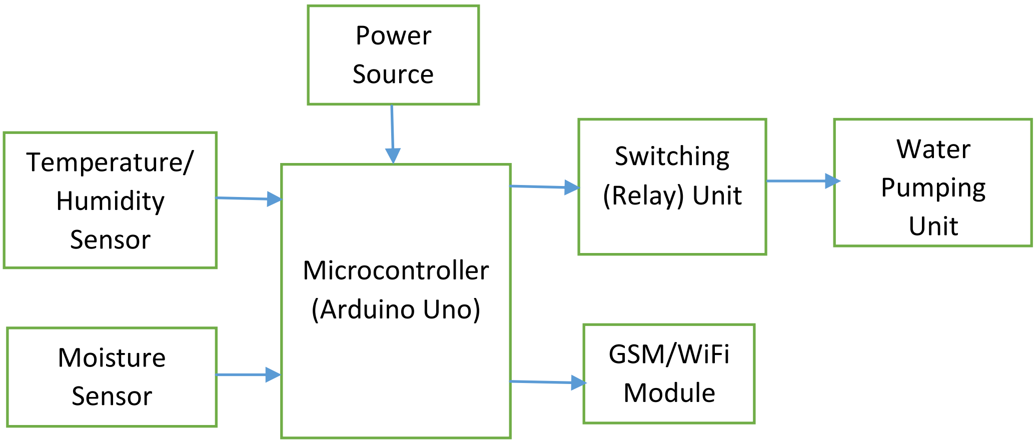

Figure 6. System Block Diagram

The stepwise operation of the smart irrigation system is as contained in the flow chart diagram of figure 7. The operation requires that the various sensors such as soil moisture, temperature/humidity (DHT11), PIR (intruder detecting system) and pressure sensors are connected to the input pins of the Arduino microcontroller.

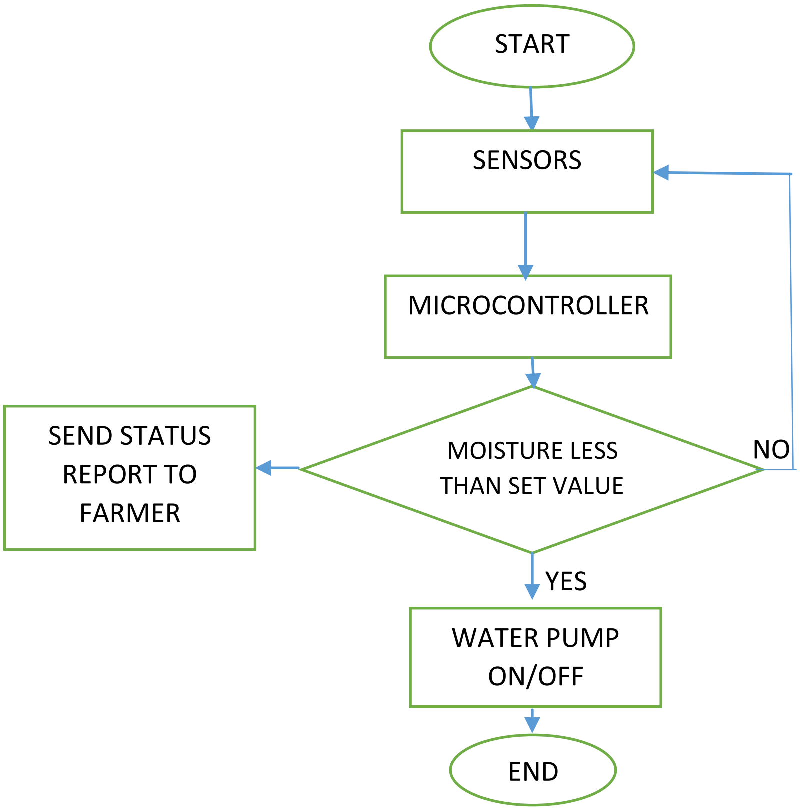

Figure 7. The Flow Chart Diagram of the System.

The sensed values from the sensors are displayed on the display (LCD) unit. If the sensed value goes beyond the threshold values set in the program, the pump will be automatically switched ON/OFF by the relay circuit connected to the driver circuit which helps to switch the voltage. The farmer will be intimated about the current field condition through GSM module and also updated in the web page. By using this system of irrigation, the farmer can conveniently access the details about the condition of the farm land anywhere at any time without involving human agents directly.

Two YL-69 soil moisture sensors along with LM393 comparator modules were placed in different soil conditions for analysis. The sensor YL-69 is made up of two electrodes dipped into the soil sample to read the moisture content around the soil sample. A current is passed across the electrodes to the soil and the resistance to the current in the soil determines the soil moisture. If the soil has more water, the resistance will be low and thus more current will pass through. Similarly, when the soil moisture is low the sensor module outputs a high level of resistance and less current flow.

This sensor has both digital and analogue outputs. The digital output is simple to use but is not as accurate as the analogue output. Since the microcontroller used for the Arduino Uno contains an onboard 10-bit 6-channel analog-to-digital (A/D) converter, the analog input pin of Arduino can read analog signals being sent from the sensor and return binary integers from 0 to 1023. Greater amount of output implies lesser moisture content and vice versa.

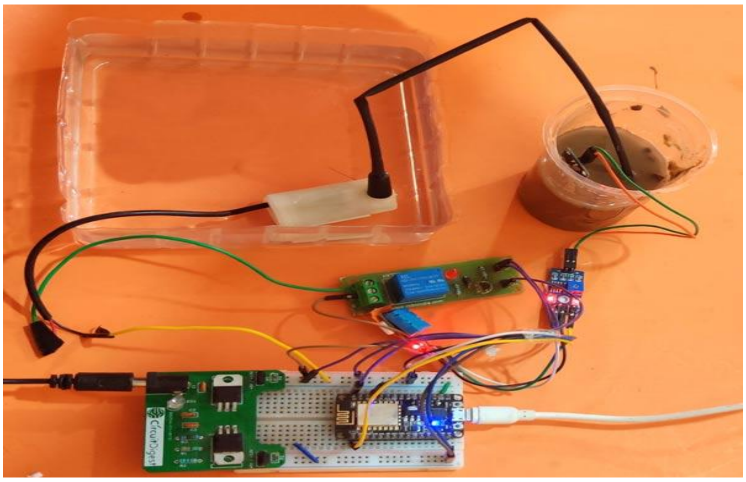

Figure 8. Overall Engineering Design of smart irrigation system.

The Arduino board which consists of the microcontroller receives information from the sensors and transmits same to control the switching on/off of the motor on which water sprinklers are attached. Sensor values from Arduino are transmitted to the GSM-GPRS SIM900A modem (a sim with 4G data pack)to provide IoT features to the system. The GSM modem is a highly flexible plug and play quad bandSIM900A GSM modem for direct and easy integration to RS232 applications. It Supports features like Voice, SMS, Data/Fax, GPRS and integrated TCP/IP stack. The tx and rx pins from Arduino are connected to the rx and tx of GSM modem respectively.

VI. RESULTS AND DISCUSSIONS

The smart irrigation system was experimented on a small potato farm to ascertain its functionality. The soil moisture sensor programmed between 300 to 600mm^3 range which corresponds to the chosen crop water need of 500 to 700mm^3 daily requirement. The system performance was excellent as the farm gets automatically irrigated based on soil conditions perceived by the moisture sensor. As the water level falls below the threshold, the sensor senses the humidity change and sends signal to the microcontroller system which in turn sends a closing command to the relay system thereby switching ON the water pump and as the water level gets to a little above 600mm^3, the moisture sensor senses it gives command to the microcontroller for the pump to be de-energized. The process repeats on and off depending on soil condition, while situation reports are generated via a GSM and WiFi module to the farmer. The graphical display of the soil moisture, temperature and humidity sensors are contained in figures9, 10 and 11.

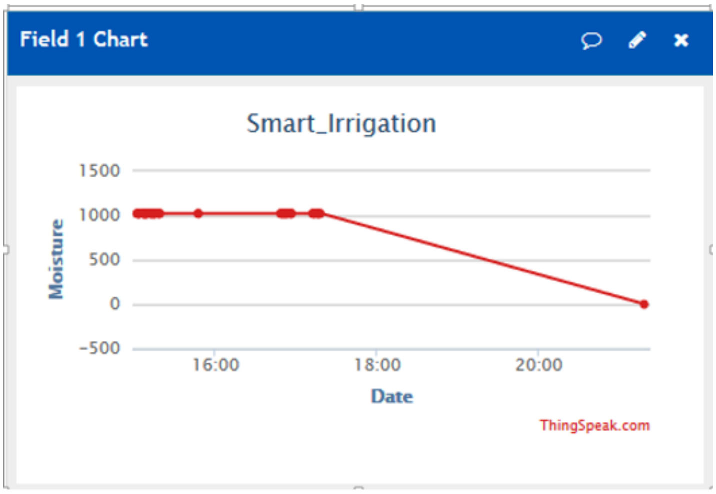

Figure 9. Thingspeak graph of Soil Moisture content

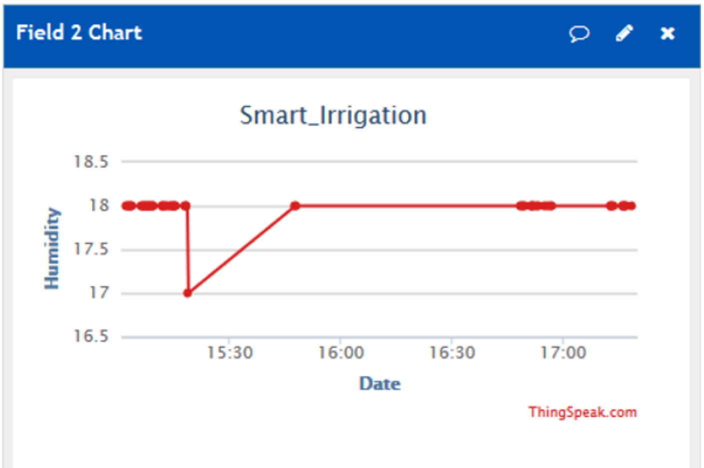

Figure 10. Thingspeak graph of Soil Humidity

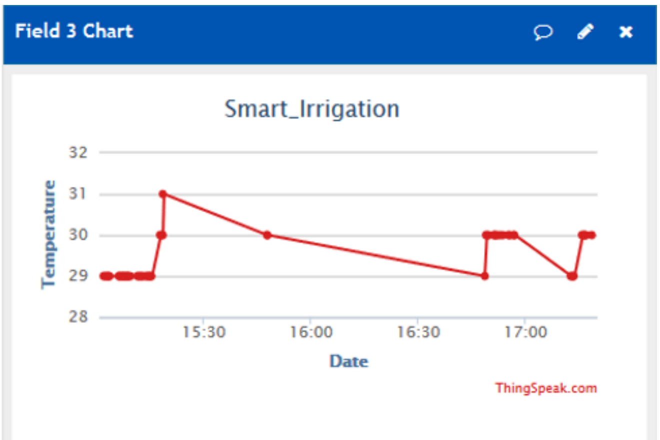

Figure 11. Thingspeak graph of Soil Temperature

VII. CONCLUSIONS

The proposed prototype smart irrigation system using IoT technology was successfully implemented. The system with its effectiveness and accuracy has the advantage of monitoring activities at the potato farm especially, the soil conditions through live data of soil moisture content, temperature and humidity with little or no human interference. The system if implemented on a large farm has the capacity to improve and guarantee all-year round agricultural productivity and water resource management. The unit is cost effective and easy to operate as it does not need a specialized training of its operation and can be monitored from anywhere.

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