Design and Implementation of Autonomous Irrigation System using IoT and Artificial Intelligence

(A Thesis Proposal)

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***Abstract*— Agriculture plays a vital role in Nigeria's economy contributing about 23 percent to the total GDP which makes it a key activity after oil. To improve crop productivity, optimum use of scarce water resources and the ability to predict rainfall is crucial in this era. The adoption of emerging technologies to automate irrigation processes is necessary to improve crop productivity. An intelligent irrigation system can be achieved through the synergy between Internet of Things(IoT) and Machine Learning(ML) algorithms, which support automation and improved efficiency in the agricultural field. The proposed system will use sensors to collect air humidity, air temperature, and most importantly soil moisture, and transmit the raw data to NodeMCU to know if the soil is dry by comparing it to a trained set of data in the NodeMCU. The NodeMCU will then obtain data from the Opensource Google weather API(Application Programming Interface), OpenWeatherMap using JSON(JavaScript Object Notation) data to know if there will be rainfall in less than an hour or not. Base on the data collected from the weather API by the NodeMCU, it will then determine whether to trigger the pump for irrigation or not. If the soil is dry and rain will likely fall in less than an hour, the pump remains OFF and allow the rain to water the field, otherwise, the pump is triggered ON and a calculated amount of water is pumped into the soil. The real-time monitoring report of this process will be sent to the cloud where the farmer can access to monitor the condition of the farmland.**

Keywords—IoT, Machine Learning, Sensors, Rainfall Prediction, Intelligent Irrigation.

I. Introduction

Agriculture which is as old as man himself has been the most important practice from the beginning of human evolution. It is one of the main aspects of human survival as it is the main source of food [1]. There exists an intricate relationship between agriculture and irrigation as they both go hand in hand. This is essential because water is imperative for the survival of any living organism. Irrigation is the application of controlled amounts of water to plants at the needed interval to grow crops. The plant consists of networks and irrigation is considered as one of the main drivers. The growth of crops greatly depends on the soil moisture content and once the moisture content of the soil is excessive, it could result in the rot of crop roots, wash away a large amount of fertilizer that can result in water pollution, impedes the exchange of gas between the soil and the atmosphere which reduces root respiration and root growth.

The unpredictability and uncertainty of rainfall have resulted in irrigation becoming an important factor in agriculture. In the western part of Africa, the over-dependence of farmers on rainfall has constituted a major setback to sustainable development in agriculture, thus making production systems vulnerable to change and variability in climate [2]. This has also forced some farmers into the adoption of seasonal farming which only functions with cycles of rainfall. In recent years, there has been an unprecedented drive towards improving agricultural productivity in Nigeria. Because agricultural contribution to GDP is on the decline nowadays, there is an urge towards increasing the productivity of crops through effective and efficient use of scarce water resources. [3] believes that a strong and efficient agricultural sector can enable a country to feed its growing population, earn foreign exchange, generate employment and provide raw materials for industries. There exists a demand for colossal technical knowledge to make irrigation systems more efficient [4].

The solution to this age-long problem lies in the adoption of automated irrigation systems [5]. In an IoT-based automated irrigation system, sensors are usually deployed for the real-time monitoring of the farm. This helps the farmers to monitor the conditions of their crops field from anywhere. This results in a highly efficient and economical system of farming when compared with the conventional approach as a result of its ability to conserve water and reduce human labour. Automated irrigation systems can be programmed to discharge more precise amounts of water in a targeted area, which promotes water conservation. The rapid advancement in technology in recent years has made lives simpler and easier. The extension of this development to farmers will result in the reduction of the cost incurred with the use of manual irrigation and monitoring, save time and energy, abate or eliminate the ever-increasing competition for the scarce water resources.

Machine learning is an aspect of computer science that can learn from previous data and experience to make more informed decisions[6]. Fig. 1 shows the process steps for ML applications.

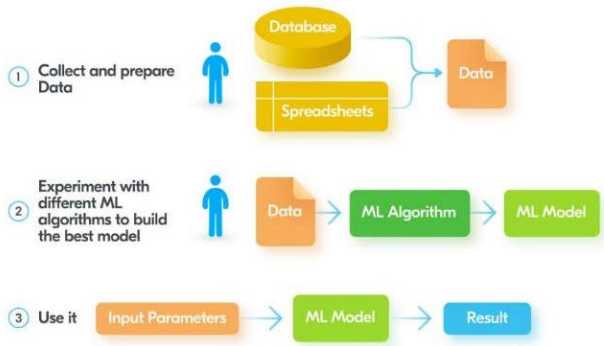

Fig. 1 Machine Learning Algorithm Workflow

II. Aim and Objectives

A. Aim

The project aims at designing and implementing cheap and efficient weather adaptive intelligent irrigation systems based on the internet of things and artificial intelligence to maximize water usage and predict future tendencies based on the acquired data.

B. Objectives

The objectives are further highlighted as shown below.

- To acquire real-time data of the soil using sensors and transmission same to the cloud.
- To analyze and train the data using a suitable machine learning algorithm to effectively predict the condition of the soil and minimize farmers' interaction with the system.
- To predict rainfall using rainfall data obtained online to avoid water wastage and waterlogging.
- To automatically irrigate the soil optimally using the above mechanism

III. Problem Statement

Irrigation of plants is usually a very time-consuming activity, for it to be done within a reasonable amount of time, it will require a large number of human resources. These days, most of the irrigation processes that are being executed by humans are being reduced in terms of human resources and timing due to technology use in irrigation purposes. Most of the technology-enhanced irrigation systems just irrigate whenever the soil moisture content is low without taking the knowledge of the weather forecast into cognizance, thereby leading to bad water management. Such systems also lack the capability of learning from the data obtained to predict future parameters neither can they work independently without manual input by the farmers. With such technology-enhanced irrigation systems, there is limited control of irrigation processes which results in the massive wastage of scarce water resources since the amount of water available is more than the plants' needs. To avoid poor water management, which could reduce yield and ultimately revenue loss, there is a need to incorporate Artificial Intelligence and weather adaptive technology-enhanced irrigation systems. Farmers in Nigeria have not embraced the concept of Climate Information Systems in the practice of agriculture talk less about adopting the same during the irrigations process for crops.

Thus, this research work intends to develop an autonomous irrigation system that is responsive to all weather conditions and cost-effective. It will also incorporate the ability to learn the pattern and work independently without manual input.

The proposed system will through the help of sensors collect air temperature and humidity, soil moisture content, and transmit the raw data to NodeMCU to know if the soil is dry by comparing it to the trained set of data in the NodeMCU. The NodeMCU will then obtain data from the Opensource Google weather API(Application Programming Interface) called OpenWeatherMap using JSON(JavaScript Object Notation) data to know if there will be rainfall or not. Base on the data collected from the weather API, by the NodeMCU, it will then determine whether to trigger the pump for irrigation or not. The real-time monitoring report of this process will be sent to the cloud where the farmer can access to monitor the condition of the farmland whenever he wishes.

IV. Literature Review

In the proposed system by [7], sensors were deployed to collect the humidity, temperature, and soil moisture content for the monitoring of the crop field. This collected information is sent to ATmega328(Arduino) and can be displayed on an LCD attached to it. The periodic update of these data is sent to a webpage through the help of a Wi-Fi module. The system also incorporates a GSM module through which messages about the condition of the farm are sent to the authorized person. In [1], a system was designed using Arduino and NodeMCU which uses the sensors' information to determine when to switch ON the pump to water the farm, thus enabling the real-time monitoring by the administrator(farmer). The parameters collected are soil moisture content, relative humidity, and temperature. The system uses Thingspeak API as the central node and this is responsible for passing information to the management node via a computer or mobile phone. The readings are also displayed on the LCD screen for the farmer to know.

The system designed by [8] used Arduino as the microprocessor and NRF24L01 Wi-Fi module for the communication network. The system is designed to operate both manually and automatically. The manual system is operated with an Android Application which enables the farmer to water his farm from anywhere regardless of the distance, while the automatic system periodically checks the condition of the field and water when the soil parameters go below a set reference value. The Authors of [4] developed and implemented a system that used a humidity sensor, soil moisture sensor, temperature sensor, and light sensor to monitor and automate irrigation processes. There is a dedicated web server database where these sensor data are sent using wireless communication. In the server database, the data are encoded in JavaScript Object Notation (JSON) format. The working principle is to periodically check if the temperature or moisture content of the field falls below the brink and automate irrigation by releasing the precise amount of water to the soil. An update is periodically sent via SMS to the farmer's phone.

The author of [9] designed and implemented a Smart system to monitor and irrigate crop-field using Microsoft Azure machine learning. The system used Arduino and through the help of deployed sensors received data from the farmland. This data coupled with weather forecasting data is processed through ML operation to better informed the farmer on irrigation scheduling. With this process, the farmer is informed of the possibility of rainfall and can decide whether to irrigate or not. The interaction is done with an android application or web page through which the farmer remotely operates the tap. This enables the farmer to make an informed decision, thus maximizing the use of water. The statistical analysis of the sensor values is displayed on a web page using a graph and also for any inquiry purposes about the application.

In [10], an Arduino-based system for watering and roofing was developed. The system used Kalman filtering to obtain accurate values from sensors through the removal of noise. The decision-Tree algorithm of ML was employed in the raining of the data to know when watering should be done. A mobile application was also developed where sensor data from the cultivation field are obtained to control irrigation processes from the phone. Using the Decision Tree Model with the help of the node.js library, the sensors' data is compared with the weather forecast data which enables the administrator (farmer) to know the appropriate time to water the crop. The system developed by [11] interfaced an android app with Arduino to control the irrigation system remotely. The wireless communication is enabled by the connected HC-05 module. Sensors were first deployed to measure important parameters of the soil and the data obtained were sent to the Arduino connected wirelessly through the HC-05 module to an Android smartphone. The farmer can also interact with the sensor data through the smartphone's GUI. This system is cost-effective and efficient as it helps the farmer remotely control the watering of his farm from the comfort of his house or anywhere without heavy demand for manual input. This affords the farmers have better control of their irrigation time.

An automatic plant irrigation system that consists of solar modules, various sensors, etc., was designed by[12]. The adoption of solar in this work is to ensure a constant power supply to the entire system. Sensors that measure water level in real-time are deployed on the paddy field and this information is constantly sent to the farmer to intimate him of the condition of the water level on the field. The farmer can start the irrigation process just by sending text messages remotely from his mobile phone which in turn triggers the motor to water the crop field. The system is also designed such that when the water level reaches a critical state without instruction from the administrator, it can automatically trigger the pump to open on its own and water the field. The effect of the system developed by [12] worked in such a way that all the devices function independently on their own with the help of inputs received from the sensors which are monitoring the agricultural land, thereby informing the farmer whether everything is in order or some critical actions need to be taken. The entire process was controlled and monitored by the programmable controller with electrical and mechanical parts. The electrical part is powered with solar energy to ensure that there is a constant supply to the entire setup. The mechanical part consists of a pump, which is used to pump out the water from the water source. The parameters in the project were soil moisture condition, water level condition, the position of the Sun.

V. Justification of the Research

So far, there have been many advancements in precision agriculture. However, almost all the breakthroughs exclude the use of an intelligent machine-to-machine interaction and rainfall prediction in irrigation. Most of the systems fetched the data at a particular time and responded immediately controlling the valves in the field. There has not been any system that takes the decision based on past experiences and analyzing real-time data with also the inclusion of rainfall prediction. With these existing systems, human input is still required for the efficient running of the systems, and the fact that rainfall prediction was not incorporated into these systems often leads it to make unintelligent decisions like watering the field when there is the possibility of rainfall in the next minute. This does not only lead to wastage of scarce water resources but could also result in waterlogging which is harmful to the survival of crops. Till now, machine learning has only succeeded in abating crop disease detection, crop management, and crop yielding problems. There is no or meagre research in the field of machine learning techniques that analyze the soil moisture content based on past data fed and controls the irrigation process without any involvement of human work. The study will develop an autonomous irrigation system that is intelligent, energy-efficient, portable, cost-effective, and can be used at any geographic position and responsive to all weather conditions.

VI. Methodology

A. *Data Collection*

In Machine learning projects, data plays an important role. It is a necessary task to collect the data from all the sensors and storing them correctly in a proper file format so that they can be used when needed to design the various machine learning algorithms on the project. We will be deploying sensors to the field in consideration to obtain a dataset containing the following parameters for the training of the model.

- Temperature
- Relative Humidity
- Soil Moisture

B. *Machine Learning Models*

In the proposed research work, we will utilize the application of Machine Learning in IoT to train sensor data. Several ML algorithm will be tested to ascertain the one that best fit the data based on the percentage accuracy. The one with the highest accuracy and least error will be adopted. The ML algorithms that will be considered are Logistic Regression, Support Vector Machine, k-Nearest Neighbors, and Decision Trees. The main classification of ML algorithms is shown in Fig. 2.

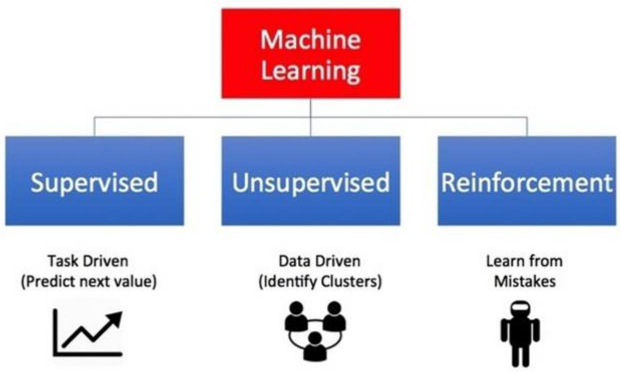

Fig. 2 Machine Learning Classifications

The following are the key factors to consider before adopting any of the following algorithms.

- High performance on both small and large datasets.
- Robust to noisy training data (especially, if we use the inverse square of the weighted distance.)
- The cost of learning is zero.

C. Rainfall Prediction

OpenWeatherMap is an online weather prediction service that can determine the minute-by-minute forecast of data for any geographical area. It does this via API which takes weather data from numerous weather station, apply convolutional neural network on them to predict precisely the condition of weather for a geographical location. The accuracy figure shows that MAE is about 0.5 degrees, RMSE is less than 2 degrees, reliability is between 90% and 100%, and inaccuracy is about 1% (less is better). The OpenWeather NWP model provides the most accurate result [13].

Review of existing state-of-the-art materials to identify various modules of the Autonomous Irrigation System with climatic adaptive conditions solutions and framework; the required modules will be designed using=26524444 Arduino IDE, and espressif SDK. The Pseudocode for smart irrigation algorithm will be formulated using a Rule-Based machine learning concept approach.
The system will be implemented using soil moisture, humidity, temperature, and GPS sensors, Arduino microcontroller (ATMEGA328P, 16MHz Crystal Oscillator), NODEMCU (ESP8266 microcontroller, 86MHz), DS1307 (a real-time clock chip that uses I2C technology), and Pump relay and Ethernet Module. Arduino IDE will program the NODEMCU and the NODEMCU will be interface with the soil moisture sensor to know when to irrigate the soil through the pump valve.

The temperature and humidity sensor will be used to collect the air humidity and air temperature while the soil moisture sensor will be used to measure the water content of the soil. The raw data collected from the sensors will be used to determine if the soil is dry by comparing it to a trained set of data in NODEMCU. The NODEMCU through the GPS module will then obtain data of the field location from the Opensource Google weather API(OpenWeatherMap) using JSON data to know if there will be rainfall or not. Base on the data collected from the weather API, the NODEMCU will then determine whether to trigger the pump for irrigation or not. The system will be connected to the internet using Wi-Fi technology embedded in the NODEMCU. The condition of the farm will be routinely uploaded to the cloud where the farmer can access it anytime.

The system will be evaluated using the performance metric of the system behavior by making a comparison between the expected system output for defined input variables and set of rule bases and the actual system output for real-time input variables with sets of rules. The prototype of the implemented system will be developed and tested to ascertain the accuracy of the entire system. Fig. 3 shows the flowchart for the entire system. The NodeMCU will first be initialized once the system is switched ON. It is then expected to read the input of the sensors and store the readings in a text file that will be readable by the machine learning algorithm. The NodeMCU will then predict the state of the soil using a suitable machine learning algorithm and compare the result with that obtained from the sensors to ascertain whether the soil is wet or dry. If the soil is wet(not dry), the system gets back to read the sensors' data over again and that loop will continue until the soil is dry. If the soil is dry, The NodeMCU through the GPS module will then obtain data of the field location from the Opensource Google weather API(OpenWeatherMap) using JSON data to know whether there is a likelihood of rainfall in less than an hour or not. If there will be rainfall within an hour, the pump remains closed as it is expected that the rain will water the soil. If on the other hand, the rain will not fall within an hour, the pump will be opened and adequate water will be pumped to water the field. The IP address of the NodeMCU will be obtained and the predicted values will be sent to the cloud for farmers' interaction.

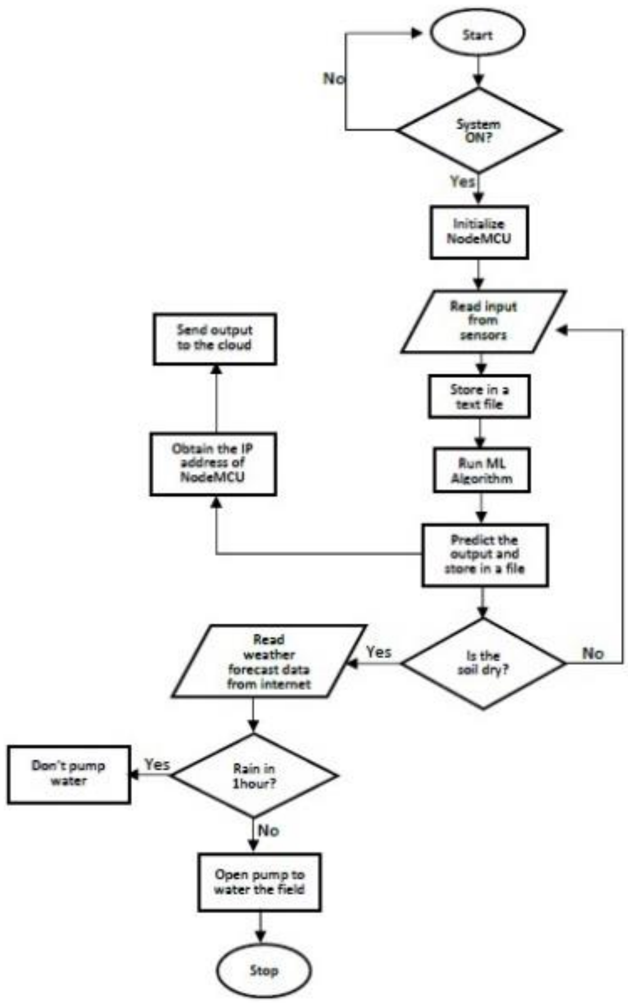

Fig. 3 Flowchart of autonomous irrigation system

The machine learning predicated decision system, when trained with precise data, can provide a precise estimate of the irrigation requisites of the crop in consideration, given the required authentic-time information including the crop and soil condition. Evapotranspiration which refers to the rate at which moisture leaves the soil to the atmosphere is essential to estimating its irrigation requisites.

VII. Scope of the Research

This study will be limited to the development of an autonomous irrigation system that will irrigate farmlands based on the information obtained from soil moisture sensors and weather forecasts. It is not designed for any specific type of crop.

VIII. Expected Contribution to Knowledge

This research work will produce a weather-adaptive intelligent irrigation system that would use water and electrical energy more efficiently by preventing water loss and waterlog, preserve electrical energy, and minimizing the cost of labour.

IX. Conclusion

This proposal gives a comprehensive overview of the entire steps required for the execution of the research work. Beginning from the introduction, aim, and objectives, problem statement, justification, the method that will be adopted, and the contribution to knowledge, it is clear that when completed, it will herald a breakthrough in the agricultural sector.

X. Timeline

The timeline for the completion of the proposed project is shown in Table 1.0

Table 1.0 Project Timeline

		2020		2021								
S/N	Activity	Dec	Jan.	Feb.	Mar.	Apr.	May	Jun.	July.	Aug.	Sep.	Oct.
1.	Literature review											
2.	Identification of research area											
3.	Identification of Research Gap/Problem Formulation.											
4.	Research Methodology											
5.	Proposal Writing											
6.	Proposal Presentation											
7.	System Implementation & Testing											
8.	Results and Discussion of Results											
9.	Conclusion											
10.	Thesis writing											
11.	Notification for Submission/Submission											
12.	Internal Defence											
13.	Effect of Corrections/amendments											
14.	External Defence											
15.	Effect of corrections/final Submission											

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