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INTERNET OF THINGS TECHNOLOGY FOR INNOVATION

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Abstract

Internet of things technology (IoT) and production rule-based expert system have been used for the innovation of various technological solutions or products across different application areas, such as home automation, smart city, and smart agriculture. Hydroponics farming was introduced as a solution to the limited farmland land and changing climatic conditions. In Nigeria, farmers are going through some problems including, but not limited to herders-farmers' clashes, kidnapping, insurgency and attacks from Boko Haram, and separatist groups which made farming almost impossible. Since hydroponics farming does not require soil but relies on water and nutrients (nutrient solution), it can offer a viable alternative to conventional farming to improve food supply. Hydroponics itself has the challenge of resources management (Lack of precision) for some crops like Spinach, Pepper, Tomato and Lettuce. So in this research task, automation model was innovated that delivered precision in farm input management. The Methodologies used in this work involved, Internet of Things Technology (IoTT) and Expert System: Nutrient Film Technique System. The data about Temperature/humidity Low (<26c), high (>29c), Nutrient solution–Temp low (<25c), high (>27c), Potential Hydrogen (pH) low (<6.0), high (>7.0), Electrical Conductivity (EC) value (<=2.0), Photosynthesis (Light) =1 obtained from the human experts and journal articles proved to be the same with the over 12000 thousand records generated by the automation model. The image data observed through the visual inspection and computer techniques indicated that, the plants grew well leading to the conclusion that the automation model innovated was able to monitor and control the growth of the plants.

Keywords: Internet of Things, Hydroponics, Boko Haram, Kidnapping and Automation.

1. Introduction

This work is concerned with innovating an automation system based on the Internet of Things Expert System for Hydroponics Agriculture. The Internet of Things (IoT) is a technology that can interface, connects, and communicates electronic items and systems like computers, television, smartphones, and refrigerators to one another over the Internet (Kularbphettong et al., 2019).

Herman & Surantha, (2019) stated that automation system can be design to monitor nutrient and water needs of plants in a hydroponics setup. In general, the system was designed based on Internet of Things concept and Fuzzy Logic which support the monitoring and controlling processes.

Herman & Surantha, (2019) further stated that Internet of Things technology is the technology that has been used to monitor every aspect of human existence, it therefore be a solution to monitor water and nutrition needs of plants. It was explained that agricultural technology is growing in urban areas now. One solution that can be adapted by the community is an agricultural system that can be done with limited land availability or urban agriculture. Urban farming or urban agriculture is one of the practical solutions to curb the reduction of agricultural land. Urban agriculture uses land that is not used in urban areas, such as roofs, balconies, patios, even on walls of buildings. One of the agricultural techniques used in urban farming is hydroponics Lakshmanan et al., (2020) explained that, hydroponics is a submenu of hydro culture and that it is a method of growing plants without the use of soil but with use of water and nutrients. The combination of water and the nutrients will result into what is called nutrients solution. It was also discussed that hydroponics method of growing plants have different techniques of implementation which includes: Nutrient film technique, Flood and Drain, the wick system and many more. These techniques are usually managed or monitored systematically using automation powered by computerized approach and so they tend to produce better than the traditional method of farming.

Lakshmanan et al., (2020) in an automated smart hydroponics system using the Internet of Things technology, concentrated on bringing the increase needed in food demand in the world and the need to appreciate a new sustainable and reliable method of farming called the Internet of Things. Aqeel (2020) the Internet of Things is the network of billions of devices, people and services to interconnect and exchange information and useful data. The Internet of Things applications are made to increase the level of comfort, efficiency and automations for the users.
The advent of Internet of Things in conventional industries has spread to other industries and the agricultural industry is not left out of this change. And that, the global connected agricultural market is expected to grow from USD 1.8 billion in 2018 to USD 4.3 billion by 2023, at a compound annual growth rate (CAGR) of 19.3%. The concept of Internet of Things technology has brought the use of electronic interface boards like Arduino boards with pins to interface with other electronic systems for the innovation of automation devices for handling agricultural operations. The Arduino board with the assistance of an expert system can control things like turning lights or motors on/off, and can sense environmental objects using sensory modalities borrowing from the field of perception. In the field of networking technology, Arduino can connect to a computer system through the universal serial bus (USB) lead. This means that, Arduino can be used as an electronic interface board to connect to a computer system so that the computer system can be used to control events or set up for improved productivity in the agricultural sector.

At the heart of the Arduino board, is the microcontroller providing light to the board and allowing it to affect communication with your computer system.

At the moment, Internet of Things device installation is seeing a compound annual growth rate of 20% in the agriculture industry. And the number of linked systems in the agricultural sector will move from 13 million in 2014 to 225 million by 2024.

The Internet of Things can make anything such as home, agriculture, city, medical devices and wearables smart, using an artificial intelligence approach. This can be demonstrated by making an automation device in the agricultural field to computationally use a temperature sensor to read the environmental temperature and submit it to the microcontroller to check if the temperature at the real-time status is good for the growing plants or not.

Shahzadi et al., (2016) indicated that, expert system is a unit of artificial intelligence (AI) that is concerned with the development of computer programs for solving various computer-based problems just like the way the human beings would have solved them. It was explained that the first expert system was developed in 1965 by Edward Feigenbaum and Joshua Lederberg of Standford University in California, United States of America (USA) and it is called Dendral and it was used to aid chemists in determining the structure of organic molecules through the use of complex array of 'IF-THEN' rules. Expert systems as it is now, have applications in the fields of medical diagnosis, petroleum engineering and finance industries. MYCIN otherwise known as artificial intelligence program is not an acronym but a name that was given to an early expert system for diagnosis and treatment of blood infections. Hydroponics farming is a type of farming that does not involve the use of soil as a growing medium for crops. All that it requires are nutrients solution, air, water, the right temperature, relative humidity, potential hydrogen (pH), and electrical conductivity (EC), farming can take place all year round. Products from this farming method are of good quality as compared to the conventional method of farming.

The term hydroponics was gotten from the Greek words, hydro meaning water, and ponos meaning labor, which can be translated to mean water work. The concept of hydroponics was initiated by Professor William Gericke in the early 1930s.
Researchers at Purdue University developed the nutrient solution system in 1940. It is a soilless type of farming. It can be practiced indoors and outdoors. It is the type of farming that has become a solution to limited agricultural land which usually affects agricultural production capacity. Hydroponics agriculture does not require the clearing of land before cultivation can take place. Therefore, it reduces human labor. To achieve all these, there is a need to have an adequate understanding of the various types of hydroponics systems to know which technique is much better and less expensive to practice at every point in time. Examples of hydroponics techniques are: Wick system, Deep pot system, Raft system, Ebb and flow (Fill and Drain System), Drip system and Nutrient film technique (NFT).

Kuncoro et al., (2021) explained that, an automation system is very important for the monitoring and control of nutrient solution application and utilization. They further explained that agricultural

industries these days are flooded with technological advancement and it is also capital oriented. They developed an automation system for the management of nutrient film technique hydroponics system. Choudhary et al., (2021) explained that, the need to bring on board agricultural automation is about increase in food production and other social economic progress among the globe. It is believed that the use of artificial intelligence in the field of agriculture has brought about the development of various machines which has reduced labour.
Anushree & Krishna, (2018) explained that the Internet of Things is a technology that allows an object to connect and communicate with each other. This has helped in changing the narratives in agriculture towards higher efficiency.

Anushree & Krishna, (2018) came up with a simple and cost-efficient smart farming approach used for evaluating various environmental parameters for farming crops. There is also the android-based smartphone farming system designed to get data from sensor nodes and send it to central computing built with wireless sensor networks. Levchenko et al., (2022) stated that, Internet of Things (IoT) is rapidly evolving recently, and that billions of devices will be connected to the it by 2025, many of which will require low energy consumption and a wide area of connectivity. Low-power wide-area networks (LPWANs) satisfy these requirements and serve large numbers of devices over long distances with relatively low energy consumption. One of the most popular LPWAN technologies is LoRaWAN: The networks have been deployed in more than 170 countries Another popular LPWAN technology is Sigfox, which is used in more than 70 countries NB-Fi is a rather new LPWAN technology, but in a short time, NB-Fi networks have been deployed in Argentina India, France, Kazakhstan, Moldova, Russia and Serbia. Amalia et al., (2023) stated that the inclusion of artificial intelligence (AI) in modern agriculture has attracted more attention than before since its automation has the potentials to bring about improvement in food production and efficiency in the use of resources.

The data collection is concerned with the sensing and sensor networks that are utilized for that purpose. In the area of decision taking function, expert systems and machine learning can be deployed. Thirdly is the intervention unit where intelligent machinery and robotic devices can be called in for field works. Sudharsan et al., (2019) indicated that, the complete cycle of activities includes data collection for measurement such as soil moisture, temperature, Potential hydrogen (PH), Electrical Conductivity (EC) humidity, or multi-spectral images. The data collection process is followed by the data analysis which produces a detail explanation for the application and utilization of the environmental and the micronutrients that were used as growing components. Kudalkar & Mandge (2020) described the Internet of Things as a system that can put together computing tools, and existing and nonexistent objects and can transfer data through the network without human-to-human or person-to-machine interaction. Internet of Things is a new method that enables the communication between electronics devices and sensors over the Internet so as to

help our existence. Internet of things takes advantage of smart devices concept and the Internet to promote innovative solutions to diverse challenges and issues as it concerns different businesses, private, public and the government the world over or globally.

2. Methodology

The methodologies used are:

1.Internet of Things and Expert System
2.Nutrient Film Technique Hydroponics Setup

2.1 Internet of Things and Expert System

Various hardware devices were used in setting up the Internet of Things system. ESP 32 microcontroller deployed serves as the brain module of the automation model, peripheral devices such as temperature and humidity sensor, potential hydrogen (pH) sensor, electrical conductivity (EC) sensor, light sensor, water temperature sensor, cooler systems, motion sensor, buzzer, relay, pump components were all sourced. ESP 32 CAM was also sourced for the implementation of computer vision. These sensors are used as data collection agents and communicate to the microcontroller all of these data collected. The microcontroller processes the data based on the expert system (Computer program) installed and transmits the result to the server in the cloud for storage and analysis through the interconnectivity device (Wi-Fi).

Expert system is a branch of artificial intelligence that is concerned with the development of computer programs that can solve problems just like the way human beings solve problems. The first step to be taken here is problem identification. Our problem here is to develop an automation model that ensures that crops grown using the hydroponics method of agriculture gets proper monitoring and control services (precision) from solution nutrient (potential hydrogen (pH) and electrical conductivity (EC)) and the other environmental components that grows them from planting to harvest. The environmental components include temperature and humidity, light for photosynthesis and security.

Accurate data are collected from human experts and journal articles of this domain and developed into a computer program (Expert System). The reason for this is that some farmers find it very difficult to have access to agricultural experts to obtain knowledge. And when they do, maybe a few of them but with the expert system, we collect input from as many experts as possible and build it into a computer program (Single application) so that it can assist farmers as the case may be. Some experts may lose lives on natural ground and that knowledge is gone forever. Farmers may be ignorant or illiterate and do not know how to go about researching data for improved productivity in hydroponics agriculture.

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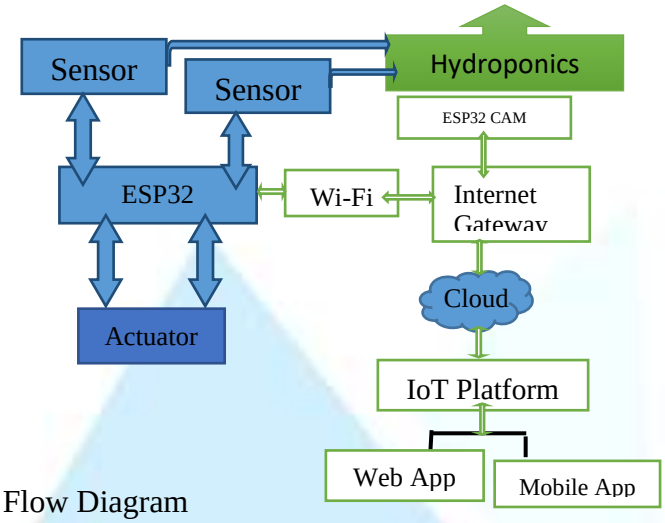

Figure.1 Data Flow Diagram

Figure.1 is the data flow diagram showing how local Area wireless sensor network was implemented.

It involves the deployment of different sensors for environmental and humidity temperature, water temperature, potential hydrogen (PH), electrical conductivity (EC), photosynthesis, intrusion sensor for security operations.

All of these wireless sensors were integrated into a single Local Area Network. The Network harvested data and communicated to the Microcontroller. Based on the program installed to the Microcontroller earlier, it carried out Logical decisions using affirmative Logic.

Data harvested by the Local Area Wireless Sensor Network and communicated to the Microcontroller were transmitted to the Web and Mobile Application domains respectively through an Internet gateway for the purposes of aggregation, storage, analysis and visualization.

2.2 Nutrient Film Technique Hydroponics Setup

2.2.1 Material Requirements

Pipe, Gum and connectors (sockets) Cutting tools such as saw, a reservoir of 50liters capacity to mix nutrients solution, transmission tube to feed the crops/plants with the nutrients solution.

2.2.1.1 Seedlings Preparation

During this phase, the first thing to do is to get the seeds from the market: Tomato, Pepper, Lettuce, and Spinach were sourced respectively. The second thing to get is the medium which is to hold the baby crops as a supporting agent and supply the required nutrients to enable them to grow well. Coconut coil was obtained for that. Thirdly, Plates or containers that held coconut coil were sourced. The seeds were planted with enough water for two weeks. This phase is monitored and controlled for these two weeks before transplanting into the nutrient film technique hydroponics testbed.

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2.2.1.2 Nutrient Solution Formulation

Master blend: Nitrogen: 4. Phosphorous: 18. Potassium: 38 Calcium nitrate: 155
Epsom Salt: 7.5 were used for formulating the nutrient solution respectively.

Figure2: Nutrient Film Technique Hydroponics Testbed with fourteen units of Tomato, Lettuce, Pepper and Spinach cultivated.

Figure.2 shows the integration of all the subunits into a functional setup, made up of the Automation Model, Nutrient Film Technique Hydroponics Testbed, Nutrient Solution Formulated and Wireless Sensor Network/Wi-Fi Technology.

The testbed was designed to accommodate fourteen units of plants such as Tomato, Pepper, Lettice and Spinach used in the experiment. Seed preparation was done before they were transplanted. It was constructed using PVC materials. The choice of this method is because, it discourages wastage as it allows reuse of farm input (Nutrient solution). Nutrient Film Technique is very effective for the achievement of optimization in the setup and the operations of a system. Attached to the setup are the controlling devices such as COOLING fans, reservoir for nutrient solution, lighting system, hydro pump, ESP 32 CAM. the solution tube is connected between the reservoir and all the units of the plants. When there is a need to supply nutrient solution to the plants, the hydro pump is activated to pump the nutrient solution through the solution tube.

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Table1: Sample of Data Harvested and Transmitted to Thing Speak Channel

1	DATE	entry_ID	Potential Hydrogen	Water Temperature	Atmospheric Temperature	Relative Humidity	Total Disolve Solid	Electrical Conductivity
2	2021-10-15T11:10:52+00:00	1	7.34504	27.1875	31	31	0	0
3	2021-10-15T11:11:33+00:00	2	7.32438	27.25	31	31	0	0
4	2021-10-15T11:13:01+00:00	3	7.31596	27.25	31	31	0	0
5	2021-10-15T11:13:38+00:00	4	7.28917	27.25	31	31	0	0
6	2021-10-15T11:14:11+00:00	5	7.34428	27.25	31	31	0	0
7	2021-10-15T11:14:43+00:00	6	7.35958	27.1875	31	31	0	0
8	2021-10-15T11:15:16+00:00	7	7.33662	27.25	31	31	0	0
9	2021-10-15T11:15:48+00:00	8	7.32973	27.25	31	31	0	0
10	2021-10-15T11:16:21+00:00	9	7.34887	27.1875	31	31	0	0
11	2021-10-15T11:16:57+00:00	10	11.33267	27.1875	31	30	0	0
12	2021-10-15T11:17:31+00:00	11	10.29558	27.1875	31	31	0	0
13	2021-10-15T11:18:03+00:00	12	9.24472	27.1875	31	31	0	0
14	2021-10-15T11:18:35+00:00	13	9.33656	27.1875	31	31	0	0
15	2021-10-15T11:19:08+00:00	14	8.85284	27.1875	31	31	390.92371	0.78185
16	2021-10-15T11:20:36+00:00	15	9.91442	27.25	31	31	1019.57513	2.03915
17	2021-10-15T11:21:13+00:00	16	9.22864	27.25	31	31	1033.69873	2.0674

3. Evaluation

Evaluation is a way or method of carrying out assessment on work done based on available data/information to ascertain if the objectives of the work are achieved, so the method used is goal-based.

Table1: shows the Sample of data harvested by the wireless sensors network, communicated to the microcontroller and Transmitted to ThingSpeak/Blynk domains respectively by the Wi-Fi device, indicating that all the sensors in the network and the actuators linked to the microcontroller functioned with accuracy and precision.

3.1 Plant Evaluation

From the visual look, one can see that, the plants height is good. The colour of the plants is green. The leave weight and height are normal, an indication that the formula used to grow the plant is rich. The researcher planted four varieties, including: Tomato, Lettuce, Pepper and spinach to check if all of them can grow together using the same nutrient solution formulation. And from the result, it is clear that they can be grown together using the same formulation because they all responded well. The researcher planted the crops, monitored and controlled them for 6 weeks using automated nutrient film technique hydroponics testbed. The computer vision used in the implementation of the plant growth evaluation was based on the acquisition and application of ESP 32 CAM microcontroller. Below are the pictorial presentations of the plants growth.

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Figure3: Digital Image of Tomato Captured.

Figure3: Shows the digital image of Tomato captured. This picture was taken from the automated nutrient film technique hydroponics testbed using digital camera.

Figure4: Digital Image of Pepper Captured

Figure4: Shows the Digital image of Pepper captured. This picture was taken from the automated nutrient film technique hydroponics testbed using digital camera.

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Figure5: Digital image of Lettuce Captured

Figure5: Shows the Digital image of Lettuce captured. This picture was taken from the automated nutrient film technique hydroponics testbed using digital camera.

4. Conclusion

This study has led to the innovation of automation model for growing crops in the hydroponics vegetable farm. The model with the use of sensors, collected, processed and transmitted over 12000 records in comma separated value CSV. format real time for monitoring and controlling of the growth of the vegetables and they are similar to the data earlier collected from experts and journal articles for growing vegetables crops.

The result suggests that, the use of this automation model for growing vegetables in the hydroponics farm has the potential to replace the method that is used by human experts and that of the journal articles.

Any variations in values will be subjected to investigation so as to make a more robust model in the future.

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