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USING IOT TO SIMULATE SMART GARDEN

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Master’s Thesis

Supervisor

Asst. Prof. Dr. Abdullahi Abdu IBRAHIM

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The thesis titled USING IOT TO SIMULATE SMART GARDEN prepared by GULLED MOHAMOUD JAMA and submitted on 25/04/2023 has been **accepted unanimously** for the degree of Master of Science in Information Technologies.

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Signature

DEDICATION

I would like to express my gratitude to all of our great Mentors by devoting this project to them. Our Mentors make it possible for us to take part in a broad range of activities and to educate others about the skills that we have acquired. My most profound gratitude goes out to my family members, who, by the example they set and the prayers they said for me, gave me a love of reading and an appreciation for the value of education that will last a lifetime.

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ABSTRACT

USING IOT TO SIMULATE SMART GARDEN

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The Internet of Things (IoT) is a subfield of computer science that focuses on the development of mechanisms and methodologies for the interconnection of a diverse set of digital devices for the purpose of automating the operation of real-world systems. An approach for monitoring smart gardens that is based on the Internet of Things (IoT) and uses a microcontroller called NodeMCU has been proposed in this research paper. The users of this method receive assistance in determining the current parameters of temperature, moisture, and humidity of their homegrown plants and gardens by using this approach. Oxygen is the one thing that is absolutely necessary for each and every person who resides in this world. The primary goal of this project is to maintain the natural state of the plants through the continuous monitoring of the parameters, which will ultimately lead to an extension of the lifespan of both the plants and the people.

This will be accomplished by preserving the natural state of the plants. It is strongly suggested that a manual system not be utilized in favor of an automatic one. With Android software, mobile applications can be developed, which can then be used to monitor the parameters of the garden and automate the process of watering the plants. The real-time profiles of environmental factors such as temperature, moisture, and humidity have been displayed by using an android mobile application that was designed for use on mobile devices. The application was developed for use on mobile phones and tablets. The people who use this system will be able to tend to their gardens in a way that is more conducive to the development and health of the plants that they cultivate than any other method currently available. This body of work does away with the need for gardeners as well as the difficulties that come up during the maintenance of gardens in large cities.

Keywords: IoT,Smart Garden, NodeMCU, Sensors, Micro-Controller.

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ABBREVIATIONS

IoT	:	Internet of Things
TFT	:	Thin-film Transistor
SoC	:	System on a Chip
IDE	:	Integrated Development Environment
RFID	:	Radio Frequency Identification

1. INTRODUCTION

Both rapid population growth and changing climate pose a risk to the world's ability to provide enough food for everyone. Both alterations in land use and shifts in the distribution of arable land can have an effect on the amount of food that can be produced to feed a growing population. Land use and agricultural practices are accountable for 25 percent of the total amount of greenhouse gases produced [1]. The ability to make a living in rural areas and the ability to produce food for human consumption are both affected by the weather. There needs to be a seventy percent increase in the amount of food that is produced in order to meet the requirements of the world's population by the year 2050 [2]. In order to ensure things like food security, population growth, and adaptation to climate change, agricultural practices that are more sustainable are required. It is possible that technological advancements will make it possible for smallholder farmers to adapt their farming practices to the effects of climate change.

The age of automation has arrived, and it has conquered the world. It is a strategy that involves utilizing computers or mobile phones in order to monitor and control the fundamental aspects of one's day-to-day life. It is going to be beneficial to the quality of life that we lead if we make a habit of using automation for jobs that are relatively simple [1], [2]. We are able to develop sensors that are effective in automation by utilizing the idea of IoT to enable interoperability between the sensors. This allows the sensors to communicate with one another. The fact that this prototype has no potential downsides in terms of either its cost or its safety is the single most important aspect of it. People, when they try to make plantings and set up their own garden, are careful in the maintenance only at the beginning stages of their efforts [2].

This is because the garden is still in its infancy. The destruction of the plants that occurs with the passage of each day is caused by the lack of maintenance that has been performed on them. With the assistance of this prototype, people will be able to automatically monitor the parameters, which will also ensure that the garden is maintained in a satisfactory manner [2], [3]. It is an essential component that, when present, offers a favorable environment for the development of plants. The Internet of Things not only offers solutions to a wide range of problems, but it also makes it possible for things to be sensed or controlled remotely from within the infrastructure of a network.

The struggle of smallholder farmers is to provide food for an ever-increasing global population. In order for the farming practices of smallholders to be sustainable, information is essential. In addition to this, they are expected to have knowledge concerning the reactions of crops to different types of weather and water. The good news is that the fourth industrial revolution will connect the physical and digital worlds and will have an impact on all different types of industries [3]. ICT is also changing agriculture; this technology helps smallholder farmers in developing countries adapt to climate change and increases the efficiency with which they produce food. In other words, ICT is making agriculture more productive.

The Internet of Things (IoT), edge computing, cloud computing, sensors, and wireless communication that is both cost-effective and energy-efficient are some of the technologies that could make information-driven farming a reality. Farmers are able to keep an eye on the development of both their crops and the surrounding soil [1][3]. The optimization of inputs and the monitoring of animal health are both made possible by data collected from farms. The use of irrigation and hydroponic systems, both of which are made possible with the assistance of technology, can be used to supplement rain-fed agriculture.

The Internet has had a major influence on society, and many new technologies are merging in a manner that suggests the Internet could soon expand to allow things to join and have their own digital identity. This confluence of technology suggests the Internet may soon expand to allow things to join and have their own online identity. This proves the Internet has changed society [1][2][3].

The Internet of computers paved the way for a number of technological advances, one of which was the conception of what is now known as the Internet of things. “This idea makes it possible for real-world objects to be connected to and controlled from within the realm of the digital. Both the Internet and personal computers are still dependent on human beings as their primary source of information at the present time [2][3].” Because information technology is so reliant on the data that humans supply, if we had computers that are cognitively independent regarding the purposes for which they utilize data, they would be able to monitor and count everything, resulting in a considerable reduction in both loss and expense [3].

Because information technology is so dependent on the data that people provide, if we had computers that are intellectually independent about the things they use data for, they would be able to monitor and count everything. It is possible that the Internet of Things will bring about as much or even more change to the world than the Internet did in its early days [2], [4]. When this revolution is fully implemented, it will have repercussions in every sector of the economy and in our day-to-day lives. These repercussions will be felt all over the world. The move toward ubiquitous information and communication networks is already well under way, as evidenced by the proliferation of wireless Internet access methods such as Wi-Fi and 4G-LTE, as well as the debut of the most recent generation of 5G technology [2][3][4]. However, in order for the concept of the Internet of things to become a reality, the paradigm of computing will need to advance beyond the traditional mobile computing scenarios that make use of portables and smart phones.

Only then will the vision of the Internet of things be able to become a reality. Instead, it will have to progress to the point where it connects commonplace objects that already exist and incorporates intelligence into our surroundings. “The Internet of Things requires a shared understanding of the situation of its users and their appliances, software architectures and widespread communication networks to process and convey the contextual information to where it is relevant, and the analytics tools in the Internet of things that aim for autonomous and smart behavior in order for technology to disappear from the consciousness of the user [4][5].”

This is necessary for the Internet of Things to be successful. This is essential in order for technology to fulfil its promise of one day being able to make itself invisible. After these three fundamental conditions have been satisfied, it will be possible to achieve intelligent connectivity and computation that is aware of the context in which it is operating. A revolutionary transformation of the internet as we know it into a network of interconnected objects that not only collects information from the surrounding environment (sensing), but also interacts with the physical world (actuation/command/control) [3][4][5].

In addition to this, it adheres to the already established standards of the internet in order to deliver services for the transfer of information, the analysis of data, the creation of applications, and communications. Devices for open wireless technologies like Bluetooth, RFID, Wi-Fi, and mobile data services, was the impetus behind the development of the

Internet of Things. These devices additionally featured embedded sensor and actuator nodes, which laid the groundwork for the Internet of Things (IoT) [5][6]. The Internet of Things (IoT) is on the verge of changing the static Internet into the fully integrated Internet of the future. This transformation will take place in the next few years.

The production of food in today's agriculture takes place on a massive scale, and in order to accomplish this, the monoculture farming method is utilized on enormous swaths of land. Mono crop farming has resulted in an increase in the availability of farm produce and a relative decrease in the price of it [2]. This is due to the fact that mono crop farming uses the same nutrients for a variety of crops while simultaneously consuming a significant amount of water [2][4].

“According to the findings of this study, the objective of the automation provided by the Smart Garden is to lessen people's reliance on industrial agriculture by giving them the tools necessary to grow their own plants with as little or as much actual manual labor as is required. This can be accomplished by providing them with the means to cultivate their own plants with as little or as much actual physical labor as is required [1].” The memory capacity that will be included with the automation of the Smart Garden will be used to assign the location of each individual plant. In accordance with the information contained in the online database, provide specialized care to each plant by providing it with water and nutrients on demand and monitoring its overall health [2][6]. People who have little to no experience in gardening will be able to cultivate the garden of their dreams.

Because of the introduction of a genuine gardening experience made possible by the smart garden automation, this can be done with little more work than making a few taps on the screen of a tablet computer. People will be able to nurture the garden of their dreams with little more work than a few clicks on the screen of a tablet computer. This will make it possible for people to realize their full potential [1][4].

The Internet of Things has resulted in technological advancements such as self-sufficient robots and helpful drones, both of which are essential components of the smart farm. The Internet of Things (IOT) concept of making things, such as machines, devices, and equipment, capable of connecting to one another, exchanging data with one another, and communicating with one another has made it possible for IOT technologies to expand into other industries, such as those that are not related to agriculture [4]. This has facilitated the expansion of IOT technologies into other industries. The sensors are able to carry out a wide range of functions, such as the gathering of data pertaining to meteorological conditions, the relative humidity of the soil, levels of irrigation, and weather conditions. This valuable information is now being put to use in an effort to enhance the machine learning capability of the autonomous robots. It will help the autonomous robots perform better in a variety of duties, including watering, harvesting, and weeding, amongst others [4][5].

This will be accomplished through the utilization of the Smart garden's limited tool set, which comes at a low cost. The Smart Garden has the potential to be incorporated into a Smart Farm along with other innovations that can operate independently, which will result in the development of a technological solution for the anticipated population that will save time and increase output. Recent developments in technology will encourage investors to take part in more agricultural activities, which will result in the creation of additional employment opportunities [1][4][5].

1.1 MOTIVATION

The mobile technology that was developed by Cisco is used in countries of the third world to disseminate information regarding early weather warnings, advisory information, and farmers markets [3][4]. To realize the full potential of information and communications technology (ICT) as well as to produce food in an effective manner, advanced technologies are required. On the other hand, developing countries have not adopted any of the more advanced agricultural technologies. The prohibitively high cost, limited internet connectivity, ineffective long-range communication, and inefficient use of power have been the primary factors that have prevented this from happening.

1.2 PROBLEM STATEMENT

It is generally accepted that there is a demand for technological solutions that can assist smallholder farmers in developing countries in increasing their food production and adapting to the effects of climate change. This demand is driven by the fact that smallholder farmers make up the majority of the agricultural workforce in these countries. It is necessary to implement technology on farms in addition to cell phone-based solutions for the exchange of meteorological, financial, and market data in order to achieve the goal of smart farming. As a direct result of the data revolution, there is a possibility that smallholder farmers will become even more marginalized and disadvantaged in the future [4].

2. LITERATURE REVIEW

In more recent times, people who lived in urban areas were observed to engage in gardening on a more frequent basis [5]. Because growing plants requires regular maintenance, some people choose not to do so because of the commitment it requires. In order to ensure the plants' continued good health, they must receive consistent irrigation [6]. A network of interconnected electronic devices that are able to communicate with one another and share data over the internet is referred to as the "Internet of Things" (IoT) [7]. It bestows upon these devices the capability of collecting data and communicating that data with a user. “In the current technological era, automation has emerged as the dominant force across the board in every region of the world [8]. Automation is also the key to significantly empowering several different sectors of the economy, which is where it is most desperately needed [7][8].” Every aspect of human activity, from manufacturing and agriculture to services and logistics, stands to gain from the increased capacities, efficiencies, and overall production quality that can be provided by technological advancements [9][10].

The term "Internet of Things" refers to a method that makes use of computers, mobile phones, or other digital devices for the purpose of monitoring and controlling the fundamental aspects of everyday life. This method is referred to as the internet of things [11]. With the assistance of concepts and pieces of knowledge obtained from the Internet of Things, a brand-new automation infrastructure that is built on sensors, software [12], and communication protocols will be developed in order to automate a wide variety of tasks (IoT) [13]. The most vital component of the Internet of Things is the sharing of data. When we make it a habit to rely on automation for the more menial aspects of our lives, the overall quality of our lives will improve as a result [14][15]. At this very moment, humanity is in the midst of the fourth industrial revolution, which is characterized by the transition of systems away from manually performed processes and toward automatically performed ones [16][17][18]. This not only presents the concept of the intelligent industry but also opens up a wide variety of new research avenues [19]. People who enjoy growing gardens and various kinds of small fruit plants inside their homes typically exercise an unusually high level of caution during the early stages of their responsibilities as caretakers

[20]. The failure to adequately care for the garden as a direct result of this causes it to deteriorate to the point where it cannot be salvaged [21].

There are also climatic conditions that can cause the lifespan of the garden to be cut short. “Some crops and plants can perish due to a lack of moisture, extreme heat, and humidity, amongst other things, and this can cause the garden's lifespan to be shortened[22].” People will hire experienced gardeners to look after their personal allotments of land for growing vegetables. The majority of plants experience some form of damage on a consistent basis as a direct result of the conditions of their environment as well as a lack of care that is appropriate [23].

An automated garden monitoring system makes use of the internet of things comes into play as a potential solution to the problems that were discussed earlier in this context [24]. The system that has been suggested incorporates all of the sensors and other components that are required in order to generate statistics in real time [25]. Communication is accomplished through the utilization of wireless sensor networks and networks of sensors. Mobile computing is an effective technology that has the potential to serve as a backbone for the IoT [26], and it can be used in the development of systems that are used in the real world [27][28]. There are mobile applications that are currently available that provide assistance to farmers with the care and maintenance of their crops [29].

Similar Internet of Things-based systems are designed for garden maintenance. These systems, which can be pricey and are frequently used for only one task at a time, such as reading the temperature or operating a mechanism to pour water, are referred to as point solutions [30]. A piece of equipment that is able to automate the process of watering plants by carrying out an analysis of the various environmental parameters that are present in the garden [31][32]. The condition of the garden is being evaluated by a mobile application that is currently under development in order to ascertain whether or not it requires additional watering [33][34]. The IoT monitoring system is equipped with temperature and moisture sensors for large gardens, so it is able to detect both the temperature and the amount of moisture that is present [35]. Arduino is used to perform the integration of soil and other supporting sensors. After that, Arduino computes the values of the soil [36][37], and then it sends this information to firebase using the WIFI facility that is already built into it [38]. The system is able to determine the humidity and moisture levels of the trees and plants, and it then provides the plants with the appropriate amount of water [39].

There will be more than 20 billion digital devices that are connected to the internet by the year 2020, which is the direction that current technology is heading. The internet of things is the direction that current technology is heading [40]. The Internet of things is going to bring about a revolution in our day-to-day lives by delivering fully automated solutions to problems ranging from manufacturing to monitoring systems [41][42]. This revolution will be brought about by the delivery of these solutions. The inability to integrate digital devices in a way that is both flexible and appropriate creates additional challenges for the development of systems that are based on the Internet of Things [43][44][45]. The process of developing systems that are founded on the internet of things will present system developers with a wide variety of challenges to overcome [46].

The Internet of Things (IoT) refers to the incorporation of digital devices, people, and processes into any system that exists in the physical world in order to enable meaningful communication and operation [47][48]. A wide variety of methodologies and techniques have been developed as a response to the challenges posed by the development of embedded systems, cloud computing, pervasive computing, and ubiquitous computing [49], [50]. This has been done in order to meet the demands of the aforementioned types of computing. On the other hand, these solutions are not capable of overcoming the problems that are posed by systems that are based on the Internet of Things (IoT) [50].

3. PROPOSED SYSTEM DESIGN

We integrate the entire module by utilizing a NodeMCU (ESP 8266) microcontroller [1]. The microcontroller includes a Wi-Fi module as an integrated component, and it is this module that facilitates the transfer of data from the sensors to the microcontroller [2]. The device is lightweight and easy to transport, but it will require periodic charging in order to function properly. The data is transmitted directly to the application without going through any intermediaries. The system diagram that has been proposed is a graphical representation that explains how each component satisfies a specific function within the whole [3]. In the middle of this figure is a representation of the apparatus, and its varity of elements are arranged around it.

The network component of the device consists of a predetermined access point that is used for the device's operation as a whole. Utilizing temperature sensors allows one to analyze the impact that heat has on garden plants by measuring the current status of heat as well as the temperature of the soil and the air. In a manner that is analogous, the YL-69 [4, 5, 6] sensor provides information regarding the present moisture levels of the soil, while the humidity sensor is responsible for calculating the proportion of water vapor in the air that is present in the air right at this very moment [7].

Because each of the sensors provides data on the plants in real time [8], we are able to acquire a more precise understanding of how the environment is currently functioning as a whole. Users can put this information to use to treat areas of the garden that have been impacted by the problem [8, 9]. The battery is used for making charging unit, which is linked to a power input chip as well as a circuit board that makes use of the battery in order to transfer DC power to the sensors so that they can function properly [10]. Additionally, the power input chip is connected to the battery via a cable. The output that can be produced by the Display unit includes not only the IP address but also the parameters that are currently being detected in the area [9, 10]. The requirements for this system are separated into their respective categories based on whether they are considered to be functional or non-functional.

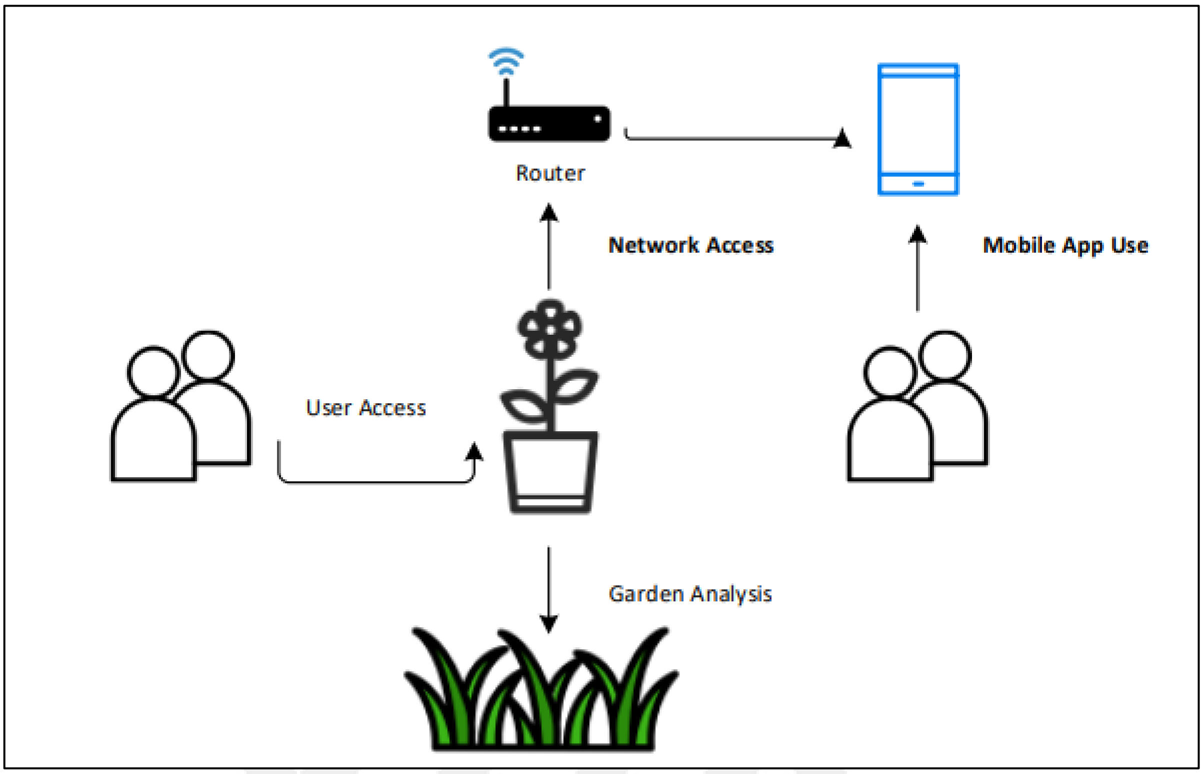

Figure 3.1: Diagram of Proposed System [1, 2]**.**

3.1 PROPOSED SYSTEM BLOCK

In most cases, it is made up of a microcontroller, which serves as the central processing unit of the system and to which various components are connected. A variety of sensors, include sensors that detect moisture and humidity, temperature, and ultrasonic waves [11], are connected to the NodeMCU [12] so that it can function as the hub of the smart garden. The ultrasonic sensor was fastened to a water tank and provided feedback on the quantity of water that was currently held within the tank at any given time.

Other sensors are connected to their respective positions, and these sensors send the data that they collect to NodeMCU [12, 13]. NodeMCU's internal architecture includes Wi-Fi technology, so it is able to receive this data. The real-time values of the sensor are updated in the database known as Firebase once every second. This database can be accessed over the internet. The creation of Android applications takes place with the assistance of a piece of software known as android studio. The software itself will be responsible for establishing connectivity between the application and Firebase [1, 14].

Consequently, the user can monitor the parameters regardless of where they are located in the world. The type of soil determines the amount of water that must be added to a garden each time it is watered [7, 15, 16]. As a result, the readings from the sensors have been permanently inserted into the software in order to make the process more amenable to automation. A toggle switch within the application will take care of the watering process automatically once the user determines that the garden needs to be watered. This contributes to the overall maintenance and care that is provided for the garden [17].

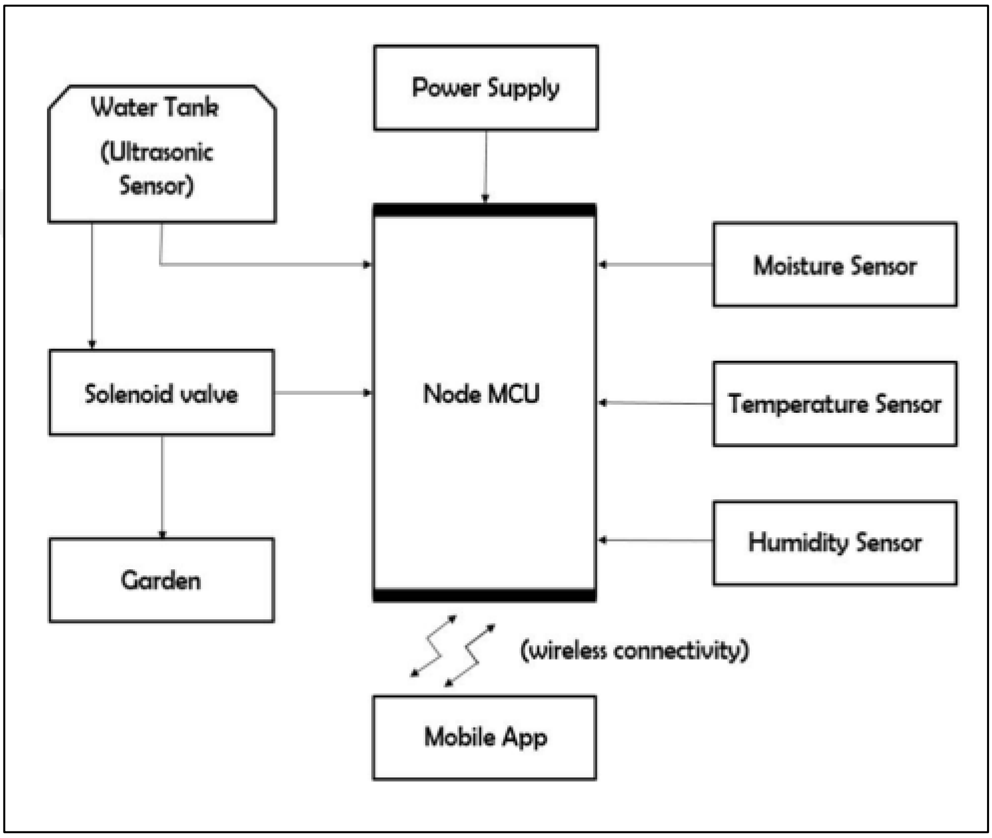

Figure 3.1: System Block Diagram [2, 4, 5]**.**

3.2 SYSTEM HARDWARE DEVELOPMENT

The following components are what make up the system's physical hardware: Before being connected to a DC power supply [18], they are put through their paces by the Arduino IDE (programming), after which they are assembled on breadboards with the assistance of jumper wires.

3.2.1 Sensors

Any device that is able to convert analogue electrical signals into their digital equivalents is referred to as a "sensor [19]," and the term can be used to refer to any such device. The following is a list of the many different types of sensors that are utilized by this system.

Table 3.1: Types of Sensors Required for System [3, 5, 7, 8]

Sensor Type	**Sensor Description**
Humidity sensor	Instruments that are utilized for determining the relative humidity of the soil.
Ultrasonic sensor	Used for determining how much water there is in the tank.
Temperature sensor	Utilized for the purpose of determining the temperature of the soil.
Moisture sensor	Used for determining how much moisture is contained in the soil.

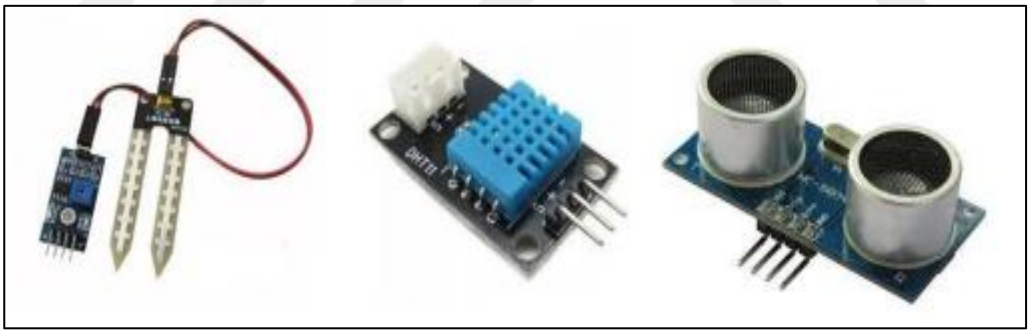

Figure 3.2: Used Sensor Types [1, 2].

Table 3.2: Hardware Components and Description [1, 2, 4, 5, 7, 8, 9]**.**

Hardware Component	**Hardware Description**
NodeMCU	A microcontroller that has built-in capabilities for networking.
“DS18B20 Temperature Sensor”	Used for determining how healthy the plants' soil is.
“DHT11 Temperature and Humidity Sensor”	Instruments that are employed for the purpose of determining the humidity and temperature of the plants.
“YL-69 Soil Moisture Sensor”	In order to determine already present moisture amount in the soil.
LCD	Show the information that was collected from the sensors.
Other Components	Among the many components it has are a charging unit, an LCD screen, and a resistor rated at 1 kW.

4. REQUIREMENT SPECIFICATION

4.1 PERFORMANCE

This item of hardware must maintain a level of performance that is adequate in order to function properly [20, 21]. The standard for the speed of data exchange between the device and mobile apps must be kept at a level of consistency that can be maintained at all times. This is an essential need.

4.2 SAFETY AND SECURITY

In order to proceed with the project, the customer usage standard for safe and secure operation of the proposed prototype needs to be satisfied [20, 22]. It is essential that users have the ability to receive authorization from the system.

4.3 SOFTWARE QUALITY ATTRIBUTE

Utilizing quality control to ensure that the optimization, system constraints, and testing grade are all met is one method of meeting these requirements [1, 22]. We are able to keep an accurate check and establish appropriate standards for business applications as a result of these characteristics. Connectivity to any and all networks, the ability to function in standalone mode without the requirement of a mobile application, portability [24, 25], and the capacity to charge the device are among the most essential features. An Android application is necessary for the device in order to gain access to the information that has been gathered and to display it. It is necessary for the user to sign in before they can access the data, as this is a requirement of the application. Once the user has been authorized [26], Not only will they be able to examine the readings that are being collected from the device in real time, but they will also be able to do so in a more historical format. But in addition to that, they will be able to look up previous iterations of the factor profiles that have been applied [26, 27].

The users will automatically be led through the best growing conditions that should be present in the garden for the plants. We utilized Android Studio to construct a customized application that operates the complete system in order to produce a mobile interface for the design of a mobile device. This application is responsible for running the entire system. This application was used to create a mobile device [24, 25, 26]. There is only one interface available from a purely technological point of view (user). The programme is designed to gather information from the device, and once it has done so [27, 28], it will either display that information on the user interface (UI) [27, 29].

The chosen standard for the device's communication protocol, which is dependent on a wireless network standard, is the HTTP protocol [1, 17, 19, 26]. Because establishing a connection to a network requires the use of an IP Address on the device in question. The JSON format will be used for any and all responses that are sent between the various linked devices [2, 4, 6, 8]. In the event that there is a problem with the network, the information will be preserved on the local server so that it may be accessed at a later time [9, 10, 15].

5. IMPLEMENTATION OF PROPOSED SYSTEM

The envisioned system will, in addition to its electrical components, incorporate the system's physical configuration. As well as methods of communication that encompass the many different ways and forms of data transfer that take place between the device and the application. The implementation can essentially be divided into two parts:

i. Device [2]

ii.Mobile Application [28, 29]

It will make use of sensors that are equipped with microcontrollers that have been programmed with appropriate instructions, and that are connected to mobile applications, for the purpose of transferring the data that has been gathered by the device [30]. The creation of this prototype necessitates not only the development of hardware but also of software, in addition to the establishment of a medium for communication.

The majority of the focus and attention is directed toward the process of fabricating a device from its component parts, which are critical to achieving the overall objective of the project. The system that is being designed to collect information about the state of a garden uses sensors [31], as was mentioned in earlier chapters, and it is intended to be portable and independent of the environment that it is in [32]. In the middle of the NodeMCU [32, 33] controller is where the block diagram begins and ends.

The display, the power supply, and the charging unit are all connected to the NodeMCU controller in some way. Additionally, temperature, humidity, and moisture sensors are connected to the controller [33]. The display, which consists of a solitary very small TFT LCD screen [30, 33], is constructed on top of the actual device itself. The display, the power, and the sensors are the three components that come together to form the whole system [34]. The unit that contains the temperature, humidity, and moisture sensors is comprised of the humidity, temperature and moisture sensors themselves.

The proposed system's overarching operation is depicted in Figure 4's Activity Diagram, which provides an overview of the system's functionality as a whole. The user is responsible for starting the device as the first step in the process, and they are then followed by a constructed device that inspects the area beneath the surface [35, 36]. The device performs an analysis of the lawn area by utilizing integrated sensors and tries to retrieve the specified parameter values on real time. This process occurs while the device is monitoring the lawn. The device will be able to determine whether or not it has access to the network if it is successful in retrieving the values without making any errors [31, 34, 36].

In that situation, the device will be restarted, and the debug procedure will be made active. Hopefully, this will fix the issue. The error can then be located and corrected thanks to this information. The user's mobile application will be used to deliver the retrieved results to them in the event that the device was able to successfully establish a connection to the network [36, 37]. In the event that there is a problem while attempting to connect to the network, the retrieved results will be displayed on the TFT screen that is integrated onto NodeMCU [38].

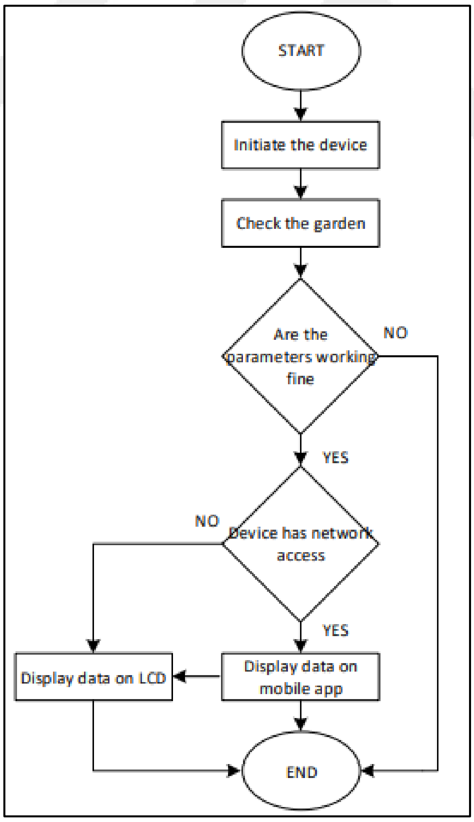

Figure 5.1: Activity Diagram [1, 2, 6].

5.1 HARDWARE

The proposed garden monitoring system cannot be successfully implemented without the following essential pieces of equipment being present and operational,

5.1.1 NodeMCU

A digital microcontroller NodeMCU that is constructed using system on chip (SoC) technology [1]. Its purpose is to facilitate the development of applications for the Internet of Things. It features other library support functions in addition to an onboard WIFI system for data communication purposes [1, 2, 3, 4]. Micro Controller Unit is what "MCU" stands for when it's abbreviated. The ability to perform tasks such as analyzing [36], controlling [38], and monitoring digital systems [30, 38] is made possible as a result of this.

The NodeMCU acts as a central node for the Smart Garden network. Open source software serves as the foundation for the Internet of Things platform known as NodeMCU [38, 39]. The Espressif Systems ESP8266 Wi-Fi System-on-a-Chip (SoC) drives it, and its hardware is based on the ESP-12 module, the most cost-effective option [41]. It is a microcontroller that is contained on a single board and has a memory capacity of 128kBytes as well as a storage capacity of 4Mbytes [40, 41]. It was designed with straightforward programming in mind, and it enables developers to rapidly prototype their ideas.

Utilizing a cloud-based build service, a Docker image, or the Linux Build Environment are the three primary choices available to you when it comes to constructing firmware for your NodeMCU device [40, 42]. It has a Wi-Fi module that is built in, so we are able to upload the readings from the sensors to the firebase. This is made possible by the inclusion of this module. Consists of a central component known as NodeMCU [40, 42].

Figure 5.2: NodeMCU Micro-Controller [1, 3]**.**

5.1.2 Temperature Sensor

The “DS18B20 (temperature Sensor) is a real-time temperature measuring sensor that can function with the use of just a single wire. You will only need to make use of a single data line whenever you are communicating with a device that is integrated. Figure 6 provides a visual representation of the DS18B20 temperature sensor.

Figure 5.3: Temperature Sensor [2, 5, 7]**.**

5.1.3 Soil Moisture Sensor

When it comes to measuring the amount of moisture present in the ground, the “YL-69” is the most reliable as well as cost-effective sensor on the market today for measuring soil moisture [41, 43]. This device is made up of two different components: Two sensor strips and a small electric board. They are jointly responsible for determining the values of the parameters. Figure 7 provides a visual representation of the YL-69 soil moisture sensor.

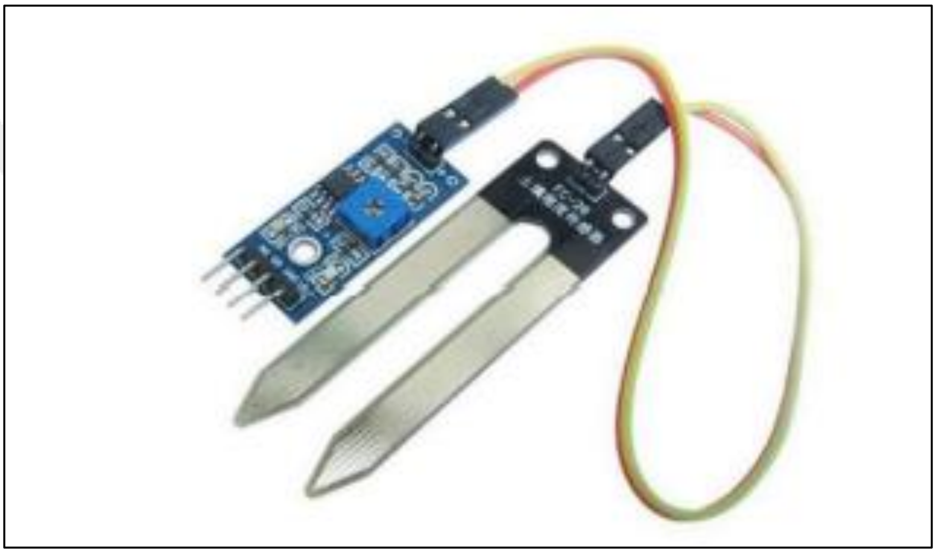

Figure 5.4: Soil Moisture Sensors [3, 4, 6]**.**

5.2 CIRCUIT DIAGRAM

The circuit diagram of a prototype shows how Arduino configures all components and sensors. The primary element is a microcontroller called an Arduino, which can be found attached to a breadboard. LCD and standard interfaces connect all other sensors to the central location, which are provided by the manufacturer [2, 15, 29, 44].

Figure 5.5: LCD [2, 5, 6]**.**

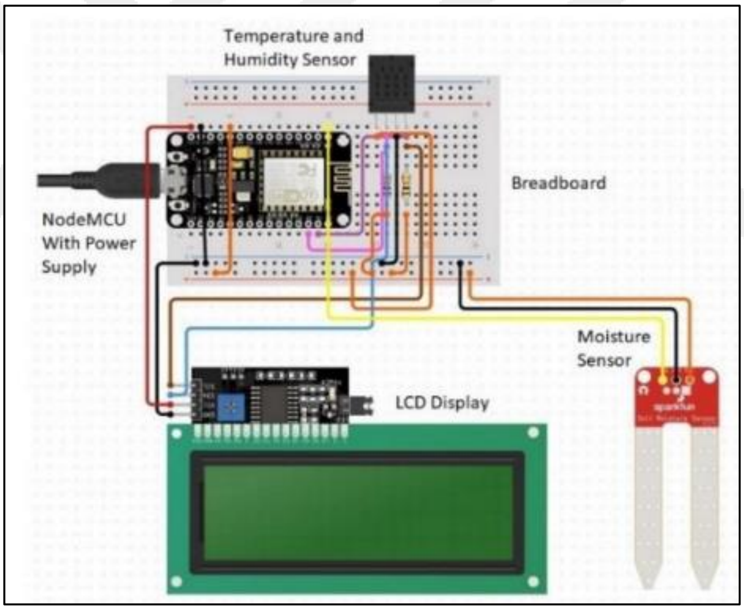

Figure 5.6: Breadboard circuit Diagram [2, 3, 4]**.**

5.3 SYSTEM HARDWARE IMPLEMENTATION

Through the utilization of a circuit board that was designed specifically for our needs, we were able to map sensors and other components onto the appropriate locations on the circuit board. In the actual garden, the instrument is utilized, and the results are retrieved in real time.s

Figure 5.7: Smart Garden hardware Monitoring Device [1, 3, 4]**.**

5.4 SOFTWARE AND TOOLS

When it comes to the process of developing mobile applications, Android Studio is the tool of choice, while Arduino IDE is the tool of choice when it comes to the process of programming the device as a whole [5, 14, 27, 31, 45]. Both will use libraries to correctly link the programme and device, it made possible by the use of the libraries [32, 44]. The application will use device data, it is imperative that both the device and the application have the appropriate library files. This is due to the fact that the system will be gathering information that is produced by the hardware. A communication interface that allows for the transfer of data between a mobile app and a device is specified by the JSON standard [39, 44].

5.5 COMMUNICATION PROTOCOL

Communication protocol specifies data transport medium. JSON serialises and sends structured data over a network [40, 41, 44]. JSON is an acronym that stands for JavaScript Object Notification. For the purpose of achieving this goal, we make use of JSON in order to transmit data from a server to a client.

JSON is a file format that is both lightweight and flexible in its design. Because it requires the transmission of information in the form of a variable between the hardware component and the software programme, this strategy is generally considered to be the approach that is utilized by the majority of the custom-built machines and devices [44, 45]. This is because it calls for the transfer of data between the application and device. The Arduino IDE's Wi-Fi Manager and Client Libraries let the device connect to the programme through IP Address and send live detected parameters [45, 46]. Using an IP Address, the device can connect to the programme.

5.5.1 Firebase

Firebase is a platform that is owned and operated by Google and is used for the development of mobile and web applications [43, 45]. It makes it easier to create more useful applications for mobile devices.

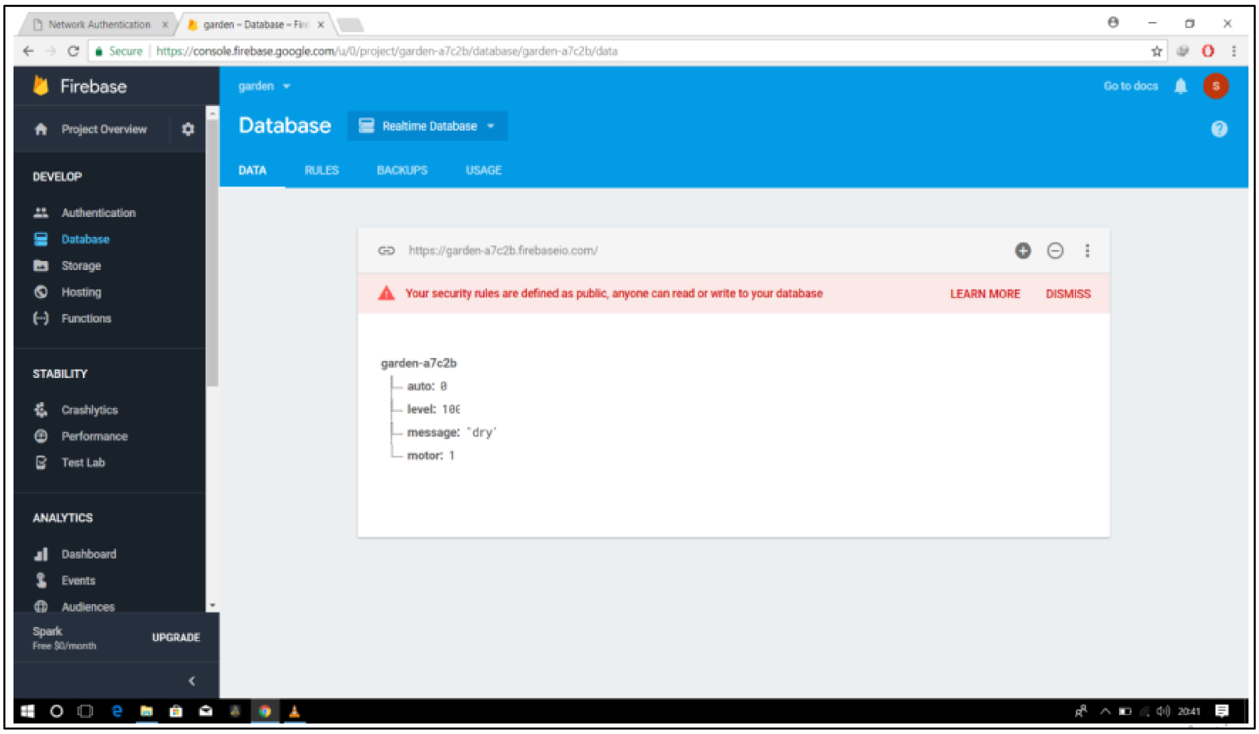

Figure 5.8: Real time updated values of Sensors in Firebase [1, 2, 3].

It offers features such as crash reporting, messaging, analytics, and database management, among other functionalities. Because it was built on Google's infrastructure, it can easily expand to accommodate more users as needed. Both mobile platforms such as iOS and Android [1, 12, 13, 47], as well as the web, are easily compatible with Firebase's simple integration process.

The capacity to support additional platforms has been maintained despite the fact that the APIs have been consolidated into a single SDK [7, 18, 21, 32]. It provides a backend service in addition to a database that is constantly being updated. The data gleaned from the sensors is sent to firebase using NodeMCU, which ensures that the data is accurate and up to date [45, 46]. The Firebase platform is integrated with mobile applications so that control can be exercised over those interactions.

5.5.2 Arduino

When it comes to writing the application that manages NodeMCU, you are free to use any programming language you like. The Integrated Development Environment (IDE) that is provided by the Arduino software is superior when it comes to the task of programming the NodeMCU. It is an application written in Java that is capable of running on a number of different platforms [45, 47]. This piece of software comes with a number of features, some of which are a code editor, the capability to cut and paste text, the ability to search for and replace text, brace matching, and automatic indentation, as well as syntax highlighting [46, 47].

It is suggested that the board in the software be changed from Arduino to NodeMCU, and that the software also incorporate the necessary libraries for the NodeMCU board. These changes are recommended because of the increased compatibility between the two boards [47 48]. After putting the board through its paces with a programme that causes an LED to blink, the code for the intelligent garden is then written down. The programme includes all of the library files required for connectivity to Firebase as part of its standard distribution. When it comes to writing the application that manages NodeMCU [46, 48], you are free to use any programming language you like.

The Integrated Development Environment (IDE) that is provided by the Arduino software is superior when it comes to the task of programming the NodeMCU. It is an application written in Java that is capable of running on a number of different platforms [48]. This piece of software comes with a number of features, some of which are a code editor, the capability to cut and paste text, the ability to search for and replace text, brace matching, and automatic indentation, as well as syntax highlighting.

```
moisture

// Set these to run example.
#define FIREBASE_HOST "garden-a7c2b.firebaseio.com"
#define FIREBASE_AUTH "JVfoUQX1foclxL3RBgGbBMf1QgFKWVdDzvuiSK87"
#define WIFI_SSID "Abbi"
#define WIFI_PASSWORD "abbiabbi"
Ultrasonic ultrasonic(4, 5);
int sense_Pin= 0;
int motor=2;
int value=0;
int distance=0;
int automate=0;

void setup() {
  Serial.begin(9600);
  pinMode(motor,OUTPUT);
  digitalWrite(motor,LOW);

  // connect to wifi.
  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
 Serial.print("connecting");
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");
    delay(500);
  }
  Serial.println();
  Serial.print("connected: ");
  Serial.println(WiFi.localIP());

  Firebase.begin(FIREBASE_HOST, FIREBASE_AUTH);
  delay(2000);

}
```

Figure 5.9: Smart Garden Code [1, 3, 4, 5].

5.5.3 Android Studio

It is an open-source Integrated Development Environment (IDE) that was developed by JetBrains specifically for the purpose of creating applications for the Android operating system [21, 48]. This application is compatible with all of today's most common operating systems, such as Microsoft Windows, macOS, and Linux [44, 48]. It is comprised of a variety of features that allow users to develop Android applications with enhanced user interfaces. This is made possible by the fact that it is possible for users to do so. It is compatible with a wide range of programming languages, such as Python, Java [8], and Kotlin [19], amongst others. It features the Android Virtual Device [25], which allows applications to be tested and debugged within the Android studio environment [29]. In the

Garden app, the code for the designing portion of the programme is written in XML [1, 7, 9], while the Java programme that is used for implementation is written in Java. Both of these programmes are written to work together. In addition, the completion of the firebase connectivity is included as part of the implementation phase [48].

The user of this mobile application can monitor and control the Smart Garden System either in their immediate surroundings or from a remote location, depending on which option they choose when using the application [49]. The application will send push notifications to the user when the values that are being monitored by the sensor have reached a predetermined maximum or threshold [49, 50]. Additionally, the application will allow the user to take control of the system from a remote location when this occurs. This tactic is an excellent financial investment because there is no cost associated with using it [50].

6. ANALYSIS AND RESULTS

On the screen that is built right into the circuit board of the gadget, the results can be viewed in real time (as shown in figure 13). It gives a reading of the current humidity and temperature of the air, as well as the moisture and temperature of the soil. Additionally, it provides a reading of the soil's temperature. The IP address of any devices that have been connected to the computer is shown in the lower-right hand corner of the screen.

Figure 5.10: Results display on LCD (Morning Time at 6 AM)**.**

Figure 11 provides a visual representation of the mobile application. This application has been incorporated into a GSM device, which makes it possible to provide services related to mobile computing. The results of the environmental analysis are displayed on the application screen in a manner that is analogous to the manner in which the temperature, humidity and soil moisture of the garden displayed.

Gardeners and users enabled to provide a greater level of attention and care to their garden as a result of this innovation. If they take advantage of these real-time results and use them in their practices. Figure 12 is an illustration that provides a more in-depth look at the moisture profile of the garden. Figure 12 displays time slots along its x-axis, and the amount of moisture in the form of a percentage along its y-axis. Both axes can be read from left to right. The early morning time slot is characterized by high levels of moisture.

As shown in Figure 12, the amount of moisture in the air decreases as the morning progresses and reaches noon, but then it starts to rise again in the evening. This pattern repeats itself throughout the day. Figure 13 is a representation of the humidity readings that were taken in the garden at a variety of different intervals of time. The levels of relative humidity are displayed along the y-axis, and the passage of time is shown along the x-axis of the graph.

Figure 13's recording of the humidity shows a difference of four hours due to the passage of time. The relative humidity reaches its highest point of the day early in the morning, and then gradually begins to drop as sunrise draws closer.

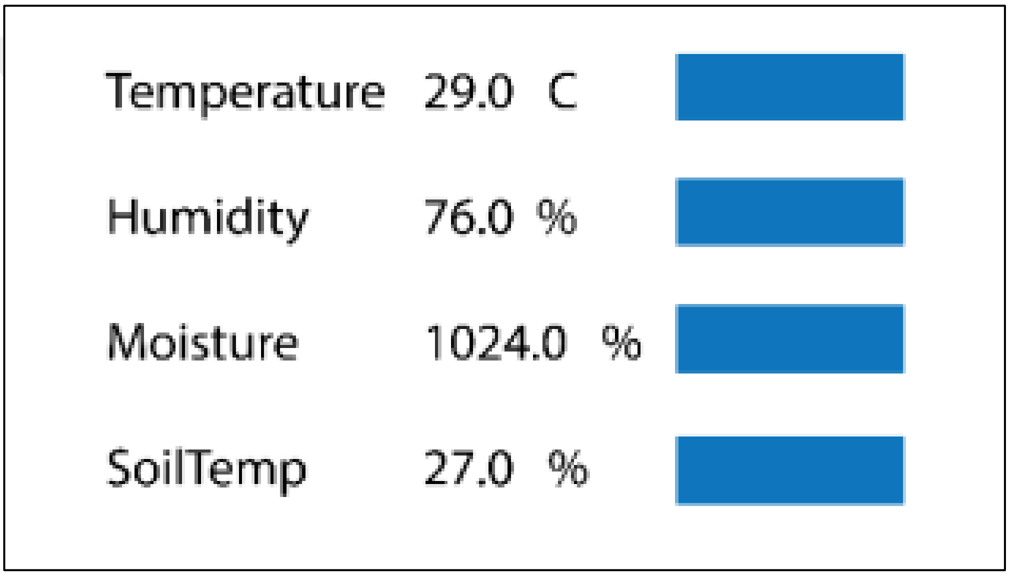

Figure 5.11: Mobile Application for Monitoring (Night Time at 6 PM)**.**

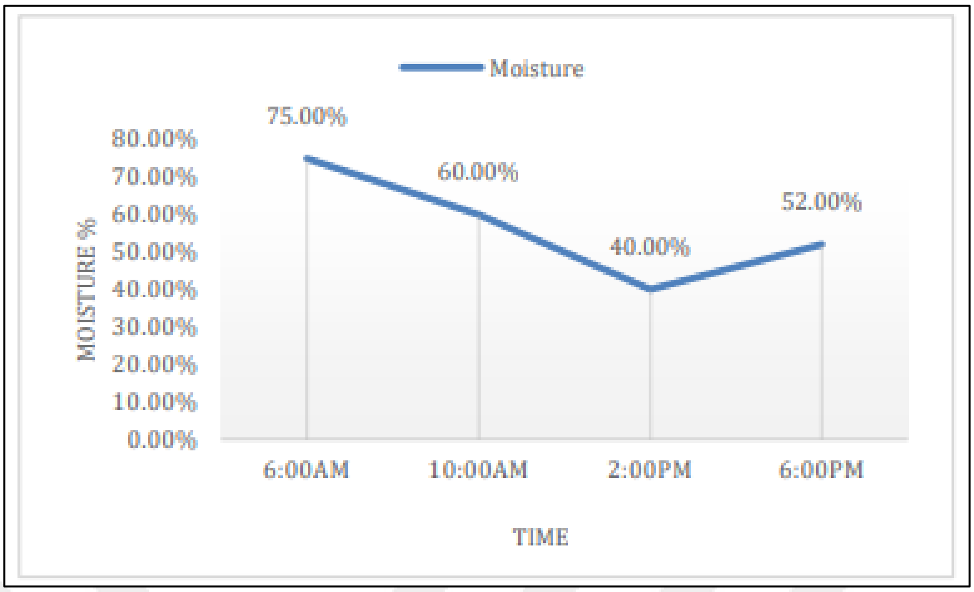

Figure 5.12: Profile of Moisture (With respect to Each Time Slot)**.**

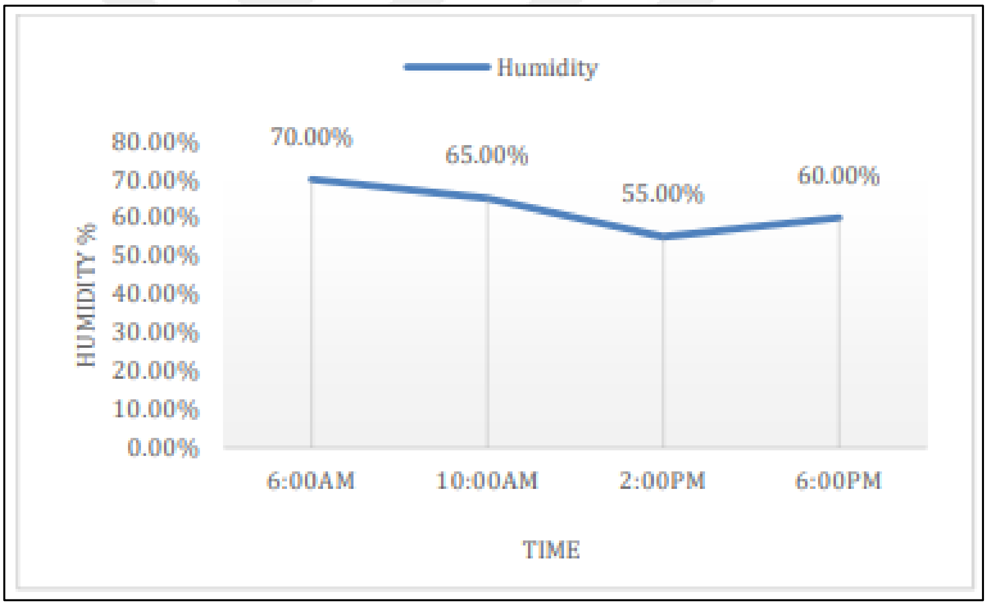

Figure 5.13: Relative profile of Humidity (With respect to Each Time Slot)**.**

The temperature profile is depicted over a range of time intervals in figure 17, which can be found here. The rate of change in temperature is shown along the y-axis of this graph, while the amount of time that has passed is shown along the x-axis. The fact that winter is the testing season for the prototype is the primary reason for the low results and temperatures.

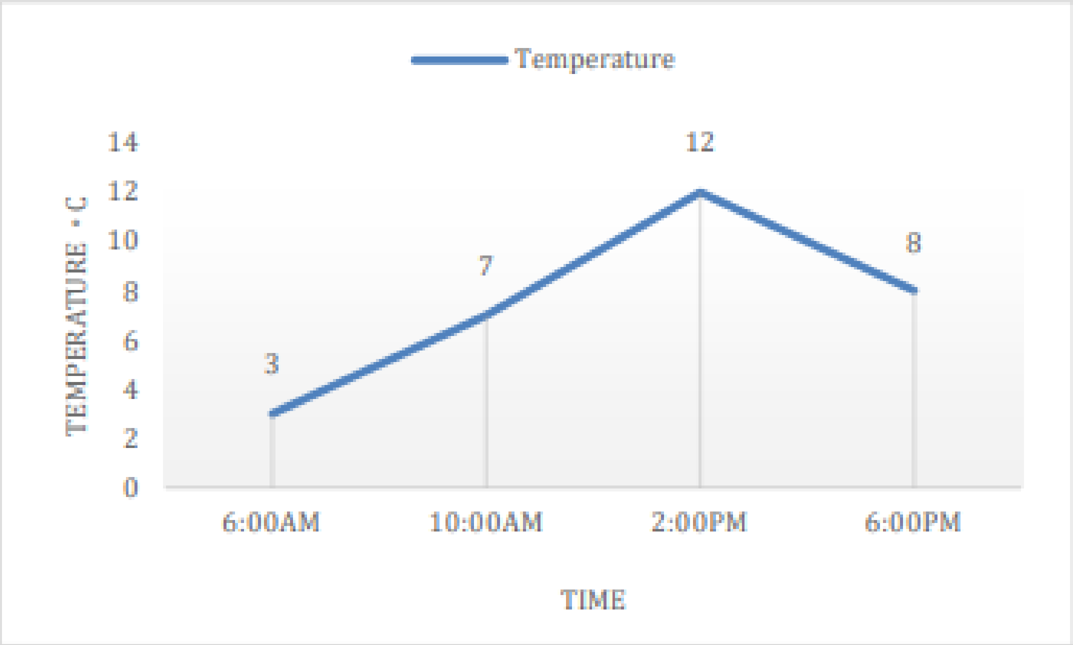

Figure 5.14: Profile of Soil Temperature (With respect to Each Time Slot)**.**

7. CONCLUSION AND FUTURE WORKS

7.1 CONCLUSION

The Smart Garden system that was put into place with the help of the Internet of Things has been shown to work effectively thanks to the connectivity of a variety of soil parameters to the cloud. Additionally, the system was able to be controlled remotely through the use of a mobile application with success. The system that was designed not only actuates other parameters in accordance with the requirement. It offers statistics in real time regarding the environmental elements that are now present in gardens. Making it feasible for users to care for their plants garden in the most efficient way possible. This will continue until the minimum value is reached again.

This procedure is repeated repeatedly until the water level in the tank reaches its maximum capacity. This system is suitable for use in any setting due to its low initial cost as well as the ease with which it can be installed. This makes it a versatile piece of equipment. New sensor technology makes it possible to take the system to the next level, which in turn enables users to make the most of the money they have invested in a manner that is more cost-effective. This is made possible by the introduction of new sensor technology.

In the event that the system can be altered to make room for the installation of soil nutrient sensors, then the garden will be supplied with the precise quantity of fertilizer that it requires. This system cuts down on the amount of manual labor that is essential and makes efficient use of the accessible water resources, which ultimately results in increased profits. The operation of the gardening process will be improved as a direct result of the feedback that is supplied by the system.

7.2 RECOMMENDATIONS AND FUTURE WORKS

The microcontroller known as NodeMCU, mobile computing, and the internet of things are the three technologies that support the smart garden monitoring strategy that has been suggested. It offers statistics in real time regarding the environmental elements that are now present in gardens. Making it feasible for users to care for their plants garden in the most efficient way possible. A number of environmental factors come into play, such as the temperature of the soil, the amount of moisture that is already there, and the relative humidity. The results are presented on the TFT screen, which is a part of the device that was suggested earlier.

In addition, the findings are presented in the form of a mobile application for users to access. This strategy has the potential to solve the gardening challenges that are present in urban areas as a result of a shortage of gardeners. These challenges are caused by the fact that there are not enough gardeners. The functionality of the system is going to be improved in the not too distant future by the addition of a user interface for archiving all of the historical records. In addition to this, we are going to include the usual preventative maintenance requirements and safety measures of well-known plants, and these will be given as a proposal in relation to particular parametric values. For the purpose of providing users or gardeners with greater ease and care in the management of their plants. In addition to this, brand new automation functions relating to the irrigation and fertilization processes will be implemented.

It is necessary for the individual components of the Smart Farm to be able to interact with one another as well as with the user or farmer in order for the Smart Farm to be able to work on its own. The Smart Farm is backed by a powerful backbone of sensors and IoT. By making recommendations and giving enhancements, the Smart Garden automation system facilitates the user's progress toward cultivating the types of plants that best suit their preferences. In addition to instructions that can be sent to the automation machine via the internet or that are pre-programmed into them according to the task at hand. These instructions can be given to the automation machine in either of two ways: either as they are a part of the task that they are being instructed to do.

The widespread implementation of IoT resulted in the development of the use of imaging drones such as the Precision Hawk Lancaster, which enables real-time monitoring of the conditions of the soil and the overall health of crops across a large area. The high cost that is associated with utilizing this method is one of the drawbacks of utilizing it. Additional enhancements that have been suggested for the Smart Garden include sowing seeds from the air, employing unmanned aerial vehicles (drones) for the purpose of spraying pesticides, and increasing the quantity of weeding and pesticide control tools that are housed in the stationary garden. All of these are very promising new developments that need to be implemented.

It is essential for the Smart Farm to be able to communicate with both one another and with the user or farmer in order for it to be able to function independently. The Smart Farm is supported by a robust backbone of sensors and the internet of things (IoT). In addition to providing the user with instructions that can be given to the automation machine remotely or as they are programmed to do for each task, the Smart Garden automation system also offers the user recommendations and enhancements to make to their garden. The user is able to get closer to the plants that they want to grow in their garden as a result of this assistance. It is possible to give these instructions to the automation machine in one of two distinct ways: either as an integral part of the task that they are being instructed to complete, or as an entirely separate instruction. The widespread adoption of IoT has led to the development of the use of imaging drones such as the Precision Hawk Lancaster, which enables real-time monitoring of the conditions of the soil and the overall health of crops across a large area. This was made possible by the widespread adoption of IoT. Because of the widespread adoption of internet of things technology, this was made possible. The high cost that is involved in carrying out this method is one of the drawbacks of utilizing this method. When you use this approach, you will incur significant expenses.

Additional enhancements that have been suggested for the Smart Garden include the sowing of seeds from the air, the use of unmanned aerial vehicles (drones) for the purpose of spraying pesticides, and an increase in the quantity of weeding and pesticide control tools that are housed in the stationary garden. All of these enhancements are expected to be implemented in the near future. In the future, all of these improvements will be incorporated into the system. All of these represent extremely promising new developments, and it is imperative that they be put into action.

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