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GreenConnect: A Cutting-Edge Optical Sensor Based Gardening Automation System

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Abstract: IoT-based garden automation "Green Connect" is a system that automates and tracks numerous gardening-related operations using internet-connected sensors and devices. Benefits of this technology include enhanced plant growth, improved watering schedules, and remote monitoring and management of plants. The system is made up of numerous parts, including irrigation sys-tems, temperature sensors, humidity sensors, and soil moisture sensors, all of which are linked to a central hub. In order to automate the watering, lighting, and other environmental conditions of the garden, the microcontroller gathers and analyses the data from the sensors. The development of an IoT-based garden automation system is covered in this article, along with the design of the system architecture, component selection, optical sensor and device integration. The experiment's findings demonstrate that the system was able to improve the garden's growth conditions, leading to better plant health and yield. According to the study, IoT-based garden automation has the ability to completely change how we think about gardening by making it simpler and more effective to grow plants in a range of settings. By remotely managing the water pump and keeping track of the soil moisture in the garden, this study integrates the IoT into the irrigation system for gardens.

Keywords: IoT; Blynk; ESP8266 NodeMCU; Arduino; Smart Garden; Optical Sensors; Irrigation

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1. Introduction

The automation industry is expanding globally providing a means of using your computer or mobile device to monitor and handle routine areas of your everyday life. IOT offers answers to a variety of issues and enables remote sensing and control of objects in network infrastructure [1]. The "Agricultural IoT" is a network in which different virtual "things" inside agricultural systems, including actual physical "objects" like flora and fauna, environmental factors, and production instruments, are connected to the Internet via tools that are aware of agricultural facts and adhere to set norms aimed at intelligently locating, tracking, observing, and managing agricultural activities and objects [2].

Agricultural IoT's "human-machine-things" linkage enables more sophisticated and dynamic human recognition, management, and control of numerous agricultural aspects, processes, and systems. Also, it may significantly improve human comprehension of the critical aspects of the lives of agricultural animals and plants, aid in the capacity to manage intricate agricultural systems [3], and help with the management of agricultural emergencies. Agricultural IoT technology is now the subject of considerable and active global research, although most applications are still in the experimental demonstration stage.

The first-time individuals try to cultivate plants and make their own gardens, they were concerned about how to take care of them. Poor maintenance causes plants to decay over time. In this work, we build sensors that can link using the IOT concept, which is good for automation. The most significant characteristics of this prototype are the cost and safety reductions. Users may automatically track parameters and guarantee plant upkeep with the aid of this prototype. It serves a crucial purpose and makes a lovely plant companion [4]. This prototype will assist users in automatically tracking the parameters and ensuring plant upkeep. It performs a crucial function and makes for a nice plant companion [5]. This article methodically reviews the state of agricultural IoT research. The present state of agricultural IoT is first displayed, along with a summary of its system architecture [6]. IoT-based garden automation "GreenConnect" provide a number of advantages that can improve plant care and gardening techniques. The following are some major benefits of "GreenConnect":

Effective water management: This is possible thanks to IoT sensors that can continuously track the temperature and humidity of the soil. Smart gardens may optimize water consumption, avoid overwatering or under-watering, and encourage water conservation by automating the watering process based on real plant demands and weather forecasts.

Enhanced Plant Health: Gardeners may keep an eye on environmental variables like temperature, humidity, and light intensity with IoT sensors. By knowing this in-formation, you can make sure that plants are growing in the best possible conditions.

Savings in time and effort: Smart gardens automate a lot of processes that would otherwise need manual labour. Automated irrigation, control, and monitoring systems lessen the need for regular gardener supervision and intervention.

Remote Monitoring and Control: Through mobile applications or online interfaces, IoT-based smart gardens may be remotely monitored and managed. Data-Driven Insights: Over time, IoT devices gather and analyze data from a variety of sensors. The health, growth patterns, and environmental trends of the garden are all usefully revealed by these data insights.

Automation and Scheduling: IoT-based smart gardens may automate ordinary operations and adhere to predetermined timetables. Based on predetermined specifications, watering, lighting, and other functions can be programmed.

Education and Learning: IoT-based smart gardens provide chances for learning for gardeners of all skill levels. Users may discover how to take care of plants, what influences the surroundings have on them, and how various inputs affect plant development. The information gathered from the smart garden may also be a useful teaching tool for learning about how plants interact with their surroundings.

IoT-based Garden automation "GreenConnect" offer more comfort, effectiveness, and control over gardening procedures. Gardeners can develop healthier, more sustainable gardens while conserving time and resources by utilizing real-time data, automation, and remote access. Intelligent gardens powered by the IoT provide effective water management, improved plant health, time and labour savings, remote monitoring and control, data-driven insights, automation and scheduling, and educational possibilities. These advantages enhance gardening techniques, maximize resource utilisation, and ease garden upkeep.

2. Literature Review

In [7] authors argue that there are several signs that the IoT is about to transform our way of life. Horticulture will undoubtedly also be covered by this new technology. This approach fosters a new culture where people demand a quality of life and well-being, especially in an elderly population, in addition to making gardening easier. Although it appears that there are now many automated indoor gardening systems, as this article has mentioned, there is still much space for advancement with IoT technology. In particular, the social side should be more concentrated in developing soft-ware to be able to respond to the present society problems like aging and health difficulties, coupled with the development of integrated sensors and garden management systems.

This study in [8] reveals that seniors are aware of the advantages of IoT Gardening System use. They discovered that technology might improve the mental health of the elderly by engaging in activities they enjoy since it is simple for them to utilize. Nevertheless, the advantage of employing an IoT planting system that emphasizes the cultural component must be used in future studies by incorporating a function to anticipate and propose appropriate plants that suit each senior person's lifestyle.

In [9], the writers claim that the majority of the technology now on the market is expensive and does not offer solutions to the practical issues faced by farmers. The majority of modern technology focuses on high-end machinery and robots that assist in completing the fundamental agricultural operation and enable farmers to eradicate weeds and apply pesticides and chemicals to the field.

In [10] authors use data visualization to find the most beneficial settings for the marigold plant. Afterwards, this trained model may be used to identify the rate of development of the marigold plant simply by providing the necessary physical conditions of the garden surroundings or environment. Moreover, with an accuracy rate of 83.33%, the best fit algorithms were discovered to be Logistic Regression, Linear SVC, and Gradient Boosting Classifier. This method has a lot of potential in the area of synthetic farming. With the use of IoT, we might build a database that would tell us which plants are best suited to a certain soil and climate, as well as identify the ideal growing conditions for some of the specific crops like millet, peppers, tea, and coffee.

In [11] authors suggest and present a system that would offer a better knowledge of environmental conditions at home following a comparative analysis and literature review of various current systems. IoT-based smart home monitoring and control systems are then discussed. Using various sensors will be helpful in putting this system into practice. With this method, a flexible, smart house may be managed with minimal expense to change its environmental conditions and insist on fixing any flaws that re-sult in energy savings.

In [12] a home management system is discussed. This essay is primarily concerned with finding solutions to difficulties that people confront on a daily basis in a society where regular power outages, unchecked urbanization, a shortage of labour in farming and agriculture, etc., are glaringly apparent. Real-time home security, automation, monitoring, and remote system control are all possible with our model system. An intelligent, cozy, and energy-efficient home automation system is offered by this implementation. It also makes it easier and better for elderly and disabled people to use the appliances in their homes.

In [13] the authors propose a low-cost home phytotron that can manage and work with a variety of communication protocols. It is built on open hardware and open-source software. The suggested design enables us to use any MQTT installation and combine it with current home systems like Home Assistant, OpenHAB, etc.

In [14] a unique IOT-enabled automatic drip irrigation system is created utilizing a web application, and a system architecture is also established for tracking and man-aging soil optical sensor/sensor data as well as temperature and humidity data. They connect wirelessly to the cloud network system via interfaces with microcontrollers and NodeMCU. With a web-based application, the stored data in this cloud network system may be accessed from a distance. A submerged pump may be used to monitor and enhance the health of plants and crops from any location. This offers a suitable method of gaining access to water sources for use in agricultural applications. This IOT-enabled irrigation technique enables agriculture to lessen the scarcity so that improvements may be made to hold water for appropriate uses. The experimental arrangement shows that an IOT enabled drip irrigation system might be a viable re-placement for various areas where harvesting is the primary necessity with the least amount of preservation.

In [15] authors discuss the design of an indoor smart gardening system with wireless monitoring and automatic watering, with a focus on the problem of energy-autonomous operating sensors. Fully energy autonomous working networks for home automation could not be implemented without special concepts for the energy supply. Wireless energy autonomous sensor actuators for home automation are possible if the measurement cycle and network communication cycle is in the range of a few minutes. The choice of energy-efficient components for the sensor and actuator electronics design is crucial. Certain design strategies, such as turning off unused components, are crucial.

In [16] a product that will make indoor gardening incredibly simple and practical is proposed. An e-retail platform is set up for community trade, irrigation is made has-sle-free, and the user is advised on the best crops to plant for his or her location at that time of year, ensuring that the organic harvest is never wasted.

In [17] a software system automates fertilizing, watering, and monitoring many elements that have an impact on plant development. A social network that enables users to observe and communicate with their friends through various features including publishing, emotional response, commenting, and private conversations, as well as trade, in order to promote user engagement. With the aid of these features, the com-munity will grow and user involvement will flourish. The suggested system serves as a model for developing an automated system in the hobbyist community, offering guide-lines.

A "Smart Pot" [18] is created by the authors in an effort to reduce the stress associated with maintaining one, allowing the user to profit from it without really doing any additional work. The Smart Pot is a green planter that runs on solar energy. It features all the equipment and modules required to run smoothly and assess all the environmental conditions necessary for a plant's healthy growth. With an automatic watering system and a power backup system, it just needs minimal outside help to run properly. Also, it has the capability to connect to any user end device through the internet, inform the user of the state of the plant, and provide guidance if any further action is necessary to ensure the welfare of the plant.

In [19] an irrigation system for indoor gardening is being developed, and it may be maintained without any human oversight. In the home garden, it automatically monitors the soil moisture under trees and plants. If the moisture is low, it signals the problem and automatically waters the plants from the water storage to which it is linked. It is important to use the irrigation method precisely because there could not be enough rainfall or there might be dry places. The soil moisture sensor will determine whether or not to pump the water based on the amount of water present. Even if a person is not physically there, this will assist to prevent water waste and aid in the growth of plants.

Temperature, humidity, CO2 concentration, and soil moisture were selected in [20] to imitate the internal climatic conditions of a greenhouse. To efficiently monitor and assess these data, the NodeMCU was linked to the installed sensors. The ESP8266 NodeMCU connected to Wi-Fi and communicated with the ThingSpeak and BlynkIoT platforms via the HTTP protocol. The cloud and his IoT platform were consulted be-fore the data of environmental factors acquired by sensors and transferred to NodeMCU firmware was delivered there over WiFi. Users could now access the data and know the status of the room in real time because it was now presented in a time-series manner on the IoT platform. After connecting the NodeMCU's GPIO pins to the relay module, users may remotely alter the on/off status of the relay through the Blynk app to modify the controller's operational state.

In [21] soil moisture content and light intensity of the garden are two characteristics that the suggested system monitors and maintains. Light intensity sensors and soil moisture sensors are used for this. Continuous transmission of the observed data to the ThinkSpeak IoT cloud. The system's data is analyzed in the cloud, and when a desired level of soil moisture is reached, instructions are sent from the cloud to the garden's autonomous watering system to irrigate the garden. The system control module is implemented using an Arduino Uno microcontroller. IoT is utilized to inform the garden owner of the sprinklers' status. The user can always examine the condition of the water sprinklers thanks to the ThinSpeak IoT cloud, which receives frequent updates from the sensors. In order to create graphs for examination, the sensor values are also sent to a ThingSpeak channel.

In [22] authors suggest a low-cost irrigation and monitoring system that may be used in backyard and neighborhood community gardens. A sensing/actuation station based on commercially available hardware and a mobile application for communication with faraway users make up the fundamental architecture. The utilization of legacy text-messaging services as a method to enable warning and control activities for monitoring and irrigation is a crucial component of the system. Without the need for new network infrastructure, this functionality makes communications between the farm station and distant users very accessible and extremely dependable. In a small open-field tomato production area, we put the system's functioning prototype into use to test its efficacy. The findings demonstrate that by utilizing both the actual data gathered from the system and open-source tools for decision support in agriculture, water use may be significantly improved. We get to the conclusion that the suggested solution has a fair chance of being utilized as a design input for other automated decision-strategies that will be applied in plant cultivation of the same sort and/or on a bigger scale.

3. Proposed System Architecture

An IoT-based smart gardening automation system functions by using a variety of sensors and devices to gather data and connect with one another via the internet in or-der to regulate and automate different gardening-related chores [23–25].

(i) Sensors: The system is fitted with a variety of sensors that gather information about the garden's surroundings, including soil moisture sensors, temperature sensors, humidity sensors, light sensors, and PIR motion detection sensors.
(ii) Data gathering and analysis: The microcontroller NodeMCU ESP8266, the system's brain, processes and analyses the data that the sensors have acquired. The data is sent from the microcontroller to a cloud-based server for archival and analysis.
(iii) Automatic irrigation: The microcontroller decides whether to water the plants based on information about soil moisture gathered by the sensors. The microprocessor instructs the water pump to irrigate the plants if the soil is too dry.
(iv) Suspicious motion: The microcontroller alerts the user that anything weird is present near the garden based on motion activities around the plant.
(v) Climate information: The device is also capable of measuring the humidity and temperature in the garden to give the gardener climate data.
(vi) Alerts and notifications: In the event of any environmental concerns or issues, such as low soil moisture levels, excessive temperatures, or pests, the system may send warnings and notifications to the user's smartphone or other devices.

Figure 1 represents the architecture of IoT based garden automation "GreenConnect". An IoT-based smart garde**n'**s design generally consists of a number of parts that work together to monitor, regulate, and automate different garden-related functions. A high-level description of system architecture is given below [26–28]:

(a) Sensors: The smart garden system uses a variety of sensors to collect information about the environmental conditions of the garden in real-time.
(b) Microcontrollers: Each sensor has a connection to a microcontroller or node that gathers data from the sensor and facilitates communication with other system el-ements and microcontroller ESP8266 NodeMCU comes with a wifi module for connecting with the internet.
(c) Connectivity: To facilitate connection with other components and the main con-trol system, the microcontrollers or nodes are supplied with wireless connectivity capabilities, such as Wi-Fi, Bluetooth, or Zigbee.

(d) Gateway/Hub: A gateway or hub serves as the system's main hub for coordination and communication. It takes data from the nodes or microcontrollers and sends it to a server locally or in the cloud for processing.
(e) Cloud/Server: To store, process, and analyse the sensor-collected data, a cloud-based platform or a local server is used.
(f) User Interfaces: Gardeners may communicate with the smart garden system through a user interface, which is supplied. A web application, a mobile applica-tion, or both may be used for this.
(g) Actuators/Control Devices: Actuators are devices that carry out certain tasks in the garden in response to control commands from the system.
(h) Data Analytics/Artificial Intelligence: To acquire insights and make wise judge-ments.

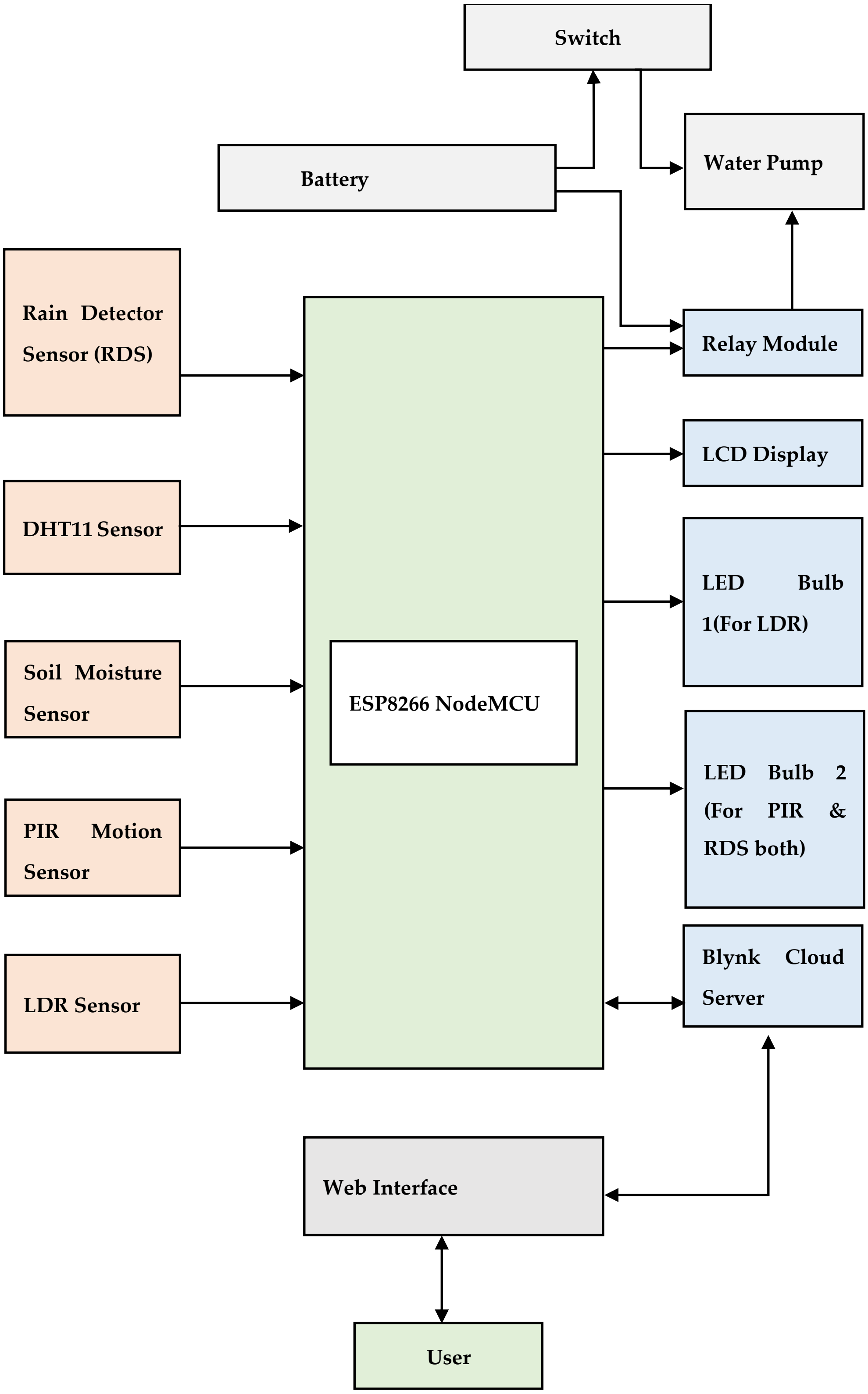

Figure 1. Architecture of GreenConnect.

An IoT based smart garden makes use of IoT technology to monitor and control several elements of a garden, including irrigation, lighting, temperature, and soil conditions. Here is a broad explanation of how it operates:

(a) Sensor Integration: Sensors are placed in the garden to collect information about the weather. Soil moisture sensors, temperature sensors, humidity sensors, light sensors, and occasionally even nutrient sensors are frequently utilized in smart gardens.
(b) Data Gathering: The sensors communicate data they continually gather from the garden to a central hub or gateway device. The sensors and the internet are connected through this gadget.
(c) Wireless Connection: Wi-Fi, Bluetooth, or Zigbee are examples of wireless connections that the central hub or gateway can make to the internet. This makes it possible to send the gathered data to a cloud-based platform for additional processing and analysis.
(d) Cloud based Platform: Sensor data is gathered and delivered to a cloud-based platform or server, where it is analyzed and stored. To get actionable insights from the data, the platform frequently uses a variety of algorithms and data analytics methodologies.
(e) Remote Monitoring and Control: Garden owners and users may access the cloud-based platform via a mobile application or online interface for remote monitoring and control. They have the ability to remotely regulate many components of the garden, such as changing temperature settings, watering schedules, and lighting. They can also remotely monitor the state of the garden in real-time.
(f) Automated Operations: The smart garden system has the ability to automate some operations based on data analysis and user-defined settings. For instance, the device might automatically start the irrigation system and start watering the plants if the soil moisture level falls below a certain threshold.
(g) Alerts and Notifications: The smart garden system may send alerts and notifica-tions to the user's mobile device or email to offer information on the status of the garden, such as low water levels, dramatic temperature swings, or unusual soil conditions.

A smart garden makes use of IoT technology to provide gardeners real-time in-sights into the state of their garden, enable remote monitoring and management, optimize resource utilization, and even provide tailored plant care suggestions based on data analysis [29,30]. An IoT-based smart garden's execution flow chart might change depending on the system's unique requirements and design [31–35].

(i) Initialization: A gateway or hub is used to set up and connect the smart garden system to the internet. Initialization and configuration are done on sensors, actuators, and other IoT devices [36].
(j) Data gathering: The garden has sensors that gather information on a variety of environmental factors, including temperature, humidity, light intensity, soil wet-ness, etc. The central system or gateway receives sensor data to process [37].
(k) Data analysis and processing: The central system receives sensor data and pro-cesses and analyses it as needed. To ascertain the present condition of the garden, spot patterns, and spot abnormalities, data is analyzed.
(l) Making Decisions: The system decides or initiates measures to maintain ideal garden conditions based on the data analysis. The basis for generating decisions might be user-defined parameters, machine learning algorithms, or established rules.
(m) Action and Regulation: Actuators and other devices are given orders by the sys-tem to carry out certain tasks. For instance, the system could start irrigation to water the plants if the soil moisture is low.
(n) Iteration and looping: The execution flow keeps going in a loop, gathering data, analyzing it, making choices, and acting on them. Based on user choices and changing environmental circumstances, the smart garden adjusts and improves its operations.

5. Results & Discussion

Figure 2 presents the complete circuit diagram of IoT based garden automation "GreenConnect". It shows the connection between PIR sensor, Soil Moisture sensor, LCD display, Rain detector sensor, relay module, water pump, battery, DHT11 sensor, LDR sensor and LED bulb and microcontroller ESP8266 NodeMCU.

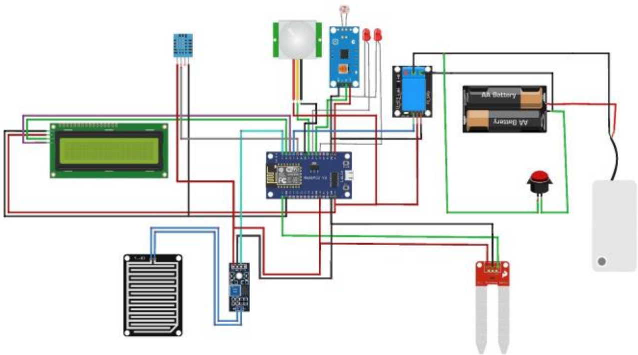

Figure 2. Circuit design for all the sensors or Hardware components combined simultanously with the microcontroller ESP8266 NodeMCU.

Figure 3 shows the web based interface of the IoT based garden automation "GreenConnect". Currently the proposed system is offline because it is not connected to some internet source. This page showing the temporary name of proposed system i.e., Smart Plant and email id of the device owner and the status of proposed system device i.e., offline.

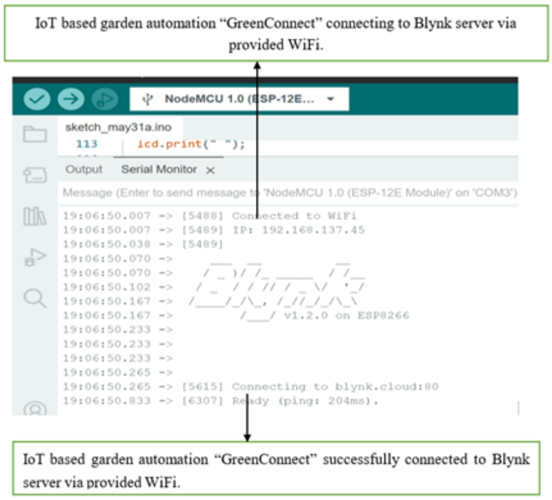

Figure 3. Synchronization between IoT based garden automation "GreenConnect" and the microcontroller ESP8266 NodeMCU.

Figure 4 represents the web interface of the proposed system "GreenConnect", here tempera-ture value representing gauge, Humidity value representing gauge, Soil Moisture sensor value representing gauge is given. PIR motion sensor on or off switch is given means, if we turn on the switch the PIR motion will on and ready to detecting motion and of the switch is off it will not detect any garden activity. A water pump switch is given means we can able to turn on or off water pump manually if the soil moisture level is between lower threshold value and the higher threshold value. And three LED widgets is given i.e., LED bulb it is connected to the LDR sensor, Rain status LED widget is connected to Rain detector sensor and it will blink for 10 seconds if the Rain detector sensor detects rain, otherwise this widget remains turn off and the last one is Motion LED widget, it will turn on when the PIR sensor detects any motion otherwise this widget remains off.

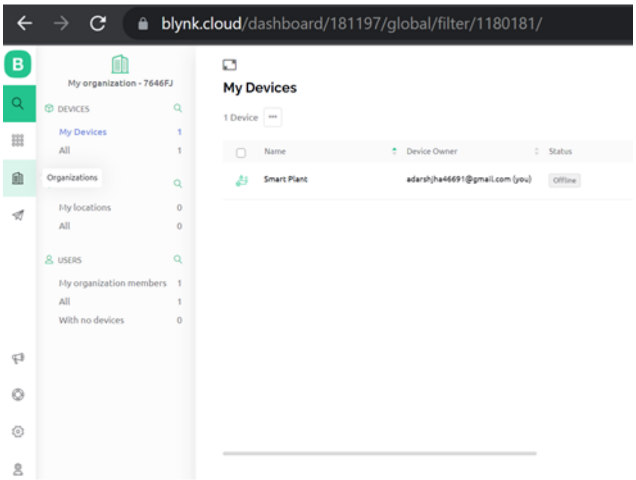

Figure 4. Web based interface, showing status of IoT based gardenAutomation,whether "GreenConnect" is offline or online, currently "GreenConnect" is offline.

Figure 5 presents the mobile interface of the proposed system "GreenConnect", here temperature value representing gauge, Humidity value representing gauge, Soil Moisture sensor value representing gauge is given. PIR motion sensor on or off switch is given means, if we turn on the switch the PIR motion will on and ready to detecting motion and of the switch is off it will not detect any garden activity. A water pump switch is given means we can able to turn on or off water pump manually if the soil moisture level is between lower threshold value and the higher threshold value. And three LED widgets is given i.e., LED bulb it is connected to the LDR sensor, Rain status LED widget is connected to Rain detector sensor and it will blink for 10 seconds if the Rain detector sensor detects rain, otherwise this widget remains turn off and the last one is Motion LED widget, it will turn on when the PIR sensor detects any motion otherwise this widget remains off.

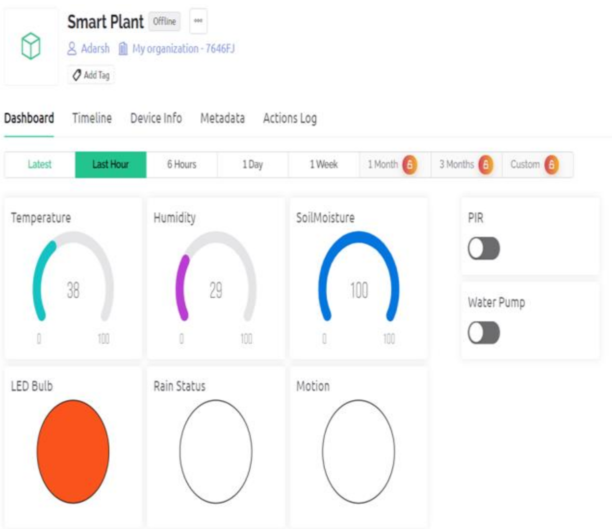

Figure 5. Web based interface, showing all the features of IoT based garden automation "GreenConnect".

Figure 6 represents the mobile based interface of the IoT based garden automation "GreenConnect". Currently the proposed system is offline because it is not connected to some internet source. This page showing the temporary name of proposed system i.e., Smart Plant and the status of proposed system device i.e., offline.

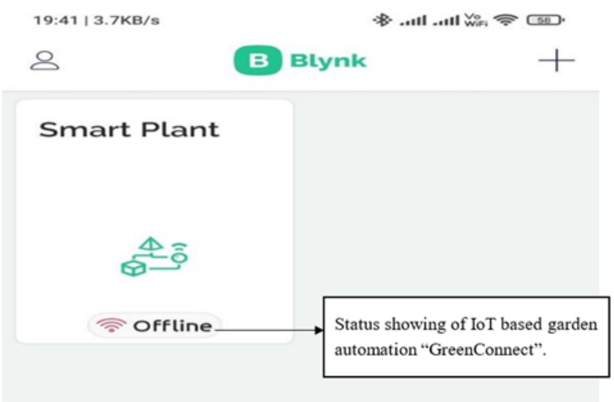

Figure 6. Mobile based interface, showing status of IoT based garden automation, whether "GreenConnect" is offline or online, currently "GreenConnect" is offline.

Figure 7 presents the mobile interface of the proposed system "GreenConnect", here temperature value representing gauge, Humidity value representing gauge, Soil Moisture sensor value representing gauge is given. PIR motion sensor on or off switch is given means, if we turn on the switch the PIR motion will on and ready to detecting motion and of the switch is off it will not detect any garden activity. A water pump switch is given means we can able to turn on or off water pump manually if the soil moisture level is between lower threshold value and the higher threshold value. And three LED widgets is given i.e., LED bulb it is connected to the LDR sensor, Rain status LED widget is connected to Rain detector sensor and it will blink for 10 seconds if the Rain detector sensor detects rain, otherwise this widget remains turn off and the last one is Motion LED widget, it will turn on when the PIR sensor detects any motion otherwise this widget remains off.

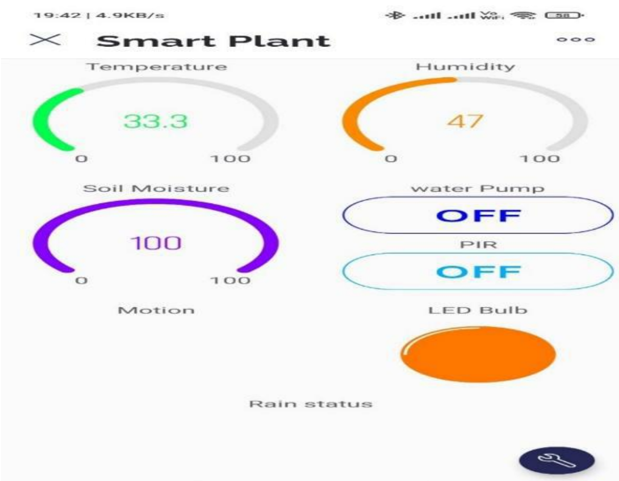

Figure 7. Mobile based interface, showing all the features of IoT based garden automation "GreenConnect".

Figure 8 represents the IoT based garden automation "GreenConnect" working Prototype. It shows the all the hardware components and sensors such as PIR sensor, Soil Moisture sensor, LCD display, Rain detector sensor, relay module, water pump, battery, DHT11 sensor, LDR sensor and LED bulb.

Figure 8. IoT based garden automation "GreenConnect" front view with plant.

Table 1. comparison between existing system and proposed system.

Features		Automation in Home Gardening Manageme-nt Through Blynk Platform	A Cloud-Based Internet-of-Things (IoT) Application in VANET	Automation in Fields Irrigation System Using RaspberryPi micro-controller	Moisture Measuring and Gardening Monitor Through Mobile App	A Smart Indoor Gardening System Using IoT Tech-nology	Automation Plant Monitoring and Height, Width Prediction Using AI, ML	Proposed System "Green Connect"
Platform		Arduino	Arduino	Arduino/ RaspberryPi	Arduino	Arduino	Arduino / RaspberryPi	Arduino
Microcontroller		NodeMCU	Arduino Uno	RasberryPi	NodeMCU	NodeMCU	RasberryPi	NodeMCU
Sensors	LDR	–	–	–	–	√	√	√
	Soil Moisture	√	–	√	√	√	√	√
	PIR motion detector	–	√	–	–	–	–	√
	Rain detector	–	√	–	–	–	–	√
	Temperature	–	–	–	√	√	√	√
	Humidity	–	–	–	√	√	√	√
	Soil Temperature	–	–	√	√	√	√	√
User Interaction	Web Based System	–	√	√	√	√	√	√
	Mobile-based Application	–	–	–	–	–	–	√
Type of conecti-on	WIFI	–	√	√	–	√	√	√
16 X 2 LCD Display		√	–	–	–	–	–	√
Notifications		–	–	–	–	–	–	√
Power Consumption		Low	Low	Low	Low	Low	Low	Low
Relay Module		√	√	√	√	–	–	√
System Refresh		–	–	–	–	–	–	√
Watering	Automatic	–	–	√	–	–	–	√
	Manually	√	√	√	√	√	–	√
IoT platform		Blynk	VANET	ThingSpeak	Blynk	Blynk	ThingSpeak	Blynk

Table 1 shows the comparison between existing system and proposed system with applicable parameters.

6. Conclusions

As a result, an IoT-based smart garden offers a wide range of benefits and chances to improve the effectiveness, practicality, and productivity of gardening operations. The ability to remotely monitor and manage different components of the garden is made feasible by combining sensors, actuators, and networking technology.

Some of the main advantages of an IoT-based smart garden are: effective resource management, automated plant care, remote monitoring and alerts, data-driven insights, gardening experience that is personalized, benefits from recreation and education.

In conclusion, a smart garden powered by the IoT combines technology with horticulture, providing advantages like effective resource management, automation, remote monitoring, data-driven insights, customized experiences, and educational possibilities. It transforms conventional gardening techniques, making them more practical, effective, and environmentally sound.

There are a number of potential future developments that might improve IoT-based smart gardens as the area of IoT develops like integration of AI and machine learning, advanced sensor technology, precision watering systems, energy harvesting, collaboration with smart house systems, monitoring of plant health.

Future developments might make IoT-based smart gardens increasingly more advanced, user-friendly, and successful at delivering efficient and sustainable plant care. These improvements will help smart garden systems expand and become more widely used as technology develops, ultimately changing how we think about gardening and urban agriculture.

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Conflicts of Interest: The authors declare no conflicts of interest.

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