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Adaptive IOT-Enabled Dual-Sensor System for Optimizing Light and Moisture Levels in Ornamental Plant Cultivation

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***Abstract*—The objective of this research is to integrate feasible sensors with cloud technology to provide a sophisticated and data-driven solution towards achieving an economically viable and sustainable future. The system comprises a synergistic duo of an LDR (Light Dependent Resistor) and Soil Moisture sensor that intelligently ascertain the requisite light intensity and soil hydration levels. This data is communicated via a Wi-Fi-enabled microcontroller to a cloud infrastructure made accessible easily on any smart device. The system is automated to administer the optimal amount of artificial illumination and irrigation based on real-time analytics. In essence, this cloud-based architecture facilitates a competent agricultural monitoring system delivering a self-sustainable and cost-effective solution.**

***Keywords*—LDR, ESP32, Soil moisture sensor, Artificial lighting, Photoperiodism, Cloud technology, Automated Irrigation**

I. INTRODUCTION

India boasts a robust floriculture market encompassing over 65,000 hectares of floricultural terrain, thereby substantially contributing to the nation's GDP through agriculture. The demand for floral purchases in India has soared tremendously with the increasing urbanization and rising disposable incomes. A diverse array of ornamental plants with varying photoperiodic necessities are cultivated by manipulating the phytochrome system of the plant to induce flowering at desired times, thereby ensuring a continuous supply of flowers throughout the year. Short-day plants such as chrysanthemums (*Chrysanthemum*), poinsettias (*Euphorbia pulcherrima*), and morning glories (*Ipomoea purpurea*) require light below the critical photoperiod combined with a continuous period of darkness in order to bear flowers, while light above the critical photoperiod induces flowering in long-day plants such as sunflowers (*Helianthus annuus*), carnations (*Dianthus*), and petunias (*Petunia*).

Given India's seasonal variations, cultivators employ artificial lighting for short-day and long-day plants to manipulate photoperiodism and attain the required critical light hours for flowering. Additionally, ornamental crops necessitate precise irrigation to preserve aesthetic quality and eliminate redundant moisture. This system addresses a paramount problem in modern floriculture: the need for an automated and adaptive system to manage the photoperiod and irrigation requirements of different ornamental plant species. While conventional methods rely on incandescent bulbs and fluorescent lamps for artificial illumination and labour-intensive manual irrigation practices, adaptive automated systems as introduced by modern-day technology, offer opportunities to enhance efficiency and conserve energy.

This system involves a dual-sensor array in its core: an LDR (Light Dependent Resistor) calibrated to detect ambient light levels and programmed to initiate artificial illumination to fulfil the photoperiodic requirements of the proximal plant species excluding diurnal radiance, and a resistive soil moisture sensor to deliver precise real-time data on the substrate hydration levels and propel the irrigation system into motion. In tandem with the ESP32 microcontroller, these are utilized in data acquisition, processing, and cloud communication. Being powered by a solar panel in connection with an appropriate charge controller and battery setup significantly diminishes energy consumption.

This design heralds a microcosm of self-sufficient floricultural practices by automating the entire process of cultivation and empowering the farmer to make informed decisions through the monitoring and alert systems enforced by the incorporation of IoT.

II. LITERATURE REVIEW

WSNs (Wireless Sensor Networks) are put to use in smart irrigation systems to optimise water utilisation. The AgriSens technology uses instantaneous soil moisture data to optimise water management, by allowing remote irrigation for the farmer while adjusting to the needs of the various phases of the life cycle of a plant [1]. Smart agricultural systems improve crop management and promise higher yields by optimising irrigation by incorporating soil moisture, temperature, and light sensors and providing farmers with essential data through a user-friendly interface to monitor the environmental conditions of the plant [2].

An intermittent LED supplemental lighting strategy preserves plants' ideal development conditions. The system in [3] proposes the usage of a flexible number of LED supplemental lights right above the plant body which, as the plant grows and develops, varies in number and position to make sure lighting is not forfeited on areas unoccupied by the plant body. IoT technology in agriculture has revolutionised the field because of its potential to improve resource efficiency and agricultural yield. The integration of decision support systems with IoT and WSNs uses predictive analytics on the paradigm of real-time data to optimise irrigation schedules to reduce water waste and improve crop health [4]. In [5], the growth of chrysanthemums utilizes temperature and soil moisture sensors connected to a cloud-based server. Temperature below 24°C instigates the system to activate a heater and adjust the fan speed to regulate the temperature. Similarly, soil moisture below 50% prompts the water pump to irrigate the plants. All data get recorded in the cloud to be monitored through graphs on a convenient smart device. The results showed that using this system enhanced the growth of chrysanthemums by reducing the standard 30-day growth period to 23 days. Irrigation can be performed based on the climatic conditions as well as soil characteristics as sensed by the IoT sensors [6].

The system in [7] lowers the greenhouse's temperature if it is above 28 °C, humidifies the greenhouse if the relative humidity is below 72%, and turns on the lights if the intensity is below 70 Lux. All the data can be seen in real-time when remote monitoring is done using a Firebase Realtime Database. The results of the Solar-Powered Smart Irrigation System implemented in [8] showed 25.2% savings in water usage and 57.8% savings in electricity bills for the farmer.

Brightness and soil moisture content can be stored on Google Sheets to be further analysed to improve the efficiency of cultivation [9]. Further sensors like temperature, soil moisture, light intensity, and CO2 concentration sensors are used in connection with a heater, solenoid valve, light, and ventilator to comprise an automated monitoring system [10].

III. PROPOSED SYSTEM

A. Microcontroller

The ESP32 DevKit V1 microcontroller gathers information from various sensors to relay it to the cloud. Its dual-core processor integrated Wi-Fi and Bluetooth capabilities, and multiple I/O ports enable it to handle multiple tasks simultaneously, allowing it to manage lighting, irrigation, and data transfer seamlessly with sub-second precision.

B. Choice of Sensors

The LDR can be easily interfaced with the ESP32 microcontroller to automate the lighting system by responding to changes in the surroundings necessary for optimizing photoperiodism, ensuring that short and long-day plants attain their critical light hours. The irrigation aspect of the design involves the Soil Moisture sensor to record the instantaneous hydration levels. When the soil moisture falls below a predefined threshold specific to an ornamental plant species, the system automatically triggers the irrigation process, to maintain the optimum moisture level required for the wellbeing of the plant.

C. Miscellaneous Components

High-power devices are controlled using the relay module, which in this context, is the irrigation pump. The DS3231 Real Time Clock (RTC) module, due to the presence of its onboard battery, keeps track of the current date and time during all operating modes of the system and ensures that the ESP32 microcontroller executes time-dependent tasks accurately. The use of solar panels is targeted at reducing the reliance on conventional energy sources and lowering operational costs in remote agricultural settings, thereby supporting eco-friendly farming practices.

D. IoT Cloud Platform

The Blynk IoT Platform is employed as the cloud infrastructure due to its user-friendly interface, and easy installation as compared to its counterparts. It allows customisations while creating the dashboard to include virtual pins and widgets, making it compatible with this system. The same dashboard can be accessed via multiple smart devices at the user's comfort.

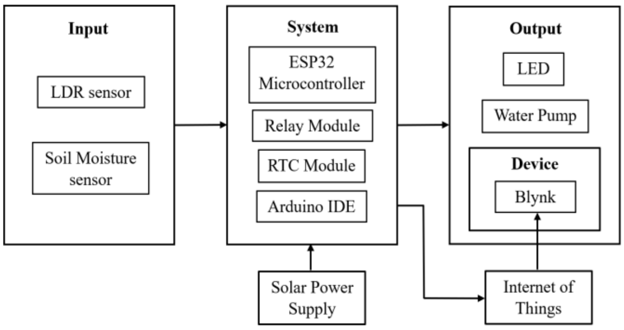

Fig. 1. Block diagram of the setup

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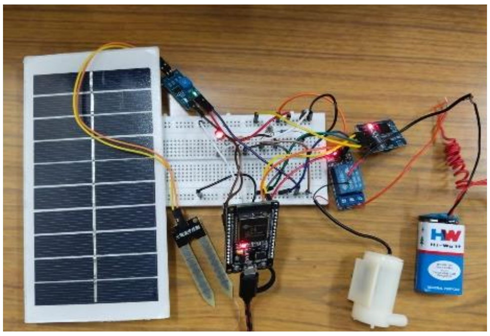

Fig. 2. Prototype of the system

IV. METHODOLOGY

The initialisation of the ESP32 microcontroller is performed by calibrating the sensors to denote the appropriate thresholds, considering optimal environmental control aspects and the species of plant that it is being administered to. The requirements standardised for the chrysanthemum species are specifically taken into consideration. The same can effortlessly be replicated for other high-value ornamental plants. The readings of the LDR are attuned to initiate artificial photoperiodic illumination for a 13-hour duration, inclusive of diurnal radiance, and is scheduled to cessation at 23:00 hours. Similarly, the resistive soil moisture threshold is set to activate the irrigation sub-system via the microcontroller upon detecting substrate moisture content below 20%.

The software for programming the microcontroller and the development of custom adaptive firmware for this system utilises the Arduino IDE software with the ESP32 board package 3.0.1 priorly installed. The LDR and soil moisture sensor are interfaced with the microcontroller by connecting the appropriate GPIO pins for efficient data collection and transmission. The actuators and control devices are set up after linking the sensors with the Pulse Width Modulation (PWM) intensity-modulated GPIO pins and are consolidated with control functions embedded in the custom firmware. The relay module is connected to the microcontroller with its control functions facilitated through the software to manoeuvre the irrigation system swiftly. The LED is integrated into the system after configuring its intensity regulation. This setup allows for external user control prioritised over the automated lighting schedules. The power management of the system uses a photovoltaic solar panel, accompanied by a Maximum Power Point Tracking (MPPT) charge controller and a lithium-ion battery for optimal energy harvesting and storage based on the requirements of the system.

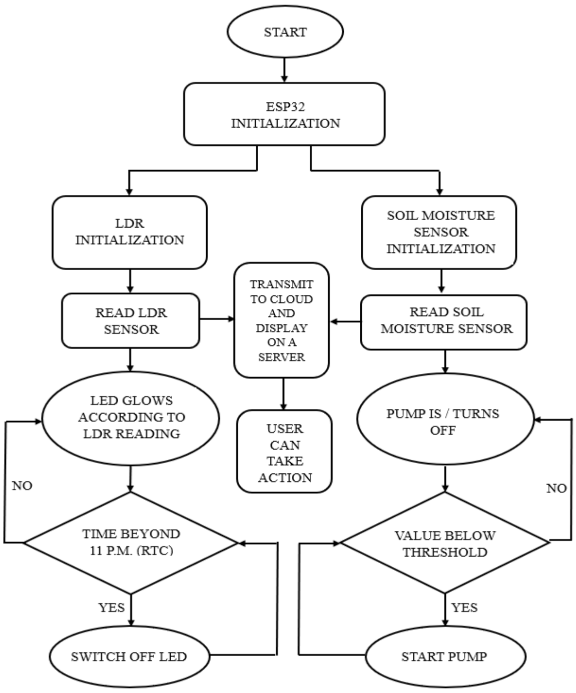

Fig. 3. Flowchart of the proposed system

The IoT integration with this system permits real-time access and regulation of the sensors, adopting the inbuilt Message Queue Telemetry Transport (MQTT) protocol of the Blynk IoT cloud platform interfaced with the hardware for consistent data transfer. Appropriate credentials, data setup, and virtual pins are administered for data input and output synchronisation of the system. The user-centric Blynk IoT dashboard, designed for efficient data retrieval, storage, and control, leveraging RESTful APIs for effortless integration is created to access the data via any smart device.

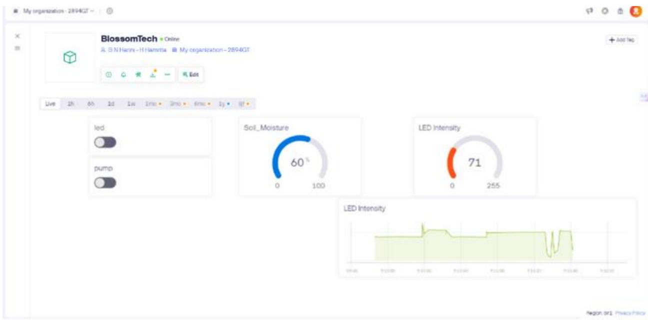

Fig. 4. Web dashboard of the Blynk platform

The assembly of all hardware components is realised by linking the software modules. A framework of performance metrics and easier maintenance is enabled by the IoT dashboard for instantly detecting any malfunctioning of a component by utilizing its real-time access to the sensors. The upcoming firmware updates and sensor recalibration schedules can be effortlessly implemented in this system.

V. RESULTS AND DISCUSSION

The system was tested for a fixed time period of 6 hours, between 14:00 hours and 20:00 hours, four parameters were observed and two graphs were plotted. The functionality of

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the lighting system can be observed from the LDR readings and their simultaneous LED values. The irrigation system can be verified from the soil moisture sensor data and the on and off modes of the water pump. The data obtained from the Blynk dashboard were scaled down and realised on graphs using MATLAB software.

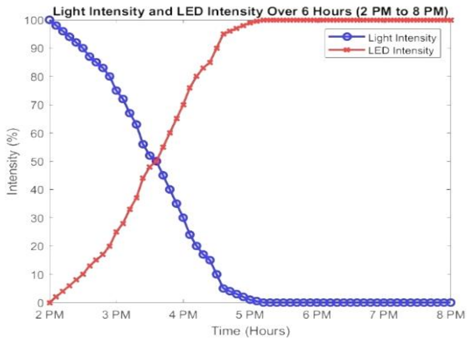

Fig. 5. Graphical Representation of the Light and LED intensities

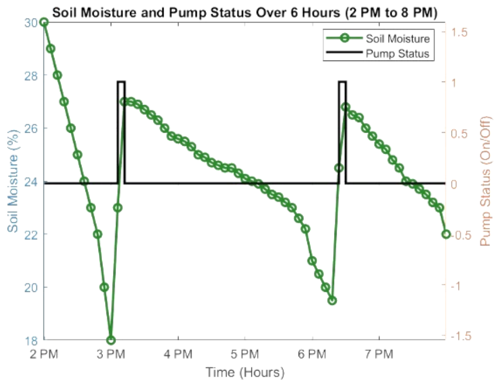

Fig. 6. Graphical Representation of Soil Moisture Data and Pump Status

The IoT capabilities can be advanced by incorporating the latest technological advancements, like employing artificial intelligence and machine learning algorithms, like analysing past data patterns to predict plant health issues. Linking the system to weather forecasting services would allow for authentic adaptive irrigation and lighting schedules based on predicted weather conditions. Further expansion of the sensor array including parameters like temperature, humidity, and CO2 sensors could provide a more comprehensive overview of the environmental conditions. Pest and disease detection sensors could identify threats early. Customizing the light spectrum to meet specific plant requirements would optimize plant growth, ensuring each plant receives the ideal lighting conditions. These developments depict the future potential of this system which will further enhance the blooming field of ornamental plant cultivation in the Indian floricultural landscape.

VI. CONCLUSION

This system combines sensor technology and cloud-based infrastructure to automate an adaptive artificial lighting and irrigation system for high-value ornamental plant cultivation, complementing the Indian climatic conditions. The ESP32 microcontroller and real-time data access and analytics of the cloud infrastructure accommodate the needs of short-day plants and long-day plants. By using LDR sensors to measure light intensity and soil moisture sensors to track hydration levels, the system is capable of adapting according to plant requirements and environment. The inclusion of the RTC module ensures timely scheduling and the solar panel allows sustainable operation of the system. The cloud-based interface makes the data accessible on any smart device and farmers can have remote control and monitoring features to enhance the reliability of their floricultural practices. By carefully addressing each aspect of the system's design and implementation, this system stands as a solution that significantly enhances the cultivation of ornamental plants, leading to improved productivity, quality, aesthetic value, and sustainability in the floriculture industry.

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