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AUTONOMOUS HYDROPONIC FARMING SYSTEM AND LETTUCE GROWING

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Annotation

This initiative aims to automate hydroponic lettuce cultivation through an electronic circuit board. Sensors collect data to optimize plant growth and monitoring. The board manages parameters like irrigation and nutrient supply, providing ideal conditions. Collected data is stored via a dedicated Discord bot, allowing real-time tracking. Remote control via Discord empowers users to adjust parameters, ensuring efficient cultivation. In summary, this project enhances hydroponic lettuce growth by automating processes and enabling remote monitoring and control.

Keywords: Hydroponics, Automation, PCB, Discord bot, IoT

Introduction

Hydroponic systems, also known as soilless cultivation (Bharti, 2019) have gained significant attention in modern agriculture due to their efficient use of resources and ability to overcome limitations posed by traditional soil-based methods. This innovative approach to farming involves growing plants in nutrient-rich water solutions (Shrouf, 2017) without the need for traditional soil. The primary advantage of hydroponic systems lies in their water-saving potential, as they can use up to 90% less water compared to conventional soil-based farming (Sharma, 2019). Furthermore, the precise control over nutrient delivery in hydroponics leads to faster and healthier plant growth, resulting in higher yields and better quality produce. In this system, we developed and introduced an electronic circuit for motor and actuator control accordingly readed sensor values. We designed the schematic and traced PCB layout of this circuit using the EasyEda program, thanks to its user-friendly interface (Ptak, 2022) and functionality, we chose EasyEda for this purpose. The circuit design consists of the following components: power supply, sensor connections, LCD screen connection, buttons, motor connections, and the MCU (Microcontroller Unit). Initially, we converted the 12-volt power source to 5 volts using the LM7805 (Adejumobi, 2012) regulator. This 5-volt output was used to power the sensors, LCD screen, button LEDs, and the 5V used for the pumps of nutrient and medication supplementation. The buttons in the circuit are used to control the three motors installed in the system. The LCD screen (Chen, 2018) provides real-time status updates, allowing users to monitor the system's performance visually. The MCU (Microcontroller Unit) communicates with the main computer via UART (Peña, 2020) to send sensor data. This enables effective monitoring and analysis of the system's operating data. Thanks to the EasyEda program, we efficiently designed this electronic circuit, ensuring all components of the system work seamlessly together. As a result, the automation system successfully accomplishes motor control and real-time monitoring of sensor data, functioning as a reliable and effective setup.

The data sent by the microcontroller to the main computer via UART communication is forwarded to the Discord bot (Gautam, 2021) which stores the data simultaneously on Discord servers and in Google Sheets using the Google Sheets API (Hodges, 2019). This ensures that the collected data is securely stored and easily accessible for analysis and monitoring. To provide redundancy and prevent data loss in the event of a possible internet connection issue, a fail-safe mechanism is implemented. If the communication between the main computer or the Discord bot is disrupted due to an internet connectivity problem, the data will be stored locally on the main computer in an Excel spreadsheet. This local data collection ensures that critical information is preserved even during temporary network outages. Once the internet connection is restored, the stored data in the Excel spreadsheet is automatically synchronized with the Discord bot and sent to the designated channels on Discord and Google Sheets. This seamless data transfer process allows for uninterrupted monitoring and analysis, guaranteeing data integrity and reliability. By combining the Discord bot and Google Sheets API, this system ensures efficient data management and provides real-time access to critical information for the hydroponic farming process. Additionally, the fail-safe mechanism safeguards against potential internet disruptions, offering a robust and reliable solution for data collection and storage in the automated hydroponic farming system.

A specialized electronic circuit board is meticulously designed to address the intricate requirements of the hydroponic system. This board encompasses microcontrollers, sensor interfaces, power management components, and auxiliary peripherals. The microcontrollers function as the central hub, acquiring raw data from sensors, implementing processing algorithms, and ultimately making data-driven decisions to finely regulate the system's parameters. During the design of the circuit board, various factors have been carefully considered. The arrangement of components on the board, signal pathways, power management, and thermal design are among the technical details that have been meticulously addressed. During the design process, possible electromagnetic interactions between different components were carefully examined. As a result, the layout of the circuit board and the arrangement of components were meticulously crafted. Additionally, special coatings and insulation methods were employed to prevent electromagnetic waves from propagating to other components. This ensured the stable and seamless operation of the system and minimized the adverse effects of external influences. This meticulous design approach has been adopted to ensure the stable and reliable operation of the hydroponic system.

A comprehensive monitoring system is established within the hydroponic environment through the strategic installation of a network of sensors. These sensors play a pivotal role in providing real-time data about the growth conditions and overall health of the plants (Lakhiar, 2018) . The carefully chosen sensors encompass a diverse range, each selected for its specific capability to gather critical data about the growth medium and the surrounding environment. The hydroponic control system has next sensors:

- EC (Electrical Conductivity) Sensors: They measure the density of the nutrient solution to ensure that the necessary minerals are provided to the plants.
- pH Sensors: pH levels directly impact nutrient availability to plants. pH sensors continuously measure the acidity or alkalinity of the nutrient solution, allowing the system to adjust the pH to the ideal range for the specific plants being cultivated. Proper pH levels enhance nutrient absorption and overall plant health.
- Temperature Gauges: Temperature is a fundamental factor affecting plant growth. Sensors monitoring temperature fluctuations ensure that the hydroponic environment remains within the optimal temperature range. Maintaining consistent temperatures promotes optimal metabolic processes and prevents stress-induced growth issues.
- Light Sensors: These sensors monitor the correct amount of light required for photosynthesis, thus optimizing plant growth.
- CO2 Sensors: They monitor the carbon dioxide level necessary for photosynthesis in plants.
- Oxygen Sensors**:** Monitoring the oxygen intake of roots, these sensors maintain root health.
- Air Humidity Sensors: By tracking air humidity, these sensors facilitate comfortable plant growth.

Each of these sensors is carefully chosen for its specific role in creating an ideal growth environment. Their collective data contributes to a comprehensive understanding of the hydroponic system's performance. By continuously gathering and analyzing data from these sensors, the system can adapt and fine-tune its processes to provide optimal conditions for plant growth. The integration of these sensors underscores the commitment to precision, efficiency, and excellence in hydroponic farming practices.

The central aspect of the data transmission process lies in the astute integration of a tailored Discord bot. This virtual entity takes on a significant role by facilitating the real-time transmission of processed data to specific Discord servers. Users gain direct access to this data through a user-friendly interface, thereby creating a symbiosis between technological advancement and user interaction.

Capabilities offered by the integrated into the system Discord bot:

- Data Transmission: Processed data is conveyed to specific Discord servers through a customized Discord bot. This enables users to acquire instant information about crucial parameters such as plant growth conditions, water levels, pH levels, temperature, and humidity.
- Remote control: Users exert authoritative control over plant growth dynamics through remote destinations, achieved through command-based interactions. They can manage a range of vital activities remotely, from adjusting irrigation schedules to fine-tuning nutrient injection rates and controlling the lighting environment (Ganesh, 2022).
- User Interaction: The Discord interface provides a platform for users to interact with real-time feedback and requests. This empowers users to inquire about the current status of the system, make suggestions, and make adjustments as needed.

This integration of the Discord bot enhances users' ability to monitor, manage, and optimize hydroponic system performance. Through remote access and interaction, users can shape plant cultivation conditions effectively. By merging technological innovation and user participation, this integration revolutionizes plant cultivation processes in unprecedented ways.

Problem of the Study

Hydroponic farming stands out as a revolutionary method that revolutionizes traditional agricultural practices by eliminating the need for conventional soil-based cultivation (Changmai, 2018). This project is strategically centered on the development of an innovative Arduino-based AI-enhanced automated hydroponic farming system, addressing the critical necessity for such advanced agricultural approaches in regions burdened with inadequate soil quality. By leveraging water as the primary growth medium and precisely administering essential nutrients through a controlled hydroponic system, this technology circumvents the limitations posed by unsuitable soil conditions, enabling optimal plant growth in areas traditionally unsuitable for conventional farming practices. Particularly in regions marked by arid or infertile soils, hydroponics emerges as a sustainable and resilient solution for bolstering food production (De Anda , 2017). The central automated control unit, driven by Arduino microcontrollers, assumes a pivotal role in ensuring the meticulous regulation of nutrient delivery, water supply, and environmental factors, culminating in the optimization of overall plant health and growth. Augmented by sophisticated AI algorithms and image processing techniques, the system facilitates real-time monitoring of plant health and the timely identification of nutrient deficiencies or diseases. Beyond its proficiency in resource utilization, the hydroponic system holds transformative potential, capable of rejuvenating regions with historically challenging agricultural landscapes into thriving centers of crop cultivation. By liberating agricultural practices from dependence on traditional soil quality, this technology-driven paradigm not only addresses food security challenges but also catalyzes economic growth and sustainable development in marginalized areas. The system's adaptability to diverse plant species not only fosters agricultural diversity but also aligns with global initiatives aimed at mitigating climate change and mitigating resource scarcity. In summary, the Arduino-based AI-enhanced automated hydroponic farming system emerges as a game-changing solution for nations grappling with adverse soil conditions. Its soil-independent cultivation method positions it as a promising avenue for sustainable and resilient food production in challenging environments. Through optimal resource utilization, continuous real-time monitoring, and flexibility in accommodating various crops, this cutting-edge approach holds the potential to make substantial contributions to global food security and agricultural development.

Purpose of the Study

The primary aim of this research is to pioneer the development of an intricate control system tailored for the hydroponic lettuce cultivation process, seeking heightened efficiency and optimization. The system's core function revolves around the continuous and meticulous monitoring and analysis of lettuce plant growth conditions, extracting data from a diverse array of sensors. These sensors span across critical components such as water mineral levels, pH values, temperature parameters, and environmental humidity, ensuring a holistic understanding of the growth environment. The paramount goal is to unravel crucial insights that, in turn, bolster the overall efficiency of hydroponic farming practices.

In a bid to operate autonomously and reduce reliance on human intervention and labor, the system harnesses sensor-derived data to dynamically regulate and optimize pivotal processes—ranging from irrigation to nutrient supply and environmental factors. This methodology anticipates not only heightened operational efficiency and data accuracy but also a reduction in associated costs, ushering in a more sustainable farming approach.

Moreover, the system extends its scope to encompass robust data storage and remote control functionalities through a repertoire of commands. This facilitates historical data access for in-depth analysis and empowers the flexible and effective management of agricultural processes through seamless remote access and intervention. For instance, the Discord bot serves as a conduit for users to remotely monitor the system, access data, and receive automated alerts for specific conditions, ensuring swift intervention and the early identification of potential issues.

In summation, the fundamental objective of this study transcends mere optimization of hydroponic lettuce cultivation; it aspires to forge a paradigm shift in agricultural sustainability and efficiency. By intricately weaving together sensor-driven mechanisms, secure data storage on Discord servers, and remote control capabilities via the Discord platform, this comprehensive approach seeks not only to elevate the potential of hydroponic farming but also to present an innovative blueprint for the future of agriculture.

The imperative to address the challenges outlined in our article underscores the urgent need for innovative and more efficient equipment. To transcend current predicaments and bolster competitiveness within the sector, there is a compelling call to design and manufacture specialized equipment rooted in technological innovations. This proactive approach holds the promise of delivering a sustainable solution that amplifies stakeholder productivity in the sector. Prioritizing the development of new equipment emerges as a strategic cornerstone, forming the bedrock of a holistic solution strategy poised to confront the multifaceted challenges prevalent in the sector.

Data Storage and remote control system with Discord BOT

In this project, the Discord bot plays a pivotal role in managing system data and ensuring effective control over the hydroponic system. To further enhance its capabilities, several technical improvements can be considered.

Firstly, the implementation of real-time monitoring commands, such as !monitor, would provide users with continuous updates on key parameters like temperature, humidity, and nutrient levels. This feature can be extended to allow users to subscribe to specific updates for more personalized monitoring.

Another valuable addition would be an alert system. A !setalert command could be introduced to enable users to configure alert conditions. This system would automatically notify users in the Discord server when specific parameters exceed or fall below predefined thresholds, ensuring prompt responses to critical changes.

Moreover, incorporating data visualization features into the bot would be beneficial. A command like !graph temperature could generate graphical representations of environmental data trends over time, offering users a more intuitive understanding of the system's performance.

In terms of data handling, strengthening error handling mechanisms is essential. Robust error management during data transfer to Google Sheets or local storage ensures data integrity and reduces the risk of potential loss. Considering potential increases in data volume, the implementation of data compression techniques is a valuable optimization. This would enhance resource usage efficiency and speed up data transfer processes.

To improve the offline mode, the bot can be designed to queue commands during internet downtime and execute them once the connection is reestablished. This ensures that no commands are lost during temporary outages. Additionally, introducing an auto-sync feature would automatically transfer locally stored data to the Discord and Google Sheets environments once the internet connection is restored, contributing to the seamless operation of the system.

For more granular control over the hydroponic system, scheduling commands such as !schedulelights or !scheduleirrigation can be introduced. These commands would allow users to set up automated schedules for specific system actions. Variable control can also be enhanced with commands like !setphthreshold, providing users with the ability to adjust parameters such as pH thresholds for nutrient supply, offering more precise control over the system.

In terms of security and user management, implementing role-based access control is crucial. This feature would restrict certain commands or functionalities to specific roles within the Discord server, ensuring that only authorized users can execute critical commands. Furthermore, secure methods for handling sensitive information, such as API keys, should be implemented. This ensures the protection of critical data like Google Sheets API keys. By incorporating these technical enhancements, the Discord bot becomes a more versatile and powerful tool, offering advanced monitoring, control, and data analysis capabilities in the context of the hydroponic system.

Electronic Schematic

The Electronic schematic section generally includes the electronic block diagram, electronic circuit schematic, and PCB layout sections of the system, along with their descriptions. The block diagram part (Fig. 2) explains the purposes of the electronic components in the system. It provides an overview of the system's electronic modules and their functions, depicting the relationships and interactions between different components, helping us understand the operating principles of the system. On the other hand, the circuit schematic (Fig. 2) illustrates in detail the units formed by electronic components on the circuit board. This schematic clearly shows how the components are connected and interact with each other. The placement and connections of electronic components are visually depicted on the schematic, aiding in comprehending the functioning and interaction of the circuit components. Moreover, the circuit schematic plays a crucial role in identifying the components to be used in electronic circuit design and enhances the understanding of any modifications made during the implementation. A detailed and accurate circuit schematic increases the reliability of analyses and simulations during the system's design phase, resulting in improved electronic design outcomes.

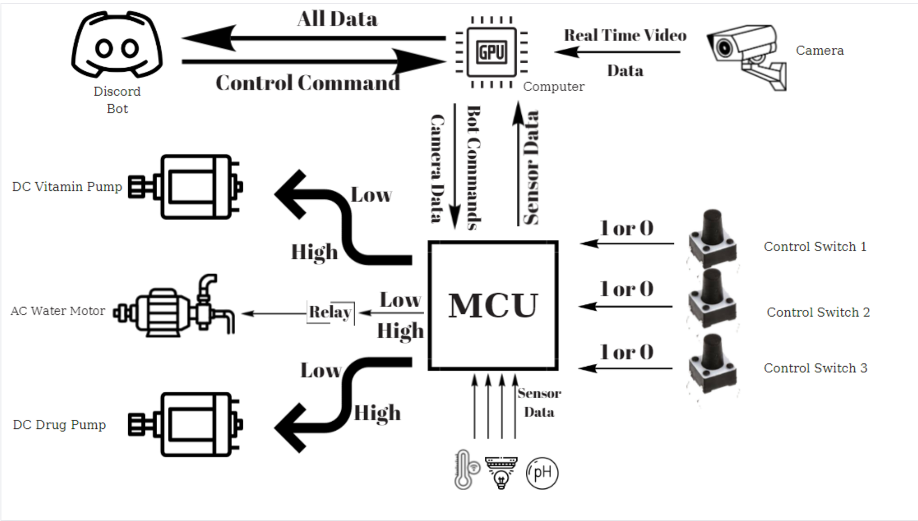

Fig. 1 - Block diagram of the autonomous lettuce growing system

The main elements of the automation system include Arduino board, motors, and sensors. The Arduino board serve as the microcontroller unit that process incoming sensor data and generate output signals for motor control. Motors are responsible for actions such as adjusting the positioning of grow lights, controlling the flow of nutrient solutions, or regulating environmental parameters. Temperature, humidity sensors, light s and pH sensors, provide real-time data on the growing conditions, allowing Arduino to make informed decisions and adjustments of system actuators. Through the programming and configuration of Arduino, the automation system enables precise control over critical parameters in lettuce cultivation. It can regulate factors like light intensity, temperature, humidity, and nutrient supply based on sensor readings. This ensures optimal growing conditions for lettuce plants, promoting healthy growth and maximizing yield. In this project, due to the absence of an existing technology to directly measure the vitamin content in water, an average vitamin supplementation plan has been devised for the lettuce crop based on the available data from online sources (Huang , 2021). This supplementation is calculated considering the essential nutritional requirements of lettuce to support its growth and health. Information gathered from relevant literature and similar agricultural projects has provided valuable insights into the general vitamin needs of lettuce plants. Drawing upon this knowledge, an appropriate average vitamin supplementation has been computed and will be implemented for the specific lettuce variety chosen in the project. This approach offers a practical solution in the absence of a direct measurement method for water-based vitamin content. By addressing the nutritional needs of lettuce plants, it ensures their well-being and proper development. Though direct measurement of water's vitamin content might be unattainable at present, this calculated average vitamin supplementation represents a viable approach to support the growth of lettuce crops and maintain their health throughout the hydroponic farming process. By utilizing Arduino's capabilities in motor control and sensor data processing, the automation system brings efficiency, accuracy, and consistency to the lettuce growing process. It reduces the manual effort required and allows for real-time monitoring and adjustment, leading to improved productivity and quality in lettuce cultivation. In this system, 5V underwater submersible pump are used for providing vitamin and medication supplements to the plants. The motors of these pumps are controlled by the MCU. The speed of the vitamin and medication supplements is not crucial for the system as they only need to be administered at low levels. However, the water circulation pumps that ensure the system's recirculation need to be powerful and have a high flow rate. For this reason, we utilized a 230V AC water pump motor triggered by a regulator. The water pump we used is the SYNCRA 1.0 Silent model (Sicce Corporate, 2014) which consumes less energy compared to other models, approximately 16W. Additionally, with a flow rate of 950 liters per hour, this water pump effectively provides the desired circulation in our hydroponic system. This robust water pump ensures that the nutrient solution circulates evenly among the plants, promoting their healthy and balanced growth.

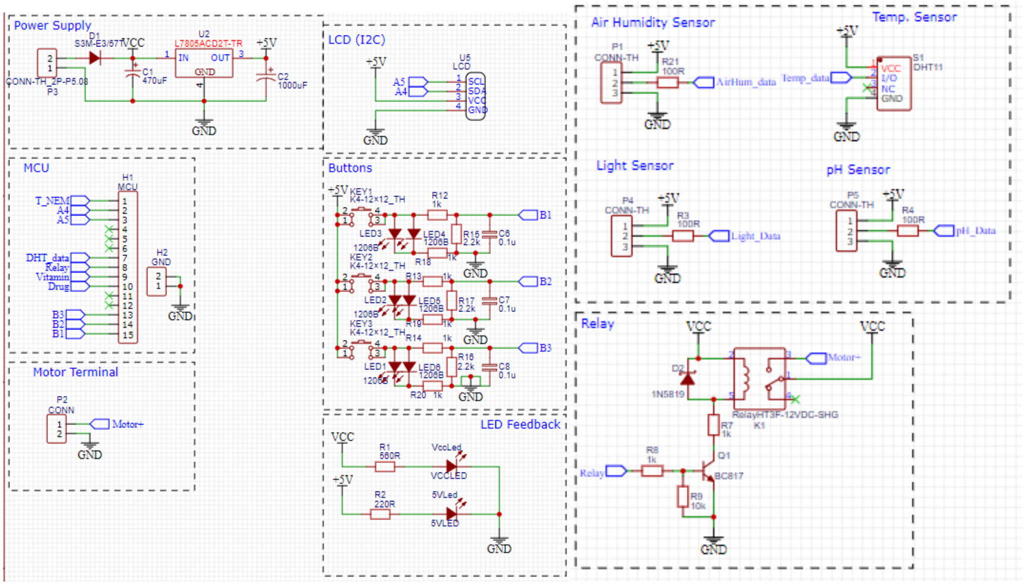

Fig. 2 – Schematics of control system

In this project, the electronic circuit schematic and PCB (Printed Circuit Board) layout were successfully developed using the EasyEDA software. The user-friendly interface and functionality of EasyEDA facilitated the design process and enhanced productivity. The electronic circuit schematic clearly depicted the fundamental components and connections of the project, effectively conveying the essential concepts of the design. The PCB layout transformed the electronic circuit schematic into a physically feasible printed circuit board, enabling the optimization of component placement and connections for a more organized and efficient production of the project. The convenience and flexibility offered by EasyEDA played a significant role in the successful completion of this project. facilitating the effective creation of the targeted electronic circuit. Electronic circuitry offers various advantages in this project (Canal Marques, 2013). In accordance with the project requirements, a custom circuit board has been designed. The power supply unit of this board (Fig. 2) utilizes the LM7805 Regulator to step down the 12V DC power from the source to 5V, meeting the general 5V power needs of the circuit. Capacitors C1 and C2 are employed to minimize power fluctuations and noise. To monitor the accuracy of the 12V and 5V sources without the need for measurements, two LEDs (Fig. 2) are used to provide feedback on these voltages. The connections for the required sensors (Fig. 2) have been established, and their data pins are linked to the microcontroller unit (Fig. 2). The 5V submersible motors used for vitamin and medication supplementation are directly connected to the microcontroller unit (Fig. 2), while the AC water pump motor is controlled through a relay unit (Fig. 2). The LCD screen is integrated to display comprehensive system information. For direct system control, three buttons (Fig. 2) have been added to the circuit.

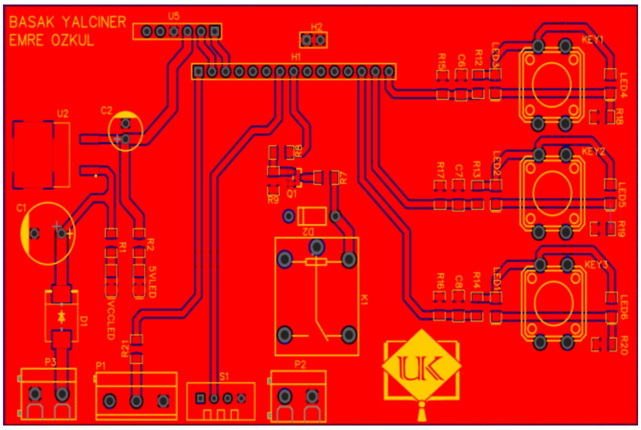

Fig. 3 - PCB Layout for autonomous lettuce growing system circuit schematic

Due to EasyEda's user-friendly interface, the electronic schematic of the circuit (Fig. 2) was designed using the EasyEda program for PCB layout. In the PCB design, all the connections specified in the electronic schematic were implemented accurately. One key aspect during component placement was to arrange them neatly to ensure clean and efficient connections. Considering all the requirements, the PCB layout was successfully completed. This step plays a crucial role in achieving the successful implementation of the project's electronic components and ensuring the circuit operates efficiently. The completion of the electronic schematic and PCB design facilitates the harmonious functioning of the hardware components, which is essential for the overall success of the project. The systematic and careful procedures carried out during this stage directly impact the project's overall performance and success.

Conclusions

This study focuses on the importance of hydroponic systems in modern agriculture. The developed system is designed to utilize resources efficiently and overcome the limitations of traditional soil-based methods. This innovative approach, which involves growing plants in nutrient-rich water solutions, has the potential to use up to 90% less water compared to conventional agriculture. Precise nutrient control leads to healthier plant growth, higher yields and improved product quality.

The design of the electronic circuit board, sensor selection and integration emphasize the future role of hydroponic agriculture. This specialized circuit board includes microcontrollers, sensor interfaces, power management components and auxiliary peripherals. Microcontrollers collect raw data from sensors, apply processing algorithms and make data-driven decisions to effectively regulate system parameters. Sensor selection aims to establish a comprehensive monitoring system by strategically placing a network of them. These sensors provide real-time data on plant growth conditions and overall health. Soil moisture sensors regulate irrigation cycles, pH sensors adjust nutrient availability, temperature meters maintain optimal conditions and humidity detectors ensure the correct water balance. The integration of these sensors provides a comprehensive understanding of system performance so that it is possible to adapt and adjust processes for optimal plant growth.

The integration of the Discord bot plays a central role in real-time data transmission. This virtual presence facilitates the transfer of processed data to specific Discord servers, giving users direct access with a user-friendly interface. This integration revolutionizes plant cultivation processes with remote manipulation, so users can issue custom commands to adjust watering schedules, nutrient levels and lighting conditions. The Discord bot combines technological innovation with user participation in monitoring, managing and optimizing the system.

Furthermore, this work emphasizes the importance of careful design of the electronic circuit board, sensor selection and component arrangement. These elements ensure stable and reliable operation. The paper commits to precision, efficiency and excellence in hydroponic farming applications. Furthermore, the paper emphasizes the necessity of a backup mechanism to increase data storage reliability during internet connectivity issues. This mechanism ensures seamless synchronization of data when connectivity is restored.

In conclusion, this paper highlights the importance of creating a system that optimizes hydroponic farming processes through electronic circuit board design, sensor integration, Discord bot usage and data management methods.

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AUTONOMINĖ HIDROPONIKOS SISTEMA SALOTŲ AUGINIMUI

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Santrauka

Šiuo tyrimu siekiama sukurti revoliucinę valdymo sistemą, kuri pagerintų hidroponinį salotų auginimo procesą. Mūsų darbas sutelktas į hidroponinio ūkininkavimo efektyvumo ir tvarumo didinimą, naudojant duomenis, gautus naudojant pažangius jutiklius. Jutikliai sukurti taip, kad apimtų įvairius komponentus, tokius kaip drėkinimas, maistinių medžiagų tiekimas, pH lygis ir aplinkos sąlygos. Renkant šiuos duomenis, siekiama pagerinti hidroponinio ūkininkavimo efektyvumą, suteikiant svarbių įžvalgų apie augančios aplinkos subtilybes. Sistema automatiškai reguliuos ir optimizuos svarbiausius procesus, tokius kaip drėkinimas, maistinių medžiagų tiekimas ir aplinkos veiksniai, veikdami nepriklausomai nuo žmogaus įsikišimo. Šis metodas padidins žemės ūkio procesų efektyvumą ir duomenų tikslumą, todėl sumažės veiklos sąnaudos ir naujas požiūris į tvarią žemės ūkio praktiką.

Tyrimas žengia dar vieną žingsnį – siūlo ne tik hidroponinį salotų auginimą, bet ir galingą duomenų saugojimo bei nuotolinio valdymo mechanizmą per Discord platformą. Naudodami „Discord“ robotą, vartotojai gali stebėti sistemą realiuoju laiku ir nuotoliniu būdu suaktyvinti pagrindinius komponentus, tokius kaip drėkinimo ir vitaminų varikliai. Ši integruota sistema nušviečia šiuolaikinio žemės ūkio ateitį, nustatydama naujus žemės ūkio produktyvumo ir tvarumo standartus.

Be to, mūsų tyrime pabrėžiamas poreikis kurti naują ir veiksmingesnę įrangą, kad būtų sprendžiamos esamos sektoriaus problemos. Šis metodas, pagrįstas technologinėmis naujovėmis, gali pasiūlyti tvarų sprendimą, padidindamas sektoriaus suinteresuotųjų šalių produktyvumą. Pateikiant ateities viziją, kai tikslioji žemdirbystė ir pažangi įranga susijungia, šiuo tyrimu siekiama formuoti būsimą žemės ūkio praktikos raidą.