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Development of IoT-controlled irrigation and fertilization system for fertigation farming

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ABSTRACT

This paper presents the development of irrigation and fertilization systems for fertigation farming with IOT control. The irrigation and fertilization method used in this study is drip irrigation. Meanwhile, an IoT system is used to monitor the irrigation and fertilization processes to ensure plant quality. Through this system, users can monitor fertigation plants in terms of water levels, the amount of fertilizer mix in the fertigation tank, and watering times using smartphones. The correct amount of fertilizer mix A and B (depending on the type of plant) will ensure that plants receive sufficient nutrients for growth processes. With the correct fertilizer mix measured using an Electrical Conductivity (EC) meter, nutrients to plants can be supplied at an adequate rate.

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Introduction

Nowadays, the concept of Industry Revolution 4.0 (IR 4.0) has gained significant importance for the future (Majid et al., 2022). It's offers bright opportunities for achieving industrial goals and involves numerous job openings that foster creativity, and also encourages innovative thinking in developing technologies to assist society. IR 4.0 represents the advanced stage of industrial development, evolving from the first, second, and third industrial revolutions (Groumpos, 2021). It integrates computer technology and automation, enabling machines, devices, sensors, and humans to interact seamlessly without direct contact. This revolution helps industries solve complex problems through automation, big data analysis, simulations, and system integrations (ur Rehman et al., 2019). Technologies related to IR 4.0, such as the Internet of Things (IoT), allow humans to use smart devices for efficient control and management (I. H. Khan & Javaid, 2022).

One of the primary challenges associated with manual planting is the constant need for farmers to monitor their gardens to ensure equipment adequacy and prevent depletion (N. Khan et al., 2021). Traditional planting methods often demand significant human labor and time for management. An innovation dating back a century ago revolutionized cultivation practices, with modern advancements now emphasizing soilless cultivation techniques, utilizing water as the primary medium. This approach not only conserves planting space but also indirectly reduces the manpower required to maintain plant freshness, consequently saving time and labor for other tasks (Wani et al., 2023).

Ensuring adequate water flow for plants poses a challenge in traditional methods. A consistent supply of water and fertilizer is crucial for optimal plant growth (Yang et al., 2023). In fertigation cultivation, where soil is not utilized, the uninterrupted flow of liquid fertilizer and water becomes imperative as the sole medium for nutrient absorption. However, in conventional methods, confirming the water level in the tank poses difficulties, potentially leading to inadequate water supply and subsequent growth issues. Such shortcomings may result in damage to water-moving mechanisms and hinder overall plant development, ultimately leading to increased maintenance efforts and associated costs. Particularly in fertigation cultivation, meticulous attention to water and fertilization is paramount for successful plant care (Chojnacka et al., 2020).

The objective of this project is to monitor the water level in the fertigation system tank to ensure that plants remain fertile even when left unattended for extended periods. To achieve this project objective, an irrigation and fertilization system with IoT control has been developed to ensure that the watering and fertilization processes can be automated. Through the use of IoT technology, users can monitor critical parameters such as water levels and fertilizer mixtures in the tank using smartphone applications like MQTT and Node Red (Rehman et al., 2022). The implementation of this IoT-based system offers numerous benefits to users and crops. These benefits include enhanced efficiency and control in the fertilization process, ensuring adequate water levels in the fertigation tank, improved crop quality, as well as time and energy savings for users.

Method

The project development started with assemble all the main components that has been selected as shown in Figure 1. Arduino Uno R3, EC Meter, ultrasonic sensor, water solenoid valve, RTC Module and water pump (12v, 240v) will be assembly together correctly. The system will be start when ultrasonic sensor detects water level reach the minimum level. This information will be notified to user. Users can monitor what is happening to their plants. information on water reduction, EC meter detection to fertilizer water solution, water flowing into the pot at a set time, will be displayed through the MQTT app which users can get into their smartphones. The expected objectives can be achieved once the system can be produced successfully.

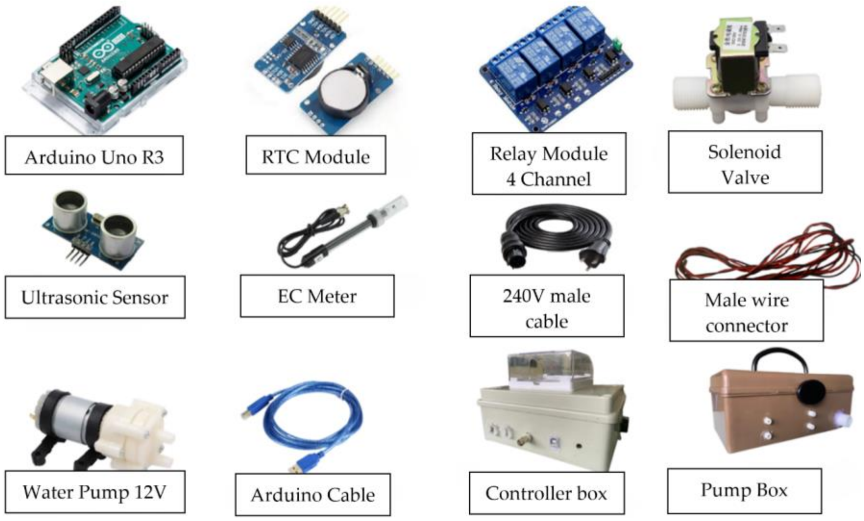

Figure 1 <List of Component>

The operational workflow of the system involves two main steps. Firstly, an ultrasonic sensor is employed to ensure continuous monitoring of water levels in the tank, maintaining a predefined threshold. Additionally, an EC Meter is utilized to verify the correct concentration of fertilizers before application to crops. Secondly, the system facilitates the automated mixing of fertilizers. A 12v pump extracts fertilizer from the manure tank and transfers it to the main tank, while a solenoid valve controls the intake of water from the main pipe into the plant tank. This process is informed by data collected over three consecutive days, ensuring that fertilizer mixtures are adjusted based on crop water uptake levels. Figure 2 describes how the circuit works. The system of the device for monitoring water with IoT system is simple by using semi-automatic and manual function. Ultra-sonic sensor detects and read water level in crop main tank that has been set using coding from the Arduino uno. When the ultrasonic sensor detects the height of the water level in the main tank reaches the minimum level, user will get notification alert from MQTT apps. The application adopted is to inform the user and monitor what is happening in the system either about the movement of water entering the vase or the level of water present in the tank. When the water is low, the system will provide data to the node red and issue a notification using the application MQTT to the user.

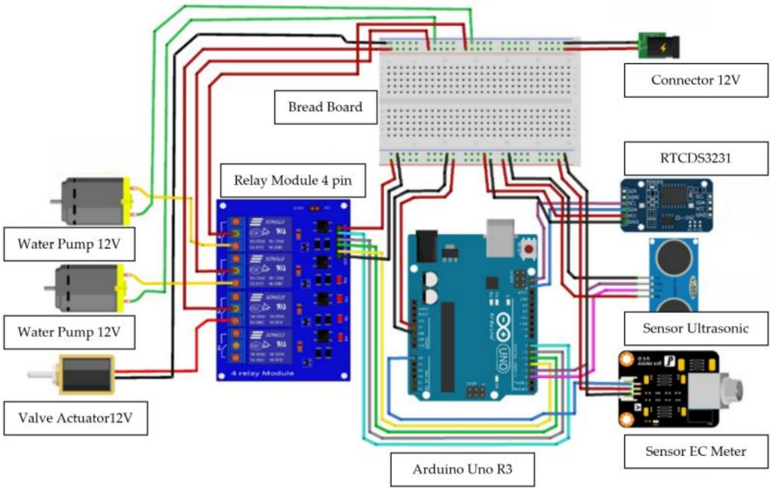

Figure 2 <Circuit of System>

Two water pumps are used to suck the type of AB fertilizer that will be used into the tank and the appropriate fertilizer water concentration for crops will be measured using an EC Meter. The valve actuator will be used as the tap water connector from the main tank to the plant tank. The use of RTC modules will also be incorporated into the system to ensure that water will always flow into the pot at setting times of the day. In this study, the developed system is used to irrigate and fertigate 100 strawberry pots using fertigation technique. Meanwhile, the irrigation and fertilization tank used has a capacity of 100 liters.

Results and Discussion

The developed system is used for the irrigation and fertilization of 100 strawberry pots grown using fertigation. In this study, the EC meter reading for the mixture of fertilizers A and B is set at 0.19 mS/cm. The water level and EC level were monitored using MQTT app. Water flow from the main pipe will stop when the water level reaches 100% and the EC meter reading shows 0.19 mS/cm. Table 1 shown the analysis of water level percentage after 5 days. After 5 days, water level reached 28% in water tank. The minimum water level set in this system is 30%. When the water in the tank reaches 30%, the solenoid valve will be activated, and water will be automatically added to the fertigation tank along with liquid fertilizers A and B until the EC meter reaches the appropriate reading.

Observations were made over five consecutive days on the percentage of water levels in the tank and the concentration readings of fertilizer content in the tank. During the observations, several factors caused the amount of water absorbed by the strawberry plants to vary. The main factor was the weather. During this period, the water levels in the tank from the first to the fifth day were 14%, 17%, 13%, 15%, and 13%. Watering was carried out three times a day at scheduled times, specifically at 8 AM, 4 PM, and 12 midnight. The percentage of water absorption on the third and fifth days was quite low due to heavy rain on those days. On the second day, the water absorbed was 17% of the remaining water in the tank because the weather was somewhat sunnier compared to the previous day. By the end of the fifth day, the remaining water in the tank was 28%.

Table 1 <Analysis of Water Level Percentage>

Day	**Percentage of water (%)**			**Average of water level use per day (%)**
	8.00 am	**4.00 pm**	**12.00 am**	
1	100	96	90	14
2	86	79	73	17
3	69	64	60	13
4	56	50	44	15
5	41	34	28	13

The direct delivery of fertilizers through drip irrigation requires the use of soluble fertilizers, along with pumping and injection systems to introduce them directly into the irrigation system. Fertigation enables precise and uniform application of nutrients to the root zone, where active roots are concentrated. This method ensures that crops receive the appropriate quantity and concentration of nutrients throughout their growing season. The system design in this project aims to improve upon conventional methods such as hydroponics and basic fertigation systems, which often involve significant labor and time. The proposed system simplifies tasks like adding liquid fertilizer and water. It incorporates an ultrasonic sensor to monitor the water level in the main tank and utilizes IoT technology to automatically transmit water level and EC data to the user's smartphone. This allows real-time monitoring and adjustment of water and fertilizer levels for strawberry crops. Analysis shows that the MQTT application successfully integrates with the system, enabling remote monitoring by users. Each component of the water tank system operates effectively, ensuring fresher and more fertile strawberry crops. The smartphone display provides real-time updates on water levels and EC values of the fertilizer mixture, facilitated by data transmitted from NODE RED to MQTT. Additionally, the ultrasonic sensor accurately measures water levels as a percentage, while the EC meter ensures precise monitoring of fertilizer mixture concentrations.

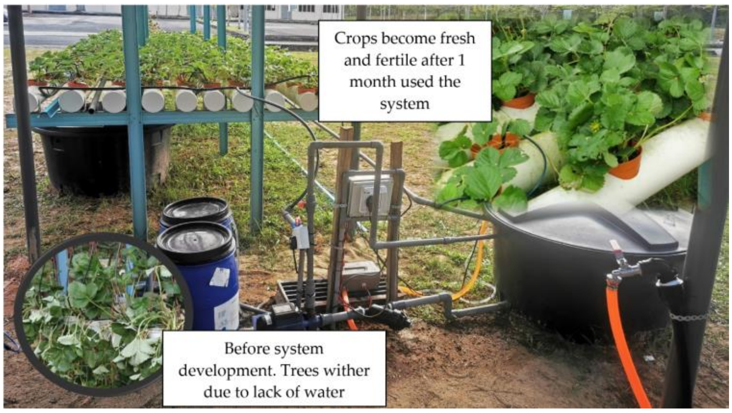

Figure 3 <Condition of Crops Before and After Systematic Irrigation and Fertilization>

Figure 3 shown conditions of crops before and after systematic irrigation and fertilization applied. Before this system was developed, the planted trees would wilt due to insufficient water and fertilizer as they were left unattended for a considerable period. After applying this developed system, the plants became more fertile due to the correct fertilizer mixture and proper irrigation. Within one month after the system was applied, the plants began to bear fruit. This system is one of the alternatives to help urban growers enjoy their crops without having to expend more energy to ensure the fertility of their plants is maintained.

Conclusions

In conclusion, this project has successfully implemented systematic and automated irrigation for fertigation crops. The system controls the water level in the irrigation tank, automatically adding water and fertilizer when levels drop to a minimum. The inclusion of an EC meter ensures accurate monitoring of fertilizer and water mixtures, optimizing nutrient delivery to the plants. Overall, the system has demonstrated several positive impacts when applied to crops. These include enhanced crop growth and efficiency, addressing operational challenges, and improving overall yield quality. Users benefit from reduced labor and time spent on crop management, with the system ensuring continuous operation and minimal oversight required.

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