International Journal of Research in Engineering and Innovation (IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

International Journal of Research in Engineering and Innovation
Vol-8, Issue-3
ISSN: 2456-6934

REVIEW ARTICLE

Automated plant watering systems- a comprehensive approach to efficient and sustainable home gardening

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Article Information

Received: 13 February 2024
Revised: 26 April 2024
Accepted: 19 May 2024
Available online: 01 June 2024

Keywords:

Automated plant watering system
Arduino
Soil moisture
Home gardening

Abstract

The significance of automated irrigation systems in gardening ceases to remain in doubt and proves to be essential and environmentally friendly. The given paper explores the system's creation and implementation containing four sensors: measuring soil humidity, temperature, humidity, and light exposure proves to be a comprehensive strategy for flora and fauna maintenance. The following document will investigate a comprehensive system with the integration of Arduino technology, automatic equipment that automates the process of flora growth maintenance, and humidity-keeping of its daily routine which minimizes manual work and maximizes water sources and provides uniform plant parameters. Inter alia, the text will include a description of hardware and software, the layout of the system, and the calibration process. Thus, the final piece will contain a review of the advantages and difficulties that were faced, seem to be met in the further perspective, i.e. the addition of other sensors or integration of connectivity.

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1. Introduction

At the moment, as more gardening and farming are carried out using technology and robotics, plant watering systems are of significance. The concept of having these systems provides an opportunity to conserve resources, do away with the use of men, and sustainability [1] [2]. An increasing number of people are practicing gardening and small-scale farming, and it has become a problem to maintain constant watering of plants and to pay attention to water saving. The required technological systems can be incorporated with technology and environmentalists; hence, automated irrigation systems present a viable solution to the situation [3]. The methods that were implemented, like using hands when watering, were inefficient and resource-wasteful because of limitations such as extra watering in the morning and less watering in the afternoon [4]. It is vital to conduct conservation frameworks in modern world society as well since the climate, together with the population growth, is affected [5]. The microcontroller Arduino code for the automatic plant irrigation system is supported by using different sensors to control the irrigation process depending on the amount of soil moisture. They relieve the amount of wasted water resources and the workload, which is an implied result of using manual means for watering [6]. Yet, this does not mean that soil moisture is the only factor that dictates the health status of plants since the surrounding temperature, humidity, and light conditions also significantly influence the growth condition of most plants [7]. So, a complete automatic garden watering system adds the appropriate sensors for other relevant parameters, such as humidity and air temperature, to have a more accurate picture of the state of microclimate in the garden. This broader network of sensors provides a solid foundation for making reliable conclusions that would be useful in achieving better

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https://doi.org/10.36037/IJREI.2024.8305

productive performance of plants for less input [8]. The incorporation of the extra sensors leads to an increased number of sensors, which makes automated watering systems more functional in various gardening setups, from small indoor gardens to large outdoor landscapes [9]. There has also been significant progress in other plant watering technologies, especially those that are technology-based and have additional features such as remote sensing. This advancement gives people the choice of dealing with the system remotely, which is more convenient for them, besides being flexible [10]. Remote monitoring becomes especially useful as the system can be controlled by showing the user information about the system's state and changes that can be made to it remotely, which provides a much greater level of control than traditional gardening methods [10].

Additionally, given the lack of resources and the fact that sustainability in gardening practices becomes vital, the final potential of automatic irrigation systems is revealed. These systems could save handicraft labor, conserve water, and optimize the management of plants. The focus of the current paper is to design a control system for the home and farmers controlling gardening and agriculture. It explains the application of the sensors as well as the microcontrollers and controllers to make up a system. The excellent scalability and flexibility provide exciting opportunities for the plant factory across a spectrum of uses ranging from the domestic gardener right through to the large-scale agricultural user [10, 11].

2. Literature Review

Advanced Automated Watering Systems for Home Gardening. In the study of automatic watering in plants, we evaluated numerous research papers demonstrating the effectiveness of using technology to automate irrigation. The consensus across various studies highlights the multiple advantages of automation, including water conservancy, reduction in labor, and improved plant health [11]. The advancements in technology have led to significant developments in the design and implementation of automated irrigation systems, making them more accessible and efficient for both residential and commercial applications. Automated plant watering systems commonly utilize a microcontroller unit, such as an Arduino board, which serves as the central controller. This unit interacts with sensor and valve nodes to manage water addition based on soil moisture levels. Numerous studies have detailed systems with fundamental functionality, where a moisture probe triggers a pump to irrigate the plants when the soil dries out. This approach exemplifies precise irrigation, which is a key aspect of water conservation. The simplicity and cost-effectiveness of this basic setup have made it a popular choice among hobbyists and small-scale gardeners [12].

Nevertheless, given the complexity of modern gardening systems, there is a significant need to incorporate more sensors. Adding various sensors enhances the system's versatility and independence, making it suitable for diverse gardening contexts. Several articles recommend integrating a hygrometer, barometer, and light sensor alongside the traditional soil moisture sensor. These additional sensors provide comprehensive data on the plant's growing conditions, enabling more nuanced decision-making. For instance, a hygrometer can measure the relative humidity of the environment, a barometer can monitor atmospheric pressure, and a light sensor can gauge the intensity of sunlight, all of which are crucial factors for plant health and growth [13, 14].

2.1 Monitor Soil Moisture

The central component of any watering system controlled through automation is to create data that the plants require watering. Additionally, soil moisture sensors will be in place to detect the volumetric water content in soil, which helps in evaluating the watering needs of plants and thus facilitates preventing the occurrence of over-watering and under-watering. Besides saving water, these methods will improve nutrient absorption, increase more robust root systems, and decrease diseases that are caused by too much irrigation [11]

2.2 Track Ambient Temperature

Ambient temperature sensors as well as took interest in the environmental conditions vacillating the plant growth. Temperature, in particular, has a leading role in the photosynthesis, respiration and the transpiration processes of plants. The system that will be monitoring temperature can come up with watering plans based on certain standards. The plans can change corresponding to seasonal variations and plants' specific needs [13].

2.3 Measure Humidity Levels

Humid sensors are basically used to monitor the level of the moisture content in the air which is a critical point for the correct state of the plants. A large humidity level is particularly problematic because it can evolve into fungal infections and mold growth. Low humidity, on the other hand, can cause plants to lose water quickly via transpiration. Therefore, the system sustains the state of balance between internal and external microclimatic conditions which are compatible with successful development of vegetative organisms, and the level of stress is reduced [15].

2.4 Monitor Light Intensity

Photosynthesis takes place to convert light into energy that aids in plant development. Light sensors detect the intensity and duration of sunlight exposure which is the key factor that determines plant advancement. Plants can be categorized into lights-loving plants and shade loving plants, and the amount of light necessary varies with plant species and growth stage. Through the management of light level, the system can be used to furnish plants with additional light and protection from light if that is required to make the plants get the right amount of light for the advancement [15].

2.5 Benefits of a Multi-Sensor Approach

The integration of multiple sensors transforms a basic automated watering system into an advanced home gardening solution. The system's ability to make informed decisions based on various climatic data significantly improves plant health and resource efficiency. For example, by correlating soil moisture data with ambient temperature and humidity levels, the system can adjust watering schedules to prevent water loss during hot and dry conditions, thereby maximizing water use efficiency [16]. Moreover, the literature indicates that highly scalable automated systems with multiple sensors are essential for various applications. These systems can be adapted for residential use, small indoor gardens, home gardens, and larger outdoor spaces. Studies also report the potential for remote monitoring and control features, enabling consumers to manage their systems over long distances, thus enhancing convenience and effectiveness [16]. This capability is particularly beneficial for users who travel frequently or manage multiple garden locations, as it allows them to monitor and adjust their irrigation systems in real-time using mobile applications or web interfaces. [17]

2.6 Advanced Features and Future Directions

2.6.1 Remote Monitoring and Control

The implementation of automated Internet of Things (IOT) technology gives a chance to monitor and control watering systems to a remote location. Users can get all the time required information with respect to their garden's status on their tablets/phones and they can even make alterations to the watering schedules and sensor thresholds from all over the world. This particular feature not only makes life easier for the owner but also guarantees that plants are properly cultivated and keep on a successful growth path even when the owner is away [17][18].

2.6.2 Data Analytics and Machine Learning

In addition to this, the complex systems are able to take advantage of data analytics and machine learning algorithms that allow forecasts of water needs for the plants and then provide the irrigation schedule. The system, gaining such expertise, is able to do that by analyzing historical data and environmental conditions and to immunize plants being done, by making decisions proactively and the resource efficiency to improve. This prognostic ability diminishes the need for manual management, empowers the system to adapt to dynamic surroundings in a self-emergent way [18].

2.6.3 Integration with Weather Forecasting

For instance, integrating level-based information from the weather forecast readings helps optimize irrigation level controls. The system will automatically use smart technology that broadly depends on the anticipated trail of rainfall, temperature change, and humidity to schedule watering, thus saving water and preventing over-watering. This integration ensures that plants receive optimal care regardless of external weather conditions [19].

2.6.4 Scalability and Customization

Modern automated watering systems are designed to be highly scalable and customizable. Users can add or remove sensors based on their specific needs and expand the system to cover larger areas or multiple garden zones. This flexibility makes the system suitable for a wide range of applications, from small indoor gardens to extensive outdoor landscapes [19, 20]. The major operation of this system lies in the fact of hooking the soil moisture sensor, which was planted with the plant, to the Arduino sub-module alongside other electronic components as shown above in figure one. The sensor is used in the measurement of the soil moisture, by passing messages and the parameter of the moisture to the microcontroller and the pump which helps in controlling the moisture. When the level of soil moisture goes lower some value, the microcontroller give the signal to the RELAY MODULE and some quantity of water is pump and supply to the plant.

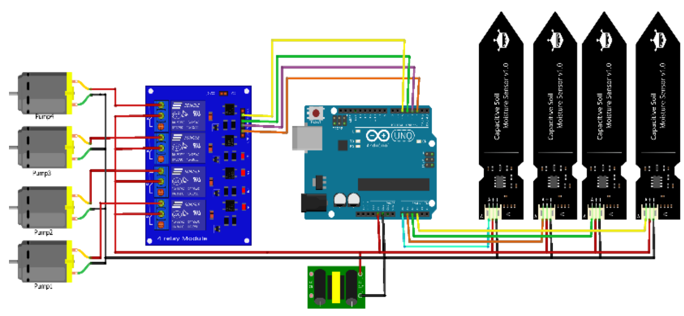

Figure 1: Circuit diagram of automatic plant watering system

The pump ceases functioning once enough water is delivered to a desired spot. Power supply is to provide power to the complete system and the recommended voltage should be within the input supply range for microcontroller, that is, 7V-12V. Relay module is an elementary electrical circuit that is composed of only one switch, various resistance boards, diodes and a relay and can only be controlled by microcontroller. It is also necessary to note that the complete system should fit in a small box, which is why Arduino Nano is an ideal microcontroller to use because of its size and performance level. Soil moisture module is consisting of the two parts: amplifier circuit and probes that we presented in "material and methods" section. This module has digital and analog outputs: in particular digital output is set at the logical 1 when the threshold of the circuit is triggered. The threshold is established by the potentiometer. The described organization of the input signal processing makes it clear that the threshold is established by the potentiometer. Analog output helps in getting the information concerning with the moisture present in the plant and this output is implemented in the system. The water pump is connected to the relay module and the latter can only operate the water pump when it receives a signal from the microcontroller.

3. System design and methodology

3.1 Hardware Components

The automated plant watering system is designed using the following hardware components:

3.1.1 Arduino UNO

The Arduino Uno is a versatile microcontroller board widely used in various systems, including those employing sensor data-based control mechanisms. As the central processing unit of the system, the Arduino Uno interfaces with sensors, such as temperature sensors, humidity sensors, or moisture sensors, to gather real-time data from the surrounding environment. This data serves as valuable input for decision-making and control within the system. Using its programmable capabilities, the Arduino Uno can analyze sensor data and execute predefined instructions or algorithms to regulate various parameters, such as temperature, humidity, or irrigation cycles, to ensure optimal conditions for plant growth. For instance, based on temperature sensor readings, the Arduino Uno can activate cooling systems, adjust heating elements, or trigger watering mechanisms to maintain the desired environmental conditions for plants. Additionally, the Arduino Uno's flexibility allows for customization and expansion, enabling integration with additional sensors or actuators as needed to enhance system functionality. Overall, the Arduino Uno plays a critical role in sensor data-based control mechanisms, serving as the brains behind intelligent automation and optimization in applications ranging from smart agriculture to environmental monitoring.

Figure 2. Arduino Uno

3.1.2 Soil Moisture Sensor

A soil moisture sensor is an essential tool in modern agriculture, providing crucial data to ensure efficient and precise irrigation practices. Embedded directly into the soil, these sensors measure the moisture content at the root level of plants, offering real-time insights into soil conditions. By continuously monitoring moisture levels, the sensor helps determine when irrigation is necessary, allowing farmers and gardeners to deliver water to plants precisely when needed, thereby optimizing water usage and promoting healthy plant growth. When soil moisture levels fall below a predefined threshold, indicating that plants require hydration, the sensor triggers the irrigation system to supply water. This automated approach minimizes the risk of under-watering or over-watering, both of which can adversely affect plant health and crop yields. Additionally, soil moisture sensors enable growers to fine-tune irrigation schedules based on specific crop requirements and environmental conditions, contributing to resource conservation and sustainability efforts. Overall, the integration of soil moisture sensors into irrigation systems enhances efficiency, productivity, and water conservation in agriculture, ensuring that plants receive the optimal amount of moisture for optimal growth and yield.

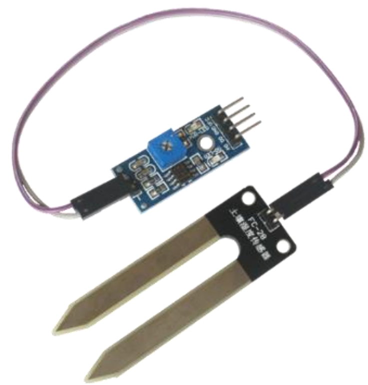

Figure 3. Soil Moisture Sensor

3.1.3 Temperature Sensor

A temperature sensor, when strategically placed within a garden or growing environment, offers invaluable insights to gardeners, aiding in the precise care of plants. By continuously monitoring the ambient temperature, this sensor provides crucial data that informs various aspects of plant care and management. Temperature plays a fundamental role in plant growth and development, influencing factors such as germination, flowering, and fruiting. With real-time temperature readings provided by the sensor, gardeners can make informed decisions regarding watering schedules, choosing appropriate plant varieties, adjusting ventilation and humidity levels, and implementing protective measures during temperature extremes. For instance, if the sensor detects unusually high temperatures, indicating a risk of heat stress for plants, the gardener can promptly take action by providing shade, increasing watering frequency, or adjusting ventilation systems to mitigate the impact. Conversely, during colder periods, the sensor can signal the need for frost protection measures, such as covering plants or activating heating systems to prevent damage. Overall, the temperature sensor serves as a valuable tool for gardeners, enabling them to create optimal growing conditions and maximize plant health and productivity throughout the growing season.

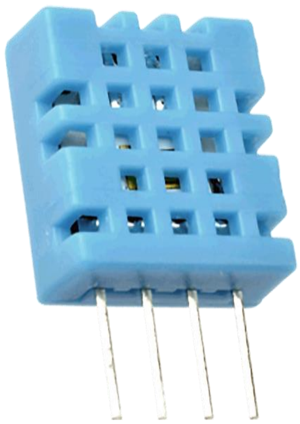

Figure 4. Temperature Sensor

3.1.4 Water Pump

A submersible pump designed to supply water directly to plants serves as a crucial component in various agricultural and gardening applications. This specialized pump is typically submerged in a water source, such as a reservoir or tank, and is responsible for drawing water and delivering it directly to the plants. Whether used in traditional soil-based gardening, hydroponic systems, or aquaponics setups, these pumps provide essential hydration to plants, ensuring their growth and health. Through a series of mechanisms involving impellers and pressurization, the pump efficiently moves water from its source to the plant roots, where it is absorbed for nourishment. Often equipped with automation features, such as timers or sensors, these pumps enable precise control over watering schedules, optimizing water usage and plant health. By delivering water directly to the plants' roots, submersible pumps minimize waste and promote efficient nutrient absorption, ultimately contributing to higher yields and healthier crops.

Figure 5. Water Pump

3.1.5 Relay Module

A relay module serves as a pivotal component in controlling the operation of a water pump, determining when it should start or stop its work. This module acts as an intermediary between the pump and the control system, whether manual or automated. When activated, typically by a signal from a timer, sensor, or manual switch, the relay module sends an electrical current to the pump, initiating its operation. This action triggers the pump to draw water from its source and begin supplying it to the designated area, such as plants in a garden or a reservoir in a hydroponic system. Conversely, when the predetermined conditions are met to cease water supply—such as reaching a desired water level or completing a scheduled watering cycle—the relay module deactivates, cutting off the electrical current to the pump and halting its function. This capability ensures precise control over the pump's activity, optimizing water usage, preventing overwatering, and conserving energy. In essence, the relay module acts as the control center for managing the start and end of the water pump's work, facilitating efficient and effective irrigation in various agricultural and gardening contexts.

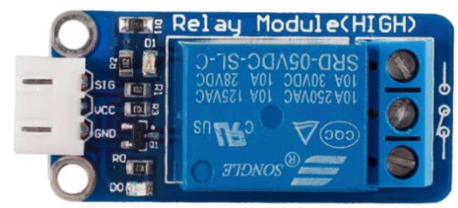

Figure 6. Relay Module

3.1.6 Water Reservoir

A water reservoir serves as the fundamental storage component in an irrigation system, storing the water used to nourish plants and crops. Typically constructed from durable materials such as concrete, plastic, or metal, the reservoir can vary in size and capacity depending on the scale of the irrigation system and the water requirements of the plants. Acting as a centralized hub for water management, the reservoir collects and stores water from various sources, such as rainwater collection systems, wells, rivers, or municipal water supplies. This stored water is then distributed as needed through the irrigation system to provide hydration to plants, ensuring their growth and productivity.

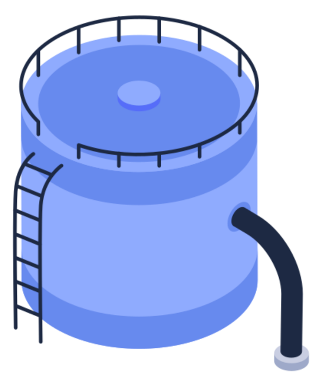

Figure 7. Water reservoir

The reservoir's strategic placement within the irrigation system allows for efficient water distribution, minimizing losses due to evaporation, runoff, or seepage. Additionally, some reservoirs are equipped with features such as liners, covers, or filtration systems to maintain water quality and prevent contamination. Overall, the water reservoir plays a vital role in sustainable agriculture, enabling efficient water utilization, mitigating the impact of water scarcity, and supporting the cultivation of healthy crops.

3.2 Software Implementation

The Arduino UNO is programmed using the Arduino IDE, with code that:

- Be reading sensor data from the soil moisture, temperature, humidity and light sensors.
- Lowers water filling level when the soil moisture is relatively low and the moisture in the soil is below the established minimum limit.
- The water pump will be automatically turned off when the soil moisture condition is already sufficient.
- Optional functionality of push notifications and alerts if the communication modules are put in.

Figure 8. Arduino IDE

3.3 System Calibration

Calibration is a very important precaution to obtain true sensor reports and system working in good order. The soil moisture sensor is precisely set to determine the water pump's trigger and shut off thresholds. The SCADA system also contains temperature, humidity, and light sensors that are calibrated to the last detail to ensure precise measurements.

3.4 Testing and Deployment

In order to prove the proper work, the system is tested under a controlled condition Submodules are debugged to ensure proper functioning, and the entire system is verified by subjects dry and wet field tests. Following the verification stage the system will be then installed into a real-world scenario, e.g., into a personal garden.

4. Discussion

Automated watering of the plants resulted in a savings on worker time and water consumption. The application of sensors had the effect of giving a more complete picture of the garden environment which, in turn, yielded irrigations that were more precise and effective. Its capability for scale and flexibility will enable it to be employed in a wide range of uses from a small garden at home to a large production farm. The impact of the research was evident too from various perspectives. One of them was the need for routine monitoring and maintenance in order to keep the system at optimum performance. We plan to include other sensors in the system in the coming future such as atmospheric pressure and wind speed sensors which will help boost the system's potential. Moreover, tele monitoring and tele control could be added for more convenience and ease of use.

5. Conclusions

This paper outlines my project of an automatic plant watering system that detects water needs with planning and sensor adjustment as needed. The system identifies water needs based on the four sensors of soil moisture, temperature, humidity, and light. The water management system not only plays a role in water conservation but also reduces need for manual labor and provides plants with better conditions. With Arduino integration, we can achieve a system that can be easily adapted and scaled to meet the varying requirements and environments. The next step to our research should be about implementing more features: solar power, telemetry, and advanced data communication could be the priority. Through the use of the judicious and empirical approach in designing automated watering systems in plants, environmental efficiency and sustainability in gardening are promoted to a great extent.

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Cite this article as: Harsh Payaal, Brajlal Sharma, Aafak Ali, Prashant Upadhyay, Gaurav Kumar, Mukesh Kumar, Automated plant watering systems: a comprehensive approach to efficient and sustainable home gardening, International Journal of Research in Engineering and Innovation Vol-8, Issue-3 (2024), 128-134. *https://doi.org/10.36037/IJREI.2024.8305*.