DOI https://doi.org/10.30525/978-9934-26-597-6-28

DEVELOPMENT OF AN ARDUINO-BASED AUTOMATED PLANT IRRIGATION SYSTEM

Khotunov Vladyslav*, Sirenok Hryhorii, Zakharova Mariia
Cherkasy State Business-College, Ukraine
**Corresponding author's e-mail: vkhotunov@gmail.com, z.maria@ukr.net*

Abstract

This paper presents the design and implementation of an automated plant irrigation system based on Arduino technology. Addressing the rising need for sustainable and efficient plant care in urban and rural settings, the system utilizes sensors and microcontrollers to autonomously monitor and control soil moisture levels. Through precise control of water delivery, the proposed solution reduces human intervention, conserves water resources, and supports plant health. The system features soil moisture sensors, relay-controlled water pumps, and LCD-based feedback, offering modularity, affordability, and ease of integration with smart home platforms. Experimental results confirm the system's effectiveness in optimizing irrigation while reducing energy consumption and manual labor.

Keywords: plant watering, Arduino, automation, soil moisture sensor, IoT, water efficiency

Automation of irrigation is not only a convenience feature but increasingly a necessity as labor shortages affect agricultural productivity and urban lifestyles limit the time people can dedicate to plant care. Conventional timers lack feedback loops and cannot adapt to changing weather or soil conditions. In contrast, sensor-driven systems respond in real time to environmental inputs, enabling precision agriculture practices that improve resource use efficiency.

In educational settings, such systems also offer an introduction to the Internet of Things (IoT), sustainability, and the importance of ecological responsibility. The system's reliance on open-source components reinforces the spirit of accessible innovation and encourages community collaboration in refinement and expansion.

In the context of climate change and increasing urbanization, the efficient use of natural resources such as water has become a global concern. Manual irrigation practices often lead to overwatering or neglect, resulting in poor plant health and water waste. This research aims to develop an affordable and efficient automated irrigation solution suitable for both domestic and agricultural applications. Leveraging Arduino microcontroller technology and sensors, the proposed system addresses these challenges by providing autonomous and adaptive control of soil moisture levels.

To support adaptive behavior, the system was modified to include real-time clock (RTC) functionality, enabling time-based irrigation profiles. This feature allows users to schedule watering events based on time of day, reducing evaporation during peak sunlight hours. It also supports day-of-week scheduling, beneficial for crop rotation and specific growth cycles. For users with advanced technical skills, configuration files stored on an SD card allow customization of schedules without modifying the core Arduino code.

To test the resilience of the system, environmental stress testing was conducted under simulated drought and high-humidity conditions. The sensors retained accurate readings, and the control logic remained consistent despite voltage fluctuations introduced during brownout conditions. Further, the relay and pump were tested for mechanical durability over 500 activation cycles with no observed failures.

In terms of user experience, feedback was gathered through a pilot program involving ten users who installed the system in household and balcony garden settings. They highlighted the ease of installation, real-time feedback through the LCD display, and the reassurance of knowing their plants were being monitored around the clock. The addition of colored LED indicators (e.g., red for dry soil, green for sufficient moisture) enhanced accessibility for non-technical users and children.

In order to ensure that the system is adaptable to various plant types and growing environments, a configuration module was developed to support user-defined soil moisture thresholds. This allows for flexible adjustment based on the plant species, soil type, and seasonal requirements. Moisture sensor calibration was performed using a range of known wet and dry soil samples, ensuring accuracy across different soil textures. The data collected from these calibration tests were used to derive analog-to-percentage conversion formulas, making real-time moisture readings more intuitive.

The system also includes a logging feature that records environmental parameters and watering cycles. This historical data enables users to track irrigation efficiency over time and identify trends in water consumption. An optional SD card module or cloud integration via ESP8266 Wi-Fi module was proposed to expand data accessibility. For future integration with mobile apps or web dashboards, the system outputs JSON-formatted strings, facilitating compatibility with common IoT platforms.

A comparative study was conducted between the Arduino-based system and manual watering routines across three test beds: herbs, succulents, and flowering plants. The automated system achieved better consistency in maintaining target moisture levels, leading to visibly healthier foliage and a 25% increase in flowering rates over a 4-week period. In terms of resource use, water consumption was reduced by an average of 38% per week.

Electrical efficiency was evaluated using a multimeter and data logger. Average daily energy consumption was recorded at under 0.05 kWh, suggesting excellent suitability for solar-powered deployments. Solar charging was simulated using a 5W panel and 3.7V lithium-ion battery bank with charge controller, validating full autonomy during daylight hours.

One of the key strengths of the system lies in its modularity. Additional sensors, such as temperature, humidity, or even light intensity, can be added through analog or I2C interfaces. The firmware includes dynamic sensor detection routines, automatically adjusting the logic flow based on detected components. This design philosophy supports scalability and long-term system evolution.

The developed system comprises several interconnected modules, including soil moisture sensors, a microcontroller (Arduino Uno), a relay module, a water pump, and an LCD display. The system continuously monitors the soil's moisture content and triggers irrigation when moisture drops below a pre-defined threshold.

Hardware design was based on ease of integration and energy efficiency. Sensors transmit analog voltage signals to the Arduino, which interprets data and activates the water pump via a relay switch. The water level sensor ensures the pump is only activated when a sufficient water supply is available. Environmental data is displayed in real time via the LCD and transmitted to a server or SD card for logging.

The system's software is written in C++ using the Arduino IDE, incorporating libraries for sensor communication, LCD output, and Wi-Fi connectivity. The program is structured into initialization, data acquisition, control logic, data visualization, and transmission modules. Soil moisture thresholds are configurable, and irrigation is managed through simple control loops.

Experiments were conducted on various plant types with different moisture requirements. Data collected over several weeks demonstrated consistent performance, with irrigation accurately triggered at target thresholds and water usage reduced by up to 40% compared to manual watering. Additional testing verified the system's performance under different lighting, temperature, and humidity conditions.

To enhance system usability, a graphical interface and smartphone integration are proposed, allowing remote monitoring and control. Energy efficiency is ensured through the use of low-power components and compatibility with renewable energy sources like solar panels.

The modular nature of the system permits scalability for larger installations. It can be expanded to include multiple moisture sensors and pump channels, allowing for plant-specific watering schedules. Integration with smart home ecosystems enables adaptive control based on environmental feedback or user-defined routines.

Conclusions

The system's educational potential is significant. It offers a hands-on introduction to embedded systems, environmental monitoring, and sustainable engineering practices. By combining physical computing with programming and IoT principles, the project serves as an excellent case study for STEM curricula. Students can explore hardware assembly, code optimization, sensor calibration, and data visualization through a unified platform.

Another promising direction involves machine learning integration. By analyzing moisture patterns and environmental inputs, predictive models could optimize irrigation timing further. Additionally, integration with open weather APIs would allow context-aware scheduling, suspending irrigation during predicted rainfall or adjusting schedules based on temperature forecasts. Support for remote notifications via mobile apps or email could alert users to water shortages, sensor faults, or power issues in real time.

In the broader context of smart agriculture and urban sustainability, this project demonstrates how low-cost, open-source hardware can deliver high-impact results. The simplicity and effectiveness of the design make it suitable for use in greenhouses, balconies, indoor gardens, and even community farming projects. As climate conditions become more unpredictable, the relevance of such systems will only increase.

The Arduino-based automated irrigation system provides a reliable, cost-effective solution for intelligent plant care. Its modular design and low resource footprint make it suitable for a wide user base, from hobbyists to professional gardeners. The system not only conserves water but also enhances plant vitality and reduces maintenance time. Its ability to interface with smart home systems and potential for renewable energy integration further elevate its utility in sustainable development.

Future research may focus on adding machine learning algorithms for predictive irrigation, expanding the system for outdoor use with weather data integration, and enhancing the interface for mobile platforms. This work contributes to the broader adoption of IoT in agriculture and urban sustainability initiatives.

References

[1] Lytvyn, Y.O., & Strokan, O.V. (2021). *Soil Irrigation System Based on Arduino Microcontroller Platform*. Information Processing Systems, 2(163), 112–117.

[2] Gilarranz Casado, C., Loizu Cisquella, M., & Altares López, S. (2018). *Intelligent Irrigation System Based on Arduino*. arXiv preprint arXiv:1803.00097. https://arxiv.org/abs/1803.00097

[3] Ravil I. Mukhamediev, Viktors Gopejenko 2023 Estimation of the Water Level in the Ili River from Sentinel-2 Optical Data Using Ensemble Machine Learning. Remote Sensing. 2023, 15, 5544. https://doi.org/ 10.3390/rs15235544. https://www.mdpi.com/2072-4292/15/23/5544, www.mdpi.com/journal/remotesensing