RIMA
Revista Interdisciplinar e do Meio Ambiente
Interdisciplinary and Environment Journal
v.6, n.1, 2024, DOI: 10.52664/rima.v6.n1.2024.e235

Prototype for automating the irrigation system using the arduino UNO R3 prototyping board for water control

Protótipo para automatización del sistema de riego utilizando placa de prototipo arduino UNO R3 para control de agua

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Abstract: The use of modern technologies in agriculture is essential, especially for irrigated crops, the sector with the highest consumption of water resources. Given this scenario, the main purpose of this paper is to report on the development of a prototype for irrigation, using low-cost technology based on the Arduino UNO R3 tool to monitor water control at specific times. The research has a qualitative-quantitative approach and was validated in a residence in the city of Castanhal, located in the northeastern region of the state of Pará, Brazil. The materials used to make the prototype were the Arduino model UNO R3, RTC module, solenoid valve, relay module, hoses, and sprinklers. The code developed was programmed in the C++ language, with the first test applied at 09h and the second at 16h, with an interval of 10 seconds. The results obtained from the tests showed that the prototype developed has a good ability to control water for irrigation, being turned on and off at the programmed times. It was also possible to see a high level of efficiency in the use of the Arduino UNO R3 prototyping board, as well as effective communication between the components used, demonstrating that technological tools are important for the management and control of water resources. Therefore, it is possible to conclude that the objective proposed in the project was achieved, since the use of Arduino enabled the creation of a prototype for irrigation, with efficiency for controlling water waste.
Keywords: *Arduino microcontroller; Water resources; Automated irrigation.*

Resumen: El uso de tecnologías modernas en la agricultura es fundamental, especialmente para la agricultura de regadío, ya que es el sector con mayor consumo de recursos hídricos. Ante este escenario, el objetivo principal de este trabajo es desarrollar un prototipo para irrigación, utilizando tecnología de bajo costo como la herramienta arduino UNO R3 para monitorear el control del agua en momentos específicos. La investigación tiene un abordaje cualitativo-cuantitativo y fue validada en una residencia de la ciudad de Castanhal, localizada en la región nordeste del estado de Pará. Los materiales utilizados para la fabricación del prototipo fueron el arduino modelo UNO R3, módulo RTC, electroválvula, módulo de relé, mangueras y aspersores. El código desarrollado fue programado en el lenguaje C++, con la primera prueba aplicada a las 09h y la segunda a las 16h, con un intervalo de 10 segundos. El resultado obtenido de las pruebas, demostró que el prototipo desarrollado tiene una buena capacidad de control del agua para irrigación, siendo encendido y apagado a la hora programada. También se pudo observar un alto nivel de eficiencia en el uso de la placa de prototipado arduino UNO R3, así como una comunicación efectiva entre los componentes utilizados, demostrando que las herramientas tecnológicas son importantes para la gestión y control de los recursos hídricos. De esta manera, se concluyó que el objetivo propuesto en el trabajo fue alcanzado, ya que el uso de arduino permitió la creación del prototipo para riego, con eficiencia para el control del desperdicio de agua.

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Received on 2024/04/04; approved on 2023/10/25.
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Palabras clave: *Microcontrolador arduino; Recursos hídricos; Irrigación automática.*

INTRODUCTION

Agricultural activities are fundamental for the development of societies and the maintenance of the population through the production of raw materials, food, and fuel. However, agricultural practices have been carried out for centuries and are responsible for directly impacting the environment, contributing to the depletion of natural resources, especially water supplies, fossil fuels, and nutrients that are essential for the balance of the environment (Henten *et al*., 2022).

According to Routis and Roussaki (2023) one of the sectors that uses the most water is irrigated agriculture, both to maintain and increase productivity, with a global consumption of approximately 70% of available water resources, which generates great concern and becomes one of the main difficulties for sustainable development.

Figorilli *et al.* (2021) remark that traditional agriculture uses water resources excessively, causing waste of both water and electricity, since it does not regard the environmental conditions of the soil or the plants. In this sense, the search for new technologies to make proper and sustainable use of water is necessary to prevent or mitigate water scarcity.

The use of technology is integrated into all areas of society and is considered an essential tool for developing mitigating solutions, generating positive impacts when used correctly. Correia *et al*. (2023) consider that the use of technological innovations can make irrigated agriculture more efficient, covering various sectors and helping improve production through solutions such as the use of low-cost equipment and savings in energy and resource consumption.

In irrigated agriculture, technological products are used in many different areas of knowledge, but they are still expensive, and few irrigators have access to them due to high investment and maintenance costs. However, with the evolution of automation systems, many producers are now able to purchase products that are more affordable and of excellent quality.

One of the current methods being disseminated in the development of control systems is Arduino technology, which uses an open-source prototyping board, known for its ease of use and affordability, thus allowing the development of research in different areas of knowledge, contributing beneficial results for the economy and sustainability (González-Buesa and Salvador, 2019). Arduino has a microcontroller which is responsible for connecting all the components, as well as sending and receiving information to control the electronic devices used in the projects (Badamasi, 2014).

Bearing in mind that water is essential for maintaining the different forms of life on Earth, but that it is also considered a limited resource and is facing major challenges in the face of environmental crises and climate change, this study is motivated by the need to produce low-cost automated irrigation methods capable of controlling the amount of water according to plant demand at specific times.

The aim of this project is to develop a low-cost automated prototype for an irrigation system, using the Arduino UNO prototyping board as a tool to ensure water control at specific times.

THEORETICAL BACKGROUND

Irrigation

The use of water resources for irrigation purposes is an ancient practice adopted to control the supply of water and is considered a fundamental technique for the productive development of plants. Water is an essential element for the functioning of the physiological processes that guarantee the survival of plant species, including photosynthesis, nutrient transportation, and stomata turgidity.

Furthermore, irrigation plays a fundamental role in the productive performance of plant organisms; as stressed by Hadelan *et al*. (2020), the amount of water in the soil provides various benefits, as the moisture needed for plant growth enables better yields and high productivity of cultivated crops.

Over time, many techniques have been developed to improve traditional irrigation models, which are gradually being replaced by modern systems associated with advances in technology. Given this scenario, many of the techniques implemented aim to minimize the environmental impact and waste of water resources by controlling the flow and optimizing the use of water, prioritizing sustainability.

Marouelli *et al*. (2011) point out that the management of water use through efficient irrigation systems must prioritize the availability of resources for plants in an adequate and sufficient manner, providing better growing conditions and productivity while reducing water waste and soil leaching, thus preventing both water stress and environmental degradation.

In order to accurately adopt irrigation techniques, a number of factors must be analyzed, such as the type of crop chosen, the climatic conditions in which it will be grown, the availability of water resources, the area available for planting and the available budget. Moreover, application efficiency also assume a prominent role among the available systems, the most widely used in agriculture being sprinkler and drip irrigation.

As discussed by Abdel-Hamid and Abdelhaleem (2022), the choice of irrigation method must consider the operational performance of the system, with the main objective being the efficient and adequate supply of water to the plants.

In addition, the authors point out that older irrigation systems perform inefficiently, since the use of water resources generally results in waste, which can affect crop performance, making it necessary to develop more precise techniques to minimize this impact.

Drip irrigation.

The main purpose of this type of system is to supply water directly to the roots of plants in small quantities, allowing the producer to have greater control over water distribution. This method is very prominent in agriculture and is one of the most widely used today, especially in regions with low water and electricity availability, due to its precision of application, lower water consumption and adaptability to the different physical and chemical conditions of the soil (Pinto *et al.*, 2022).

Drip irrigation involves the use of hoses or tubes with small emitters in droplets, and, according to Mackić *et al*. (2023), tends to be highly efficient in mitigating water deficit, with advantages over conventional methods. Berça, Mendonça and Souza (2019) point out that in addition to the savings in water use, the technical feasibility and production of plants are also noteworthy, as well as the use of automation technologies, decreasing the use of labor.

Sprinkler irrigation

In this method, water is used by sprinklers that simulate rain, surrounding a specific area close to the plant, providing greater coverage (Testezlaf, 2017). However, unlike the drip system, the demand released by the sprinklers is more accelerated and can cause water to be wasted through evaporation, and its deployment must factor in the type of crop and the need to seek regions with little slope and susceptibility to strong winds, as mentioned by Coelho *et al*. (2017).

To this end, although it is effective for certain crops, with the advantages of flexibility and uniformity, there are some disadvantages, such as expensive operating costs, as well as its lack of adaptability to all types of terrain.

Water control

In irrigation systems, water control is paramount, especially in places where there is a risk of water scarcity. The efficient management of water resources contributes to adapting and obtaining more sustainable methods that optimize plant productivity and promote the environmental conservation of soils.

Water is a limited resource, hence the need to develop technologies that can prevent waste. To this end, as mentioned by Bwambale, Abagale and Anornu (2022), knowledge about cultivars is essential, and it is essential to observe variations in the chemical and physical structure of the soil, humidity, and climatic conditions of the environment, in order to facilitate the development of technologies that monitor the amount of water to be made available to the plants.

According to Goap *et al.* (2018), excessive water consumption for better yields occurs to a greater extent in developing countries, due to the low acquisition of intelligent and low-cost irrigation methods.

In this context, new strategies are emerging associated with technological resources such as Artificial Intelligence (AI) and the automation of systems using humidity, temperature, and flow sensors, enabling producers to make efficient use of water resources and avoid water deficits or excesses in crops. Using too much water on crops can lead to leaching, percolation, waterlogging and surface runoff, while a lack of water results in production losses and plant stress (Bwambale, Abagale and Anornu, 2022).

Arduino

Arduino is an open-source prototyping tool with easy-to-use software and hardware, an Integrated Development Environment (IDE) and control of electronic components and external modules through programming (Arduino, 2023d). Arduino is programmed using the C++ programming language, which makes it simple and accessible for beginners to use the platform.

Kondaveeti *et al*. (2021) point out that Arduino is an embedded system, containing a microcontroller and other essential components for operation, such as an oscillator crystal, *bootloaders* and pins that help connect sources, which make the platform complete and allow the program to be executed in the IDE.

There are several boards with different functions and applications on the market, including the UNO R3 model, which is considered the most popular among beginners due to its versatility and ease of use. This board's microcontroller is based on the ATmega328P and has 14 digital pins for input and output, 6 of which are for PWM (*Pulse Width Modulation*) output, 6 input pins for reading analog signals, a 16 MHz ceramic resonator, a USB (*Universal Serial Bus*) port, a power supply, an ICSP (*In Circuit Serial Programming*) connector for controlling the microcontroller and a reset button for restarting the program (Arduino, 2023c).

The second model is known as the Arduino Mega, based on the ATmega2560. It has a larger and more developed board than the UNO, with 54 pins, 15 of which are for PWM output, 16 analog inputs and 4 serial *hardware* ports, making it suitable for developing more complex projects (Arduino, 2023b). The Arduino Due has a SAM3X8E microcontroller board, ARM Cortex-M3 core, with greater processing capacity and performance, 54 pins for input and output, 12 of which are used for PWM outputs, as well as 12 analog inputs (Arduino, 2023a).

Prototyping boards are commonly used for programming automation and electronic systems, due to their versatility of use. As Pereira *et al.* (2020) point out, this tool offers flexibility, as it allows the code created to be executed, updated, and altered by the user themselves, without requiring the Arduino's physical circuitry to be altered.

One of the advantages of Arduino boards is that they are affordable compared to other microcontrollers available on the market (Kondaveeti *et al.*, 2021). Because of its affordability and ease of use, Arduino is increasingly being used to develop simple and complex automatic systems.

In some areas of agriculture, technological innovations using prototyping boards and sensors have already been developed, such as small and medium-sized seeding systems and irrigation using Arduino and sensors (Kumar and Rajagopal, 2022).

With the increased use of water in agriculture, there is a notorious need to develop new techniques that minimize the loss of this resource, making the prototyping board essential. It tends to be a viable resource for the development of automated irrigation systems, as it can be adapted as desired to meet different goals.

METHODOLOGY

This paper describes a research project based on a qualitative-quantitative approach. It consists of a brief theoretical background on the main concepts covered in the research, and then a discussion on the development of the prototype for automating an irrigation system using the Arduino UNO prototyping board.

The prototype was built in a residence located in the city of Castanhal, in the northeast of Pará (Brazil), approximately 75 km from the capital, Belém, and the test was carried out on October 15, 2023.

The construction stage began with a survey of the materials needed to build the system, to reduce possible unforeseen problems. The materials used were (1) an Arduino UNO R3 prototyping board, responsible for processing the time data collected from the RTC (*Real Time Clock*) module, which receives minute and second data; (2) an RTC module, which acts as a clock, employed to avoid possible problems related to Arduino programming, considering the need to measure time accurately; (3) a solenoid valve, which works through an electromechanical system, being activated by a coil with the passage of electrical charges; (4) a relay module that acts as a control device for electrical circuits, controlled directly by Arduino; (5) hoses and sprinklers to supply water to the irrigation system.

Finally, the programming code for the automation process was prepared in the C++ programming language, as shown below, establishing specific times for observing the system, the first at 09:00 and the second at 16:00, each irrigation period lasting 10 seconds.

C++ language code used to communicate with the hardware and control the water:

```
void ligaRele (){
  myRTC.updateTime ();
  if(myRTC.hours == 8 && myRTC.minutes == 0 && myRTC.seconds == 0){
```

```
    digitalWrite (relay, HIGH);
  }
  if(myRTC.hours == 8 && myRTC.minutes == 0 && myRTC.seconds == 10){
    digitalWrite (rele, LOW);
  }

  if(myRTC.hours == 16 && myRTC.minutes == 0 && myRTC.seconds == 0){
    digitalWrite (relay, HIGH);
  }
  if(myRTC.hours == 16 && myRTC.minutes == 0 && myRTC.seconds == 10){
    digitalWrite (rele, LOW);
  }
}
```

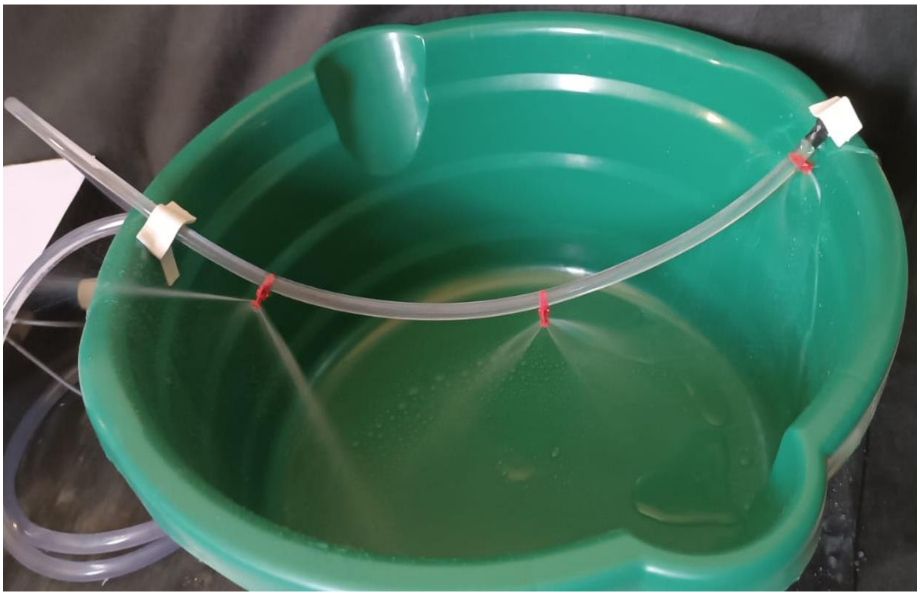
RESULTS AND DISCUSSION

When the test was carried out, it was observed that the prototype developed was well suited to the irrigation system, demonstrating that from the programmed code the system was switched on and off at the set time, releasing water at specific intervals (**FIGURE 01**). The system has a hose connected directly to a tap, which is connected to the Arduino, and is made up of three *micro-spray* sprinklers (**FIGURE 02**).

FIGURE 01: Irrigation prototype using arduino UNO R3.

SOURCE: Research data (2023).

FIGURE 02: Prototype irrigation system using micro-sprinklers connected to a hose.



SOURCE: Research data (2023).

By carrying out the tests using the Arduino prototyping board and the other associated items for building the irrigation system, it was possible to note the processing capacity of the Arduino UNO R3, with efficient communication between the components used. Siqueira and Ferreira (2023) corroborate that the use of automated systems brings several benefits to irrigators, among which they underline the reduction of mistakes due to human error, since the system is programmed to guarantee the correct irrigation for the plants, as well as optimizing the consumption of supplies through targeted application, promoting better production yields.

In this sense, the results presented show that the use of technological elements in the operation of automatic irrigation systems are important tools for the efficient management and control of water resources, thus contributing to minimizing the waste of energy and water, besides improving production and the quality of the products obtained.

Although current irrigation models have numerous advantages in terms of efficient water use and are accurate for different growing media, some problems can be encountered, especially with regard to financial and installation costs, as they require a certain level of complexity. As Marouelli *et al*. (2011) point out, irrigation techniques generally make use of water without adequate control, contributing to waste and increasing undesired byproducts, as well as favoring environmental imbalance and potentially causing scarcity and affecting the quality of water resources.

Another point to be emphasized in this paper is the use of Arduino, since systems that use these prototyping boards tend to be more accessible, as they are known for their affordability, making it possible to develop technological tools with the same capabilities and functions as high-tech equipment (Siqueira and Ferreira, 2023). Therefore, it can be considered that the prototype is advantageous as it allows water control at a low cost.

However, it is important to note that the system has not been tested in large farming systems, so further study is needed into the possibilities of implementing it in larger irrigable areas, also factoring in the type of crop, environment, climate, and soil where the system will be installed, as well as using sensors for better precision and control of water resources. According to Rivas-Sánchez, Moreno-Pérez and Roldán-Cañas (2019), the environmental parameters of temperature and humidity are essential for knowing the exact conditions of the plants and the environment.

CONCLUSIONS

Considering the results here described, the objective proposed in this project was efficiently achieved, using Arduino to enable the creation of a prototype for an automated irrigation system, given that, as predicted, the system made it possible to release water at the established times.

Although the system is simple, it is efficient at controlling water, limiting waste, and improving sustainability, providing protection and conservation of natural resources, as well as accessibility to small producers due to its low cost of acquisition and implementation.

Further research using sensors for application in cultivation systems in different environments will need to be conducted in the future.

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