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Automated Irrigation System, AIS: Technological Development

Sistema de Riego Automatizado, SRA: Desarrollo Tecnológico

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Abstract

As a natural resource, water is vital for the development of human life and economic development in any region of the world. Although this resource is renewable, it is also finite, which is why its conservation is important; Within the agronomy process, water waste in Mexico, amounts to 57% of the total used, mainly due to inefficient irrigation infrastructures. In relation to mechatronics, it is possible to develop devices that dose consumption through an automated control system. The objective of this document is to present the technological development built based on mechatronic elements, of an AIS, automated irrigation system, which integrates solar panels to make it self-sustainable, humidity and temperature sensors programmed by a microcontroller and control of the on/off when detecting indicated levels; It is monitored in real time through a human-machine interface, being the main visible element that will be responsible for managing all functions remotely by implementing the IoT, for the user's convenience.

Technological Development, Automated Irrigation System, Renewable energy, Internet of things

Resumen

Como recurso natural, el agua es vital para el desarrollo de la vida humana y el desarrollo económico en cualquier región del mundo. Aunque este recurso es renovable, también es finito, es por eso que toma importancia la conservación del mismo; dentro del proceso agrónomo, el desperdicio de agua en México asciende a 57% del total utilizado, debido principalmente, a infraestructuras de riego ineficientes. En relación con la mecatrónica, es posible desarrollar dispositivos que dosifiquen el consumo a través de un sistema de control automatizado. El objetivo de este documento es presentar el desarrollo tecnológico construido con base en elementos mecatrónicos, de un sistema de riego automatizado SRA, que integra paneles solares para hacerlo autosostenible, sensores de humedad y temperatura programados mediante un microcontrolador y, control del encendido y apagado al detectar niveles indicados; es monitoreado en tiempo real por medio de una interfaz humano-máquina, siendo el principal elemento visible que se encargará de gestionar todas las funciones remotamente implementando el IoT, para facilidad del usuario.

Desarrollo Tecnológico, Sistema de Riego Automatizado, Energía Renovable, Internet de las Cosas

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Introduction

Water is a vital resource for the development of human life and economic development in any region of the world, although it is renewable, it is also finite, which is why strategies for its conservation take on importance in established global programmes. According to the UN (2016), 36% of the world's population lives in water-stressed regions and 52% will experience serious water shortages by 2050. The consequences of this are reflected both in the development of nations and in the quality of life of the population, since poor water quality, inadequate sanitation and, above all, insufficient water supply have a negative impact on educational opportunities for families, livelihoods and the availability of food, leading to increased hunger and malnutrition in the poorest countries (UN, 2016).

Irrigation is one of the activities with the greatest impact on water wastage worldwide, according to Comisión Nacional de Agua, (2018). Estadísticas del agua en México. México. CONAGUA, in Mexico 57% of the water used for this activity is wasted by inefficient irrigation systems and structures; in addition to agriculture, irrigation systems are used for other purposes, one of the main ones being the maintenance of ornamental green areas, which also require cleaning and guaranteed light for their continuity.

Given this need, both green areas in the landscaping industry and the agricultural sector, the theoretical foundation shows Sustainability as responsible for reducing the environmental impact generated by the lack of effective use of the liquid resource; through the 2030 Agenda, the Sustainable Development Goals are known, of which SDG 6, Clean water and sanitation, SDG 7, Affordable and clean energy, and SDG 9 Industry, innovation and infrastructure, contemplate areas of opportunity in which they can converge in technological developments (UN, 2016).

In relation to the innovation promoted in the implementable suggestions of the SDGs, it is considered that mechatronic contributions can present developments that channel their effectiveness in the dosing of water consumption through an automated control system.

In addition to this, it contributes to society in terms of water care, as it is generated through collaborative and simple strategies that contribute to awareness, such as irrigation, an activity where this natural resource is most consumed.

Theoretical Basis

Renewable Energy

Currently, many of these energies are a reality, and they also contribute to reducing greenhouse gas emissions, as well as the energy supply, mainly oil and gas. Since they do not release polluting emissions in the generation of energy, renewable energies are sustained by natural resources that are constantly regenerated and inexhaustible (Machado, Lussón, Leysdian, Bonzon and Escalona, 2015).

Internet of Things

The Internet of Things and Industry 4.0 are changing the design, manufacturing, and monitoring of different projects. According to Ladino, García and Zamudio (2023), it is predicted that, by 2025, more than 75 billion IoT devices will be connected to the Internet. This technology contributes to the intelligent construction of applications and tools that contribute drastically to control and monitor variables. IoT applications can be implemented in various spaces, one of the areas in which it has begun to have and is predicted to have great relevance, is environmental sustainability. This type of applications allow the user to interact with the system in an easy way, because, from the state of variables, structured records can be generated, which generate changes from the information obtained by processing data (Rodríguez, López, Vega and Flórez, 2017)

IoT visualises images and videos for processing data stored on the internet, links and monitors aspects of the environment, ensuring that a process is fulfilled according to a pre-established approach, interconnected devices only provide relevant content in real time to users. The main benefit of this technology is an effective reduction in wiring and maintenance costs, and by collecting real-time information directly from the control system, this integration allows for improved forecasting and process monitoring. (Alvear, Rosero, Peluffo y Pijal, 2017).

Automation

Control for optimal autonomous execution in a system is considered as the management of information for decision-making in real time, minimising direct intervention. The application of electromechanical and electronic devices allows the automation of repetitive activities, thus increasing the control of physical quantities in a more precise way and, as a whole, productivity levels. More precise quality control in conjunction with the integration of different systems, repeatability, increased productivity, reduced incidents and greater efficiency are some of the advantages of automating a process (Pérez, 2015).

With the need to minimise human intervention in direct processes to reduce labour effort, automatic systems have been implemented that ensure optimisation without direct intervention, so production acquires an automatic cycle course that manages to reorganise itself quickly and efficiently. According to Cordoba (2006), automation is the convergence of three technologies: mechanics, electronics and computing, although it has gradually been unified specifically with mechatronics, in the same way, in order to improve production processes, the industry adopts the Internet of Things.

Methodological Bases

With a mixed research approach, and explanatory information management, a methodology based on the practice of knowledge and scope of the area of mechatronics (Hernández, 2014) is implemented; the general objective presented for this technological development is to build an automated irrigation system, which integrates a control and monitoring structure, programmed with microcontrollers and sensors, to optimise and reduce water consumption.

In its executable format, this objective presents a methodology based on the science of mechatronics, presented in phases to structure and programme the effective construction of the device. This involves the design of a model in CAD software, taking into account the operating principles of the irrigation system.

The programming of the microcontrollers, sensors and other system components to detect the level of humidity in the soil and ambient temperature, the assembly of external and internal electronic and mechanical components of the system that contribute to automatic operation.

It also considers the integration of solar panels to make use of renewable energy in the system and make it self-sustainable and, as a fundamental part, the implementation of an IoT platform, responsible for monitoring variables in the system facilitates the deployment of information for intelligent control and a clearer visualisation for the user, by monitoring the data from the sensors used in the irrigation system.

Methodological Development

The systematically implemented methodology is expressed in five phases, which individually pursue goals that allow specific activities to be programmed to form the physical and operational structure of the RAS.

In the first stage, a model of the prototype was developed in CAD software in which the electrical and mechanical components were integrated, taking into account the dimensions. For the choice of these elements, general and technical characteristics were taken into account, as well as the cost.

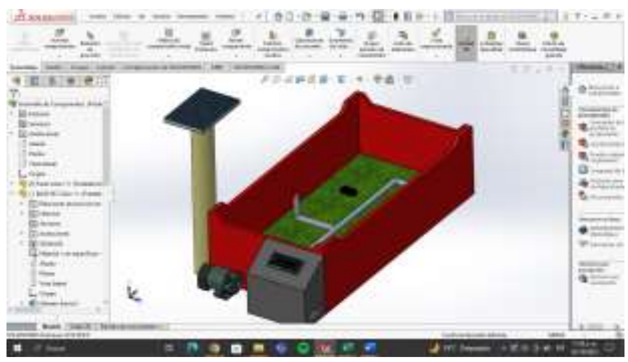

Figure 1 Prototype design
Source: Own Elaboration

In the second stage, the components that were established in the design of the prototype were analysed, comparing physical and operational characteristics. In the third stage, the construction of the prototype was carried out, including the mechanical and electronic elements, taking as a reference the previously elaborated designs and the acquired materials.

As part of the construction process, modifications were made to the design, according to the elements, aesthetics, design and operation of the system.

Figure 2 Component assembly
Source: Own Elaboration

Starting from the environment prepared in order to obtain a complete visualisation of the circuit, in the fourth stage, the simulation of this was carried out to verify the behaviour in order to elaborate the electronic assembly. The information of the technical characteristics of each element that integrates and the adequate simulation was fundamental in the success of this stage.

Figure 3 Simulation of the environment
Source: Own Elaboration

For the fifth and last stage, two IoT platforms were configured within the system for the interconnection of interfaces with the components, the electronic and mechanical elements used to send and receive signals via a WiFi network were programmed.

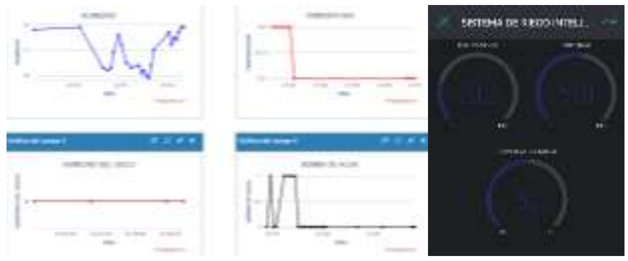

Figure 4 a, b IoT platforms
Source: Own Elaboration

Results

The field work resulted in the articulation of sustainable principles and the application of scientific knowledge in terms of mechatronics, expressed in a technological development called SRA.

The automated irrigation system is developed from the simulation by means of CAD software, which allowed the prototype to be projected in a virtual environment, where there is the option to make modifications and adaptations of materials and detailed visualisation of electrical connections, so that there was effectiveness in understanding the diagram during the stage of connecting various sensors to the microcontroller, also allowed a preview of what was going to be built, mitigating errors at the time of assembly.

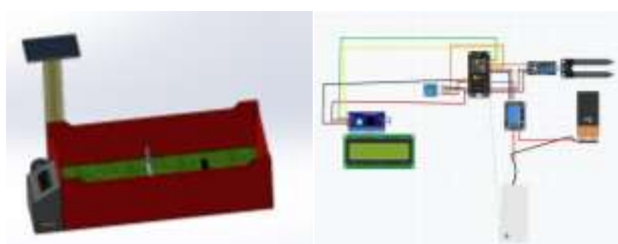

Figure 5 a, b Simulation
Source: Own Elaboration

This programming, became a substantial part since it generated the opportunity to establish the parameters with which the microcontroller operates according to the humidity and temperature sensors connected.

December, 2023 Vol.7 No.20 20-25

In the same way, by means of the programming, the data to be shown on the screen are established, making this system have HMI - Human Machine Interface -, in this way, the user has access to the state of the system.

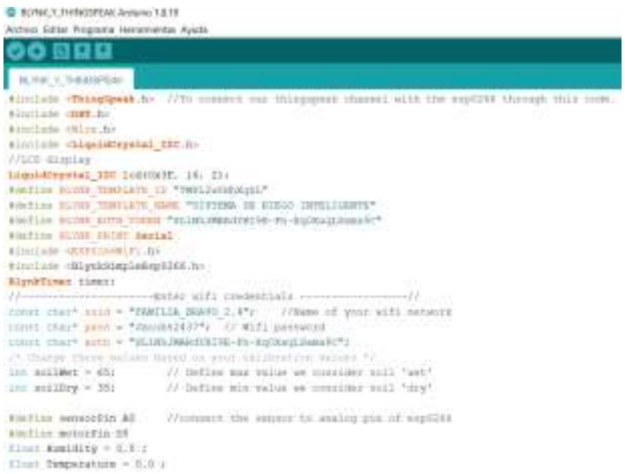

Figure 1 Component programming
Source: Own Elaboration

The HMI is the main source of visualisation of performance and data, thus helping users to extract measurements in real time. The design of the interface is simple in its operation and understanding, this in order to have access to the anomalies that arise and facilitate the operational adjustments of the system.

Figure 7 HMI interface
Source: Own Elaboration

Monitoring is crucial in RAS, as it is necessary to have control over water use, both to avoid waste and to meet the water needs of the crop. For the monitoring of this system, the IoT -Internet of Things- was integrated, which allows access to the status of the system by linking the data provided by the sensors to a web page, in the same way, to have monitoring from a mobile device, since an application was programmed simultaneously.

Figure 8 IoT monitoring
Source: Own Elaboration

The use of sunlight allows the irrigation system to be its own source of energy supply; calculations of the orientation and inclination of the solar cell will avoid or reduce the loss of efficiency caused by shadows generated due to external factors. San Luis Potosi is located in the northern hemisphere, where the proper placement of a solar panel is towards the south, which will result in a peak production around midday.

Figure 9 Solar cell assembly
Source: Own Elaboration

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Conclusions

The results obtained corroborate the validity of the hypothesis since the automation of an irrigation system has been carried out. This implementation has made it possible to optimise irrigation control by reducing water consumption and guaranteeing an adequate supply according to the water needs of the plants, thus contributing to obtaining the best quality plants. In addition, the integration of a solar panel in the system supplies energy, ensuring that the system is self-sustainable by providing the energy necessary for its operation in an ecological and sustainable way.

Iot is one of the cutting-edge technologies that not only offers convenience to humans, but also allows for detailed statistical monitoring. This technology allows to obtain information based on data, which favours productivity, efficiency and at the same time the prevention of technical failures. However, it is necessary for the data linked to the network to be accurate and faithful to the real data, which required the right choice and connection of the electronic elements.

Although the electronic components are responsible for the control of the system, the mechanical elements that make the system perform its function cannot be left out. For the assembly of the electronic and mechanical components, the specifications and function of each one of them were considered, taking into account these aspects to determine the distribution and position within the system.

The good design and assembly of the system promote its optimal functioning, however, this is not its only purpose, but the design of the system, in addition to having a relatively simple operation, also allows access for repairs or modifications, depending on the required specifications.

The validity of the hypothesis raised about the possibility of building an integral device that under the characteristic of automation, doses the water consumption and guarantees the adequate supply according to the water needs of the flora, contributing to obtain the best quality in these. As an added value, a solar panel was integrated into the system, which supplies energy, ensuring that it is self-sustainable.

The continuity of this technological development establishes the protection and implementation in pilot space within the facilities of the Instituto Tecnológico de San Luis Potosí.

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