Design and Implementation of a Multi-Field Irrigation Monitoring System Using LabVIEW and Remote Control via Arduino

Mohammed M. Alsharani, Abdulmajeed O. Albkoosh*, and Aymen S. Alteer

Department of Electronic Engineering, Faculty of Engineering, Alasmarya Islamic University, Zliten, Libya.

***E-mail:** aalbkosh@asmarya.edu.ly

تصميم وتنفيذ نظام مراقبة ري متعدد الحقول باستخدام اللاب فيو والتحكم فيه عن بُعد بواسطة الآردوينو

محمد ميلاد الشراني، عبد المجيد عمر البكوش*، و أيمن سليمان التير

قسم الهندسة الإلكترونية، كلية الهندسة، الجامعة الأسمرية الإسلامية، زليتن، ليبيا.

Abstract

Irrigation consumes most of the agricultural water, and it is the process of supplying land with water. Traditional methods, such as manual pumps and irrigation channels, relied on inaccurate techniques for estimating crop needs of water, leading to problems such as over-irrigation and the resulting waste of water, leaching of nutrients, loss of soil fertility, and degradation of its quality. With the increasing demands for food and water scarcity, there is a need to find solutions to rationalize water consumption in agriculture and enhance irrigation efficiency. This research aims to design and implement an automated irrigation system in two fields (A and B) and control it remotely, ensuring effective management of water resources in agriculture. The system uses a set of sensors to measure various environmental factors such as soil moisture, temperature, light intensity, and water level in the irrigation tank. The data is collected from the sensors is wirelessly transmitted via two communication units (nRF24L01-E) to the main control unit (Arduino UNO), which processes it to determine the amount of water needed for each field. A graphical user interface is designed using LabVIEW to display the data visually, allowing farmers to monitor the system's performance and make appropriate decisions. Consequently, water pumps are remotely controlled to provide the appropriate amount of water at the right time and maintain the required water level in the irrigation tank. The system demonstrated its ability to improve water use efficiency that would increase crop productivity, and reduce the negative effects of traditional irrigation.

Keywords: *Automated Irrigation System, LabVIEW, Arduino, Remote Control, Water Management.*

الملخص

الري يستهلك أغلب المياه الزراعية، وهو عملية إمداد الأراضي بالماء. وقد اعتمدت الطرق التقليدية، كالمضخات اليدوية وقنوات الري، على أساليب غير دقيقة في تقدير احتياجات المحاصيل، مما أدى إلى مشاكل مثل الإفراط في الري وما يترتب عليه من هدر للمياه، وترشيح للعناصر المغذية للنبات وفقدانها من التربة وتدهور خصوبتها. ومع تزايد الطلب على الغذاء وندرة المياه، تستدعي الحاجة إلى إيجاد حلول لترشيد استهلاك المياه في الزراعة وزيادة كفاءة الري. يهدف هذا البحث إلى تصميم وتنفيذ نظام ري آلي لحقلين (أ، ب) والتحكم فيه عن بعد ممّا يضمن إدارة فعالة لموارد المياه في الزراعة. يستخدم النظام مجموعة من المستشعرات لقياس العوامل البيئية المختلفة مثل (رطوبة التربة، درجة الحرارة، وشدة الإضاءة، ومستوى الماء في خزان الري)، يتم نقل البيانات التي تم جمعها من هذه المستشعرات لاسلكياً عبر وحدتي الاتصال (nRF24L01-E) إلى وحدة التحكم الرئيسية (Arduino UNO) التي تقوم بمعالجتها لتحديد كمية المياه المطلوبة لكل حقل. تعرض واجهة المستخدم الرسومية المصممة باستخدام برنامج (LabVIEW) هذه البيانات بشكل مرئي، مما يتيح للمزارع مراقبة أداء النظام واتخاذ القرارات المناسبة. بناءً على هذه البيانات، يتم التحكم في مضخات المياه عن بعد لتوفير الكمية المناسبة من المياه في الوقت المناسب والحفاظ على مستوى المياه المطلوب في خزان الري. أثبت النظام قدرته على تحسين كفاءة استخدام المياه، زيادة إنتاجية المحاصيل، يقلل من الآثار السلبية للري التقليدي.

الكلمات الدالة: نظام الري الآلي، لاب فيو، آردوينو، التحكم عن بعد، إدارة المياه.

1. Introduction

The agricultural sector faces many challenges due to population growth, climate change, and water scarcity. Water scarcity and the deterioration of crop quality are the most significant challenges. A report from the Food and Agriculture Organization of the United Nations (FAO, 2011) indicates that water scarcity poses a major threat to global food security, especially in arid and semi-arid regions. Traditional agriculture heavily relies on inefficient traditional irrigation methods, leading to significant water waste and negative impacts on soil fertility. A study conducted in 2016 confirms that the use of modern irrigation systems can reduce water consumption by 73% compared to traditional irrigation (Jha et al., 2016). Additionally, it is difficult for a farmer who owns vast areas of land to monitor and care for them personally, especially since these processes are currently done entirely manually (Ren et al., 2019).

To overcome these challenges, the need to adopt modern agricultural technologies has emerged, foremost among them being automated irrigation systems. These systems contribute to rationalizing water consumption and improving its efficiency, leading to increased agricultural productivity and improved crop quality. Several systems have been developed in this context, some of which rely on controlling irrigation rates based on soil moisture levels as in (Aswale et al., 2016; and Zhu et al., 2022), and others that use Internet of Things technologies to monitor agricultural fields remotely (Kushwaha & Beniwal, 2017; and Chethan et al., 2018; and Silalahi et al., 2021).

This research aims to design and implement an automated irrigation system in two fields (A, B) that is low-cost and easy to use, contributing to solving the problem of water scarcity and improving crop quality.

2. Proposed System Framework and Structure

The proposed automated irrigation system relies on an Arduino control unit and a set of sensors that monitor environmental factors affecting plant growth. This system allows for precise water delivery according to crop needs, contributing to improved plant growth and reduced water waste. The system consists of a field unit: which includes an Arduino Uno 1 board and a variety of sensors that measure soil moisture to determine the water content in the soil, distance to know the water level in the tank, and other environmental factors, along with a wireless communication unit (nRF24L01-E). The central unit: contains an Arduino Uno board 2, LabVIEW software, and a computer. The field unit collects data from the field and wirelessly sends it to the central unit, which analyzes it and determines the optimal amount of water needed for each agricultural field. Based on these decisions, the central unit sends on and off commands to the pumps in the field unit to accurately distribute water to the crops. The system features an easy-to-use interface built on LabVIEW software, allowing farmers to monitor and control the system remotely and easily adjust its settings.

3. Block Diagram

The block diagram of the proposed irrigation system, as shown in Figure (1), displays the main physical components of the system, including sensors, pumps, control units, and communication units. It also shows how the system components interact together to achieve effective irrigation management. Through this diagram, farmers can visualize how the system works and how they can benefit from its features, such as remote control and reduced water waste.

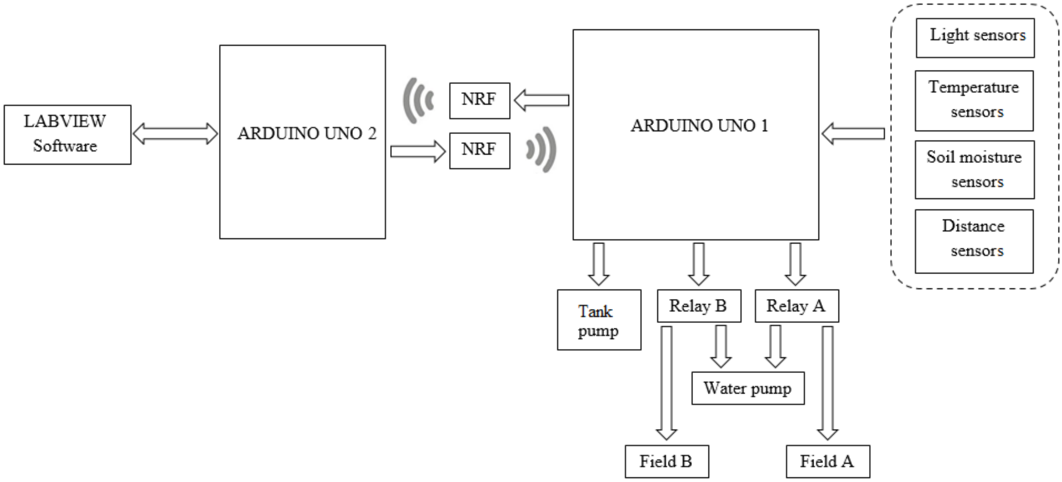

Figure 1. A Block diagram for the proposed irrigation system

Based on this design, the system was implemented practically as shown in Figure (2), where all the physical components were assembled and connected to function as an integrated unit.

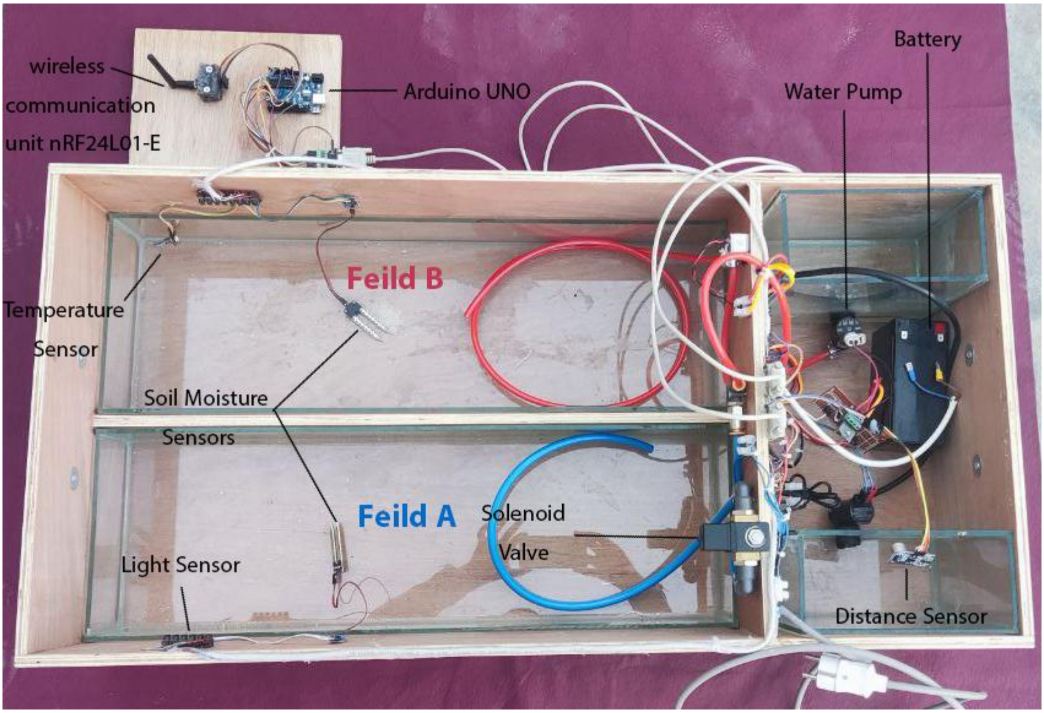

Figure 2. The implemented irrigation system

In addition, a user-friendly interface was designed using LabVIEW, allowing the user to easily monitor and customize the proposed system (adjust threshold values and change operating modes) as shown in Figure (3), where the interface displays live data from the sensors used and provides advanced features such as pump speed control and continuous remote monitoring of the system's status.

Figure 3. Main user interface

After designing this interactive interface: the user can easily monitor and customize the system remotely., The system begins by setting threshold values for the sensors and the operating state shown in Figure 4. Arduino 1, which is the field unit, reads the sensor data and sends it wirelessly to Arduino 2, which in turn sends this data to the computer running the LabVIEW program. LabVIEW checks the system status and determines whether the control is manual or automatic. If the operating state is manual, commands from the user are executed directly. However, if the operating state is automatic, the data is processed, and decisions are made regarding whether to turn the pumps on or off based on the sensor values and their specified thresholds. Subsequently, the final commands are sent from LabVIEW to Arduino 2, which then sends them to Arduino 1 for execution. This process continues periodically, and the user can adjust the threshold values of the sensors while in operation.

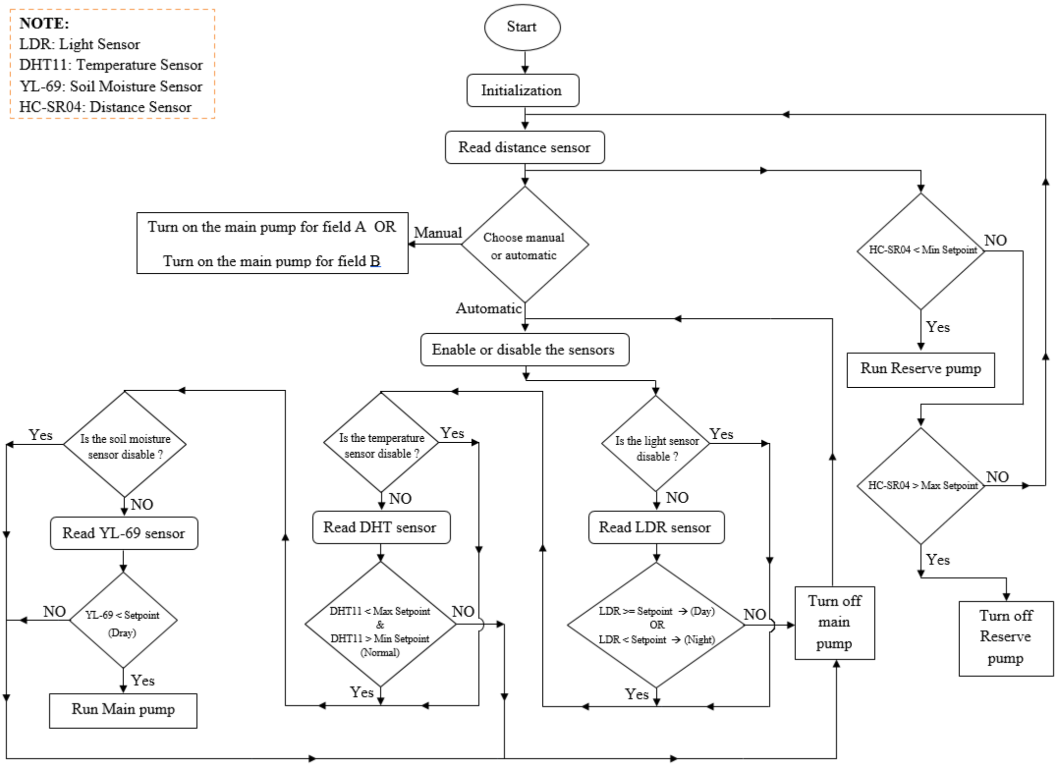

Figure 4. Flowchart for the proposed irrigation system operation

4. Results and Discussion

4.1. Success in Developing the Irrigation Monitoring System

Figure (5) displays a simulation interface of the system, where different components such as tanks, pumps, and agricultural fields are visually represented. This interface allows the user to track the flow of water within the system and monitor water levels in the tank, as well as the operational status of the pumps, making it easier for the user to understand how the system works and how its components interact with each other. Additionally, this interface enables the user to quickly and effectively diagnose any problems that may occur in the system. For example, the user can notice a sudden drop in water levels in the tank or the failure of one of the pumps, allowing them to take the necessary corrective actions.

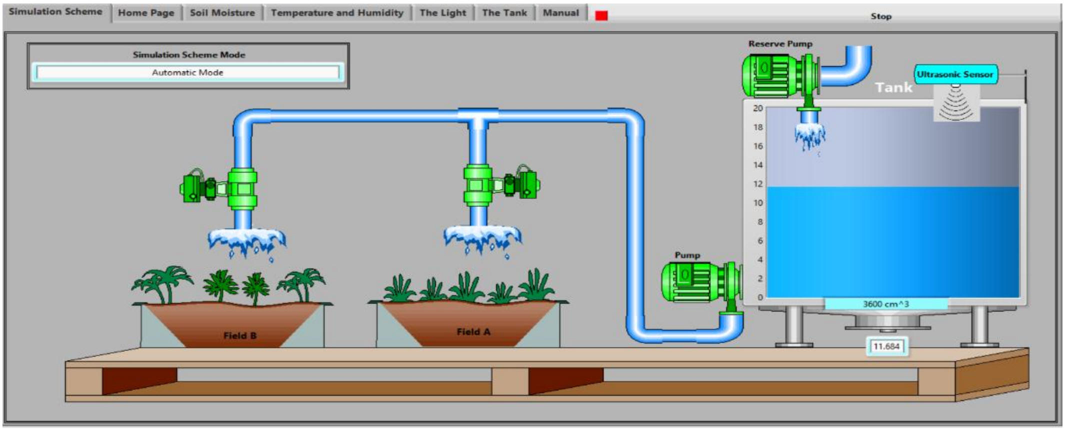

Figure 5. Simulation scheme

Figure (6) shows the manual control window, which allows the user to manually control the operation of the irrigation pump. This feature provides additional flexibility for the user to manage the irrigation system as needed, especially in emergencies and when technical issues are encountered.

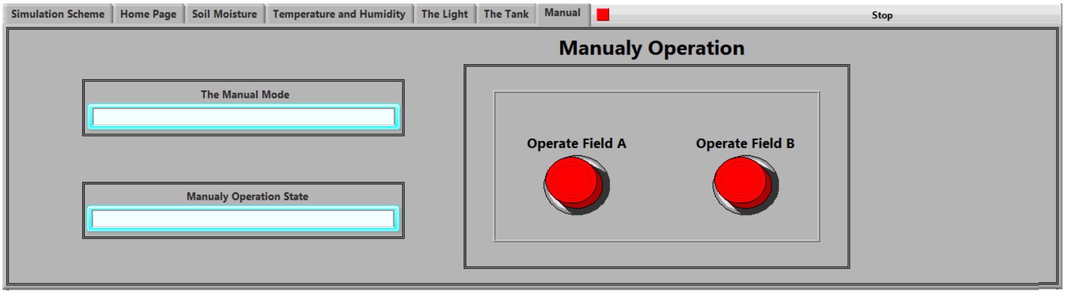

Figure 6. Manual control

Figures (7-10) present interactive windows displaying detailed data for each sensor individually, including graphs illustrating changes in readings over time. These windows assist in analyzing data for each sensor separately and better understanding the system's behavior.

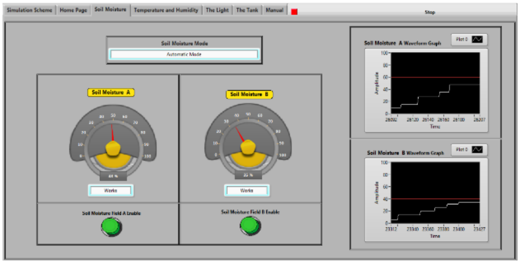

Figure 7. Soil moisture

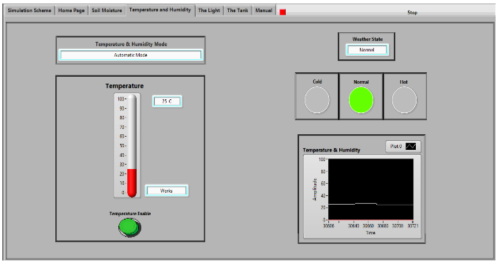

Figure 8. Temperature and humidity

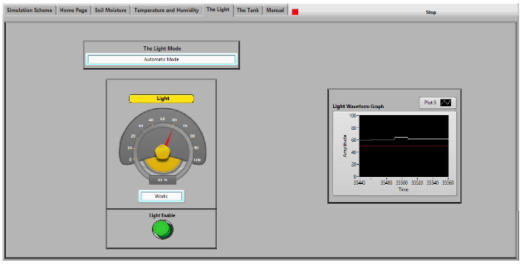

Figure 9. The light

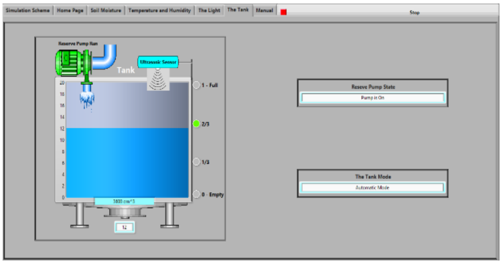

Figure 10. The tank

4.2. Evaluation of Sensor Accuracy

- **Temperature sensors cross calibration:** Experiments showed that the readings from the DHT11 sensor closely matched those from a separate measuring device, with a very slight difference (0.2 degrees Celsius). This result confirms the reliability of the temperature data provided by the sensor.
- **Sensors Response to Environmental Changes:** Experiments demonstrated that all sensors (LDR, soil moisture, water level) correctly responded to simulated changes in the test environment. This result confirms that all sensors operate efficiently and are capable of detecting changes in different environmental conditions.

4.3. Evaluation of the proposed irrigation system operation

- **Operating/Stopping Water Pumps (Irrigation/Filling the Tank):** Experiments showed that the system can automatically turn on and off the water pumps for irrigation and tank filling based on sensor readings and predefined threshold values. This feature allows for efficient management of the irrigation process, saving time and effort for farmers.

5. Conclusions and Future Work

An automated and cost-effective irrigation system has been developed using modern technologies such as Arduino and LabVIEW. The system relies on a set of sensors to measure various environmental factors for plant growth, such as soil moisture, temperature, light intensity, and water level. Farmers can easily control and monitor this system, contributing to increased productivity and saving water, time, and physical effort. The system is characterized by its flexibility and adaptability to suit different types of crops and agricultural conditions. For future development, more sensors can be added to measure additional environmental factors such as soil pH levels and oxygen levels. Additionally, a smartphone application can be developed for easier remote control.

References

Aswale, P. S., Sali, S., Zarole, S., & Patil, P. (2016). Automatic irrigation control system based on Lab-VIEW Arduino interfacing. *International Journal of Innovative Research in Technology*, 12(6), 261-264.

Chethan, R., Damodharan, G., Elumalai, K., Eswaran, C., & Manjula, C. (2018). Smart irrigation system for agricultural field using LabVIEW and IoT. *International Journal of Innovative Research in Science, Engineering and Technology*, 7(1), 143-146.

Food and Agriculture Organization of the United Nations. (2011). *Biotechnologies for agricultural development: Proceedings of the FAO international technical conference on "agricultural biotechnologies in developing countries: Options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change"* (FAO Agricultural and Food Sciences Series, No. 10). Rome.

Jha, A. K., Malla, R., Sharma, M., Panthi, J., Lakhankar, T., Krakauer, N. Y., Pradhanang, S. M., Dahal, P., & Shrestha, M. L. (2016). Impact of irrigation method on water use efficiency and productivity of fodder crops in Nepal. *Climate*, 4(1), 1-13. doi:10.3390/cli4010004.

Kushwaha, N., & Beniwal, N. S. (2017). Smart field system using LabVIEW and IoT. *International Journal of Advanced Research in Computer and Communication Engineering*, 6(5), 428-432. doi:10.17148/IJARCCE.2017.6580

Ren, C., Liu, S., van Grinsven, H., Reis, S., Jin, S., Liu, H., & Gu, B. (2019). The impact of farm size on agricultural sustainability. *Journal of Cleaner Production*, 220, 357-367. doi:10.1016/j.jclepro.2019.02.151

Silalahi, L. M., Budiyanto, S., Silaban, F. A., & Hakim, A. R. (2021). Design a monitoring and control in irrigation systems using Arduino Wemos with the Internet of Things. *Journal of Integrated and Advanced Engineering*, 1(1), 53-64. doi.org/10.51662/jiae.v1i1.13

Zhu, H.-H., Huang, Y.-X., Huang, H., Garg, A., Mei, G.-X., & Song, H.-H. (2022). Development and evaluation of Arduino-based automatic irrigation system for regulation of soil moisture. *International Journal of Geosynthetics and Ground Engineering*, 8(13), 1-9. doi.org/10.1007/s40891-022-00360-8