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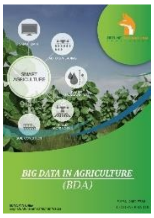

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RESEARCH ARTICLE

SMART IRRIGATION MONITORING AND WATER THEFT DETECTION SYSTEM USING IOT AND CLOUD COMPUTING

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ABSTRACT

The world is experiencing a rising water crisis with agriculture taking over and using over 70 percent of the freshwater at their disposal. This has been worsened by poor traditional irrigation methods and illegal water diversion through canals and distribution channels resulting in disproportional water distribution and low production of crops. It is not feasible to manually keep track of large irrigation networks, particularly at night, to detect water theft in real-time. To overcome these shortcomings, this paper introduces an IoT-based smart irrigation monitoring and water theft detection system. The proposed system installs several sensors of water levels at predetermined points on the irrigation pipeline to continuously check and compare water levels in real time. The sensor data are sent to an IoT-enabled communication framework to a cloud interface where they are analyzed and visualized to be remotely monitored through mobile or computer-based applications. The experimental findings through repeated tests indicate that under normal conditions there is a gradual change in water levels, but large drops at downstream areas indicate clearly potential cases of water theft or leakage. The system will be able to detect the specific location and time of such anomalies and produce alerts to intervene in time. The proposed solution will enhance the efficiency of irrigation and make agricultural activities in water-limited areas sustainable by decreasing human input and maintaining equal water distribution and minimizing water wastage.

KEYWORDS

IoT, smart irrigation, agricultural, water level, water theft monitoring, business, sensor data, automation.

1. INTRODUCTION

Irrigation systems play a vital role in managing water supply and demand in agriculture (Obaideen et al., 2022). With the world's growing population, there is an increasing demand for food, which means there is a need for more irrigation systems to produce crops (Stein, 2021). However, water resources are limited, and water scarcity is becoming a significant concern in many parts of the world (Xiang et al., 2021). Therefore, there is an urgent need to address the disparity between water supply and demand by implementing a well-regulated system that promotes water productivity and improved irrigation practices. By implementing a well-regulated system, the distribution of water can be optimized to ensure that water usage is efficient, and there is minimal wastage (Martos et al., 2021; Singh et al., 2022; Viani et al., 2017). This can be attained in a number of ways, including the water metering, water pricing and water allocation schemes (Tsani et al., 2020). In addition, better irrigation can be adopted to make sure that water is utilized efficiently in crop production. An example of this is drip irrigation systems that can be applied to deliver water to the roots of plants to minimize water loss to the atmosphere through evaporation (Moslehi, I., Jalili Ghazizadeh, and Yousefi Khoshghalb, 2020). An economic approach to water distribution is also essential in optimizing the benefits of water usage. This means that water should be allocated based on its economic value, which considers the cost of water production and delivery and the value of the crops produced. By allocating water based on its economic value, the most efficient use of water resources can be achieved (Fernández et al., 2020). Agriculture is among the leading occupations in developing countries such as Pakistan that are required to ensure human survival. Agriculture is a very important sector of economy in Pakistan and therefore it is a critical sector to the prosperity of the country. Success of agriculture, conversely, relies on the knowledge that farmers have on crops management (Jatoi et al., 2021; Najdenko et al., 2024). Addressing the disparity between water supply and demand is crucial for the sustainability of irrigation systems. A well-controlled system which encourages water productivity and better irrigation techniques as well as an economical method of distributing water can be used to maximize the utility of water usage and to make sure that water resources are utilized in an efficient and sustainable manner. The process of stealing or diversion of irrigation system water, which is meant to be used in agriculture, is referred to as irrigation water level theft. This may happen where there is a shortage of water or where there is a water-resource competition. Water theft may have a substantial economic and environmental effect since it may decrease the supply of water to the legitimate users and damage ecosystems that rely on water (Jacoby et al., 2021). There is an urgent need to address the disparity between water supply and demand by implementing a well-regulated system that promotes water productivity and improved irrigation practices. An economic approach to water distribution is essential to optimize the benefits of water usage (Cao et al.,

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2022). The problem of irrigation water theft is rather acute and can adversely affect the sustainability and productivity of agriculture (Alahmad et al., 2023; Biswas et al., 2025). To overcome this problem, a system has been suggested to measure the levels of water at different distances and predict the point where the levels are lowered more than normal that could be a sign of possible water theft. This system would easily determine the time and the location of any theft and immediate action could be taken in order to avert additional losses. The proposed system will be programmed to irrigate in a predetermined schedule and monitor and measure the water levels at different distances to identify where the water levels are dropping at an abnormal rate. It monitoring the level of water in a canal and verifies the irrigation condition remotely via an IoT-based system and mobile application. This will enable the farmers to monitor their water sources remotely through the internet on their respective day, eliminating water theft and guaranteeing that they get their fair share of the water to irrigate their farms. The system is useful in fighting irrigation water level theft, which makes water resources to be utilized effectively and sustainably in agriculture. Tracking the water levels and reporting possible instances of theft, farmers can take immediate steps to avoid the additional losses and see to it that they are not deprived of the necessary amount of water to irrigate their lands.

2. MATERIALS AND METHODOLOGY

This section has described the methodology and materials of the proposed IoT-based system in terms of developing a smart irrigation monitoring and water theft detection system that can be used to efficiently irrigate and detect unauthorized use through real-time monitoring. The prototype system was designed and connected with water storage source line that had three different water level sensors at specific locations (L1, L2 and L3) to detect the flow and height of water in the water supply. These sensors were used to collect real-time data and send it to an IoT-based control unit, which was assembled with a WeMos D1 ESP8266 and an Arduino microcontroller, which served as the central processing and communication units. In order to improve the accuracy of measurements, an external ADS1115 ADC Module was used to digitize analog sensor signals to high-resolution digital values. The system was also included a 4-channel relay module in order to control electrical loads, and a battery and charger system to supply an indefinite source of power in remote farmland use. Jumper wires were used to assemble a prototype circuit which connected all hardware components. The sensor data was transmitted to a cloud-based server via an Internet of Things framework over a Wi-Fi router, making it easy to store, process, and analyze the sensor data remotely.

Real-time water levels were shown in graphical form on ThingView mobile application and PC interface Dashboard of ThingSpeak cloud platform providing the users view irrigation status anywhere. Water theft was identified by comparing water levels between the next sensor nodes; a sudden or unusual drop between two sensors was an indicator of possible unauthorized diversion, or leakage. Finally, this methodology has provided a low-cost, automated, and scalable approach through a combination of sensing, wireless communication, and cloud computing, which improves agricultural water management. Methodology of the proposed system is depicted in Figure 1, prototype in Figure 2 and material is mentioned in Table 1.

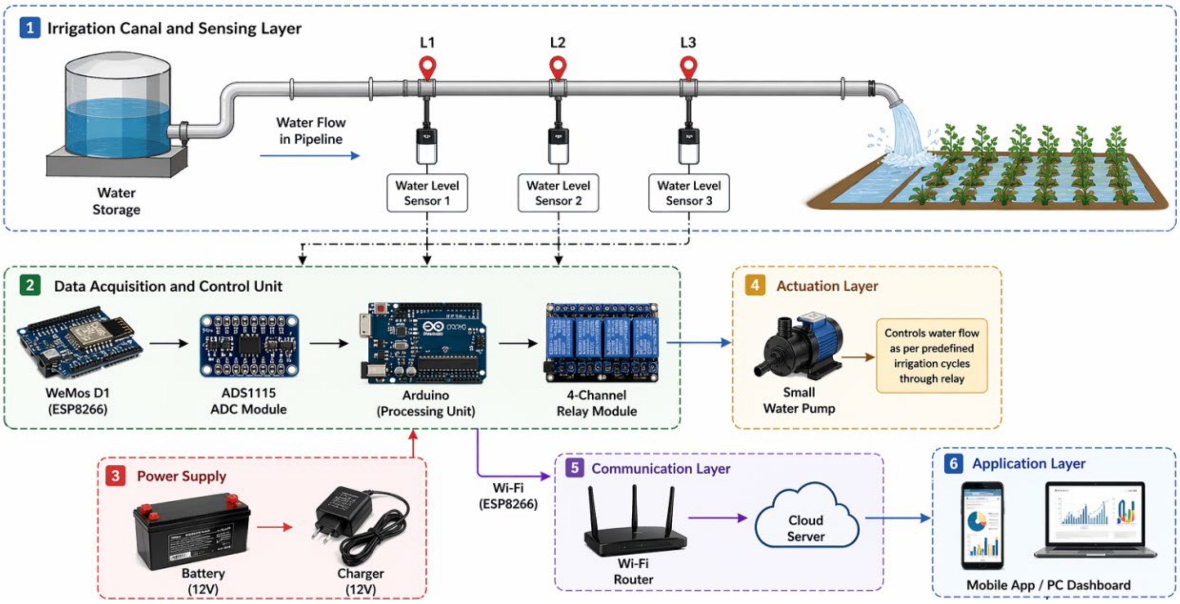

Figure 1: Proposed framework.

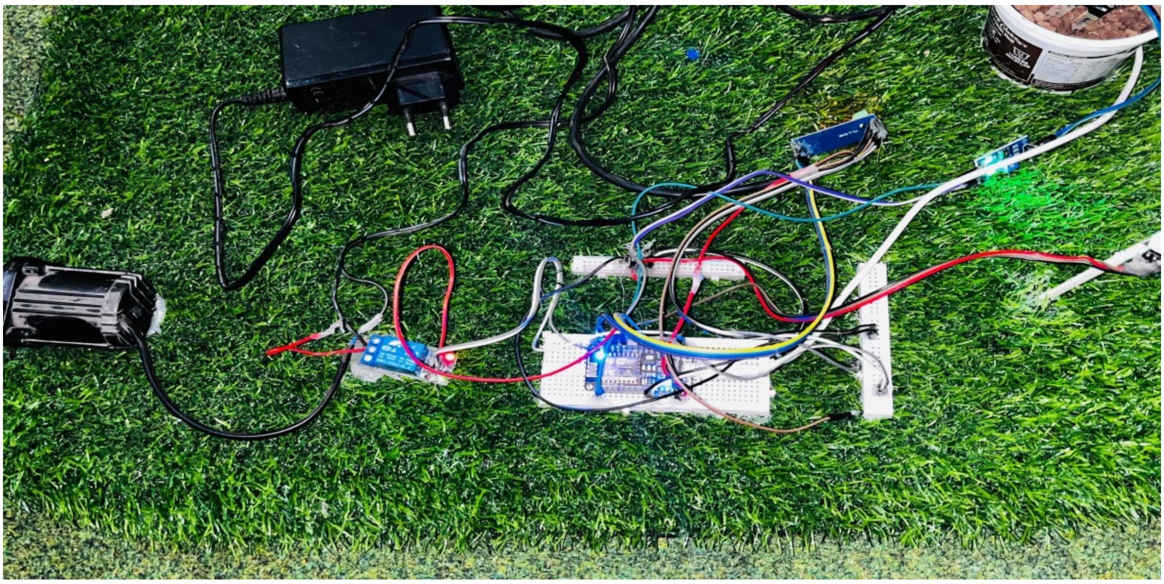

Figure 2: Prototype of the proposed system

Table 1: Hardware Components Used in the Proposed System		
Sr. No.	Hardware Component	Description / Function
1	WeMos D1 ESP8266	A WiFi-enabled microcontroller used to collect sensor data and transmit it to the cloud/server using IoT technology.
2	Water Level Sensors	Used to measure the water level at different points along the canal for monitoring and theft detection.
3	Four-Channel Relay Module	Controls high-voltage devices such as pumps or loads using low-power signals from the microcontroller.
4	Small Water Pump	Used to control or simulate water flow and increase water pressure in the system.
5	Battery and Charger	Provides power supply to the system and ensures continuous operation using stored electrical energy.
6	Jumper Wires	Used to connect different electronic components on the breadboard or circuit for signal and power transmission.
7	Arduino Board	Acts as a microcontroller unit for processing sensor data and interfacing with other hardware components.
8	ADS1115 ADC Module	Converts analog signals from sensors into digital data for accurate processing by the microcontroller.

3. Results and Discussion

The practical study of water theft is discussed below with water level values measured by three sensors along the water supply line. Table 2 is presenting the sample testing record of three water level sensors and Figure 2 is the graphical illustration of record.

Table 2: Sample testing record of three water level sensors			
Reading No.	L1 (Sensor_1)	L2 (Sensor_2)	L3 (Sensor_3)
1	100	98	96
2	100	97	95
3	100	98	94
4	99	97	70
5	100	98	95
6	100	97	94
7	100	98	93
8	99	97	65
9	100	98	94
10	100	97	93
11	100	98	92
12	100	97	60

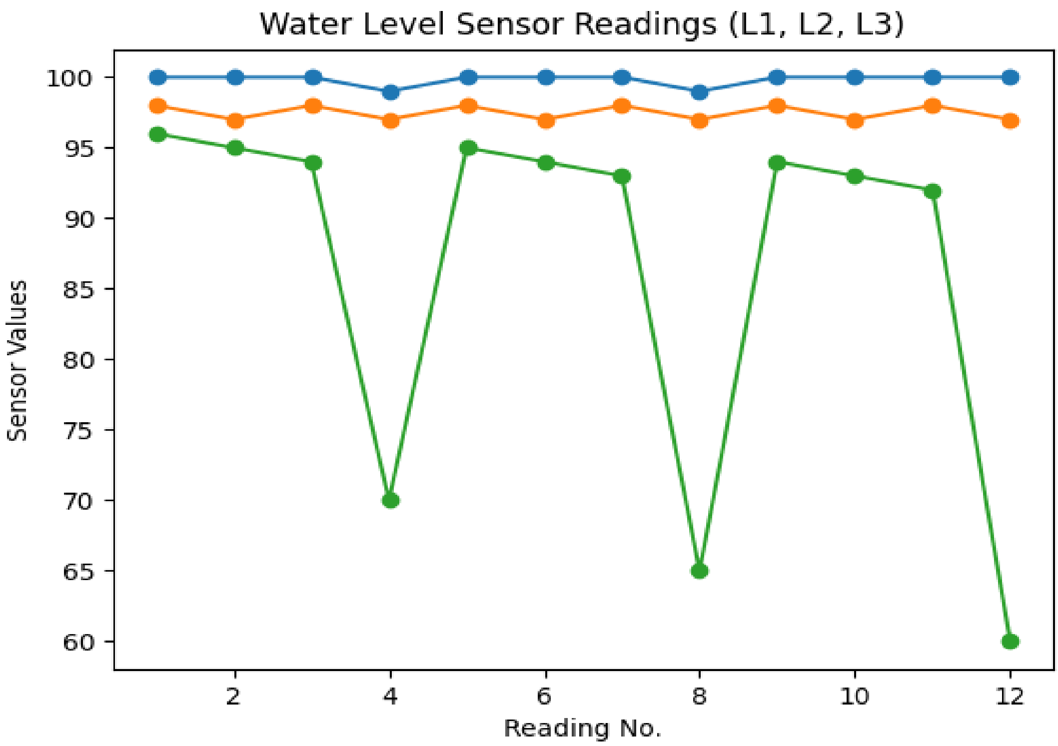

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Figure 3: Graphical representation of sensors data

The table 2 shows 12 experimental measurements of the water levels at three sensor positions (L1_Blue, L2_Orange and L3_Green). In the normal conditions, water levels will reduce slowly to L3 because of losses of flow. But in readings 4, 8 and 12, we see a sudden decrease in water level at L3 which is way out of the expected trend. Such abnormal drops signify potential water theft or leakage between L2 and L3. The fact that this multi-reading data corroborates the efficacy of the suggested IoT-based monitoring system in detecting and tracking irregularities with a steady stream of data, as well as in locating the compromised part of the pipeline precisely proves the usefulness of the proposed solution.

4. Conclusion

The study explains the concept and execution of an IoT-based smart irrigation monitoring and water theft detection system to respond to the key issues in the efficient agriculture water management. The system allows conducting a continuous observation and comparison of water levels by installing water level sensors at several points on the irrigation pipeline to detect irregularities. The experimental data recorded of various readings of the tests demonstrate that the normal flow conditions show gradual variations and large drops at the downstream points are reliable indicators of the possible water theft or leakage. The connection of IoT-based communication ensures the transmission of real-time data to a cloud platform and allows remote monitoring using convenient interfaces and decreases the reliance on manual inspections. Moreover, the system promotes scheduled irrigation, which guarantees effective water allocation and better use of resources. In general, the research proves that the suggested system is feasible, expandable, and efficient in improving the efficiency of irrigation, reducing water wastage, and encouraging sustainable agricultural activities, thus providing a promising solution to the contemporary precision farming setting.

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