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An Automated Irrigation System for Smart Agriculture Using the Internet of Things

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Abstract— Water is a valuable but limited agriculture resource, and it is becoming harder to manage it efficiently. This paper discusses a system of an automated irrigation that integrates the cloud computing, tools, and IoT (Internet of Things) for optimization in order to reduce water usage in the agriculture. Low-cost sensors have been utilized by the automated irrigation system to monitor important factors like soil type, pH, soil moisture, and meteorological conditions. For information storage & analysis, the data is kept in the Thing speak cloud service. The field data is sent to the cloud by utilizing the networks of GSM cellular as well as a Wi-Fi modem. Subsequently, using an optimization model, the ideal irrigation rate is determined. This rate would then be automated by utilizing a solenoid valve & regulated by an ARM controller (WEMOS D1). The essential variables are available to farmers as a cloud-based service. When the recommended approach is used in a pilot-scale agricultural operation, our findings show a decrease a water use, a rise in the amount of data available, and better imagining.

Introduction

Innovations in agriculture is necessary to maintain agricultural output, provide security of food, and boost economic development in the face of changing climatic circumstances, a declining labour force, and shifting soil conditions. More over half of the population in India works in agriculture, which accounts for 18% of the world's GDP [1]. Despite these efforts, the industry is under pressure, and the Indian government's latest economic review has highlighted the need to obtain "more produce per drop," which refers to using technology and sensible procedures to increase production per drop of water. Recent technological advancements are being hailed as solutions even if this is mostly reliant on the irrigation system [2]. The crop lifetime is influenced by current environmental factors, including moisture in soil, temperature, evapo-transpiration, humidity, cropping cycles, and etc. Real-time monitoring of these types of parameters and remedial action on the basis of sensed data might improve resource use.

In light of this, the IoT is a tool for farm automation [3], [4], [5]. The IoT enables new applications and services by using recent advancements in sensor, networking, and computing technology. Fusing crop statistics data and agricultural environmental data was investigated in [6] through [9], and [10]. The "Energy Savings Through IoT and Nonlinear Model Predictive Controller (TMD/CERI/BEE/2016/088) project is sponsored by the DST as part of the Initiative to Promote Habitat Energy Efficiency".
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Agricultural environmental data has been researched in [10]. Control functions, however, have not been examined in this experiment. According to the research in [11] & [12], a context by few functions of control was suggested. Numerous scientists have also looked at the significance of IoT in regulating water use for irrigation. In [13], a simple irrigation system had been examined. A cutting-edge approach that tries to modernize conventional farming was put out in [14]. According to the study in [15], wireless sensor networks might be used to control irrigation on fields where there are crops. The suggested structure made it possible for users to comfortably engage that with data & consult. Zigbee has been employed for communication among the base stations and sensor nodes in a system of smart farm irrigation that has been suggested in [16]. The use of cloud computing or IoT had been not completely explored in these investigations, despite the fact that data must have been gathered and analysed. As a result of the cloud's service delivery paradigms, this opens up new possibilities. However, in these investigations, control capabilities were not examined. A framework with few control functions was suggested by the findings in [11] and [12]. Numerous scientists have also researched how IoT can manage how much water is used for irrigation. [13] examined a straightforward irrigation system. A cutting-edge approach was put forward in [14] with the intention of modernising conventional farming. The study in [15] suggested employing wireless sensor networks to control irrigation on fields where there are crops. The suggested structure made it easy for users to consult and interact with the data. A suggested IoT-based smart agricultural irrigation system has been made in using Zigbee for communication in base stations and sensor nodes [16]. Although data was gathered and processed for these investigations, the possibility of merging cloud computing with IoT was not thoroughly investigated. Due to the cloud's service delivery paradigms, this opens up more options.

Important attempts have recently been made to merge IoT with cloud computing. [17], [19], and [20] proved that doing so may increase the advantages of IoT. Precision agriculture's use of cloud-based IoT systems was researched in [18]. The question of ultimate control, though, has never been taken into account. Similar studies of irrigation optimization models excluding talks of monitoring and control may be found in [21]. According to an examination of the literature, monitoring and data aggregation are the only IoT applications now

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being used. Our best knowledge indicates that final control, which includes resource optimization, has not been researched in the literature. In this research, we integrate cloud interfaces with IoT sensing and networking capabilities, analyse the data to determine the best rates of irrigation, and then apply the calculated rates of flow into practise by instructing a solenoid valve. As a result, an all-encompassing approach that incorporates networking, sensing, optimization, and control is suggested. According to our knowledge, no such strategy was printed for agricultural irrigation purposes. The primary contributions of the article has been given below:
A smart irrigation system which employs cloud connection & IoT to gather and store data, an optimization technique to find out the ideal watering settings, and solenoid valves for final control.
Design considerations for IoT hardware, software, or their integration are explored, but also networking & cloud connection.
3)Experiments and simulations should be used to illustrate the hardware and control technique.

The rest of the research is structured has been mentioned. The system design & architecture, that outline the main system components, are presented in Section II. At Section III, the optimization approach for control the irrigation is described. Section IV presents the findings and observations. Conclusions are formed from the research findings and section V's analysis.
System Architecture and Design

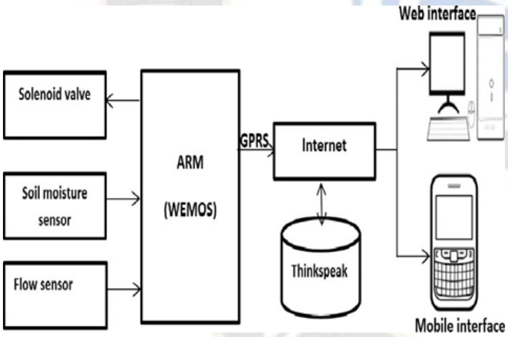

Fig. 1: The smart irrigation system's IoT architecture

Fig. 1 depicts the IoT architecture utilised to build the precise irrigation system. Tab. I includes a list of a architecture's features. Based on a cost-reliability study, the components are chosen. Although the inexpensive sensors have reliability problems, they function adequately well for the application under consideration. Low priced soil moisture & flow sensors are employed in this study. The WEMOS D1 controller receives data from the sensors and uses it to regulate the flow of fluid. The solenoid valve, that is used to irrigate the field, is controlled by the controller. However, the motor must be active only at any 1 of the valves is in the position of open, the controller likewise regulates the DC motor's on/off state. The module of GSM GPRS allows the controller to access the internet. GSM is used to offer internet connection since broadba-nd is not practical in several rural regions of agricultural, while GSM-based cellular networks are practical on more over 70% of India's land. In addition to being utilised to regulate the irrigation system, the data collected from the field is also kept in the cloud (Thingspeak) for future research. Through this web interface or a mobile app, field monitoring was made remotely available. The farm has been divided in distinct sectors as shown in Figure. 2, as well as the flow of water via various valves for every sector that have been installed by a variety of sensors for monitoring as well as the solenoids for actuators.

The sectors are essentially regulatory regimes for which irrigation with water is permitted. Better management may be accomplished by coordinating the irrigation and monitoring to fulfil the demands of the various sectors. Having explains architecture, we offer a brief overview of the various hardware parts that are employed.

Device	Specifications
pH sensor	pH meter probe (0-10)
Humidity & Temperature sensor	DHT 11
Water Flow Sensor	YF-201
Drip irrigation hose	4 mm, 2 meter (length)
Gardening sprinkler	4-hole female
Solenoid Valve	1/2 Inch, 12V
Soil Moisture Sensor	YL69
WEMOS D1 Controller	ESP-8266EX

TABLE I: Architecture's constituent parts

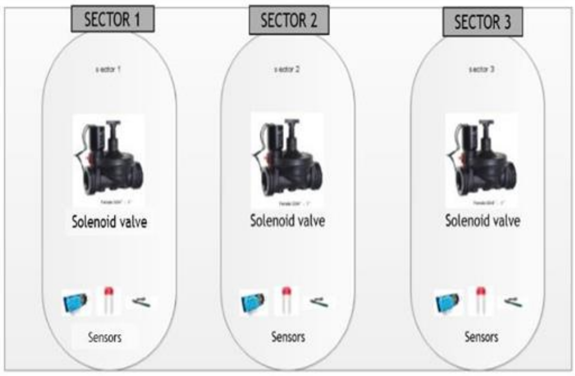

Fig. 2: Agriculture Land Sector Organization

1)WEMOS D1 Controller: The D1 is a controller built on the ESP8266 (Wi-Fi) platform and is compatible with arduino IDE. The WEMOS features the ESP8266 module through the default at the board, minimising the difficulty of integrating an ESP8266 using Arduino Uno while maintaining the same functionality as that of the Arduino Uno controller. Multiple analogue sensors have always been interfaced to the controller using ADCs (“Analog to Digital convertors”).

2)Solenoid Valve: For regulating the flow, solenoid valves have been used in lieu of the conventional valves. The flow is controlled by pulse-width modulation, and the quantity of flow is proportional to the number of duration the valve is at ON-state during a specific time-duration. The valve may be operated in either an ON or OFF mode. The solenoid valve is switched ON/OFF using a 24 V relay.

3)Soil Moisture Sensor: Our design utilizes a probe or soil moisture sensor from the YL69 series to estimate the volumetric soil moisture content. In agriculture, measuring soil moisture is seen as a crucial activity that helps farmers operate irrigation systems more efficiently. These probes provide a quick reaction time in comparison to other inexpensive sensors like gypsum block sensors. This is the rationale for the sensor's selection and usage in the suggested design. Correctly situating the soil moisture sensor is essential because irrigation is managed by the soil moisture sensor value placed for a specific sector. The soil moisture sensor's power supply should range from 3.3V to 5V. The value of sensor's output ranges from 0 to 1000 ohms. Based on the reading of sensor the soil could be considered into wet, dry and humid. The analogue pin of the controller is wired to the analogue pin where the sensor of soil moisture is attached. The range of sensor for identifying the kind of soil is displayed in Table. II.

Soil Type	Resistance value range
Dry	0- 300 Ω
Humid	300-700 Ω
Wet	700-100 Ω

TABLE II: “Range of Soil Moisture Sensor Resistance

Time stamp	Entry Id	Soil Moisture in ω	Flow in s
2018-03-26 10:38:51 UTC	94	310.00	6.12
2018-03-26 10:39:12 UTC	95	316.00	6.21
2018-03-26 10:39:33 UTC	96	330.00	6.29
2018-03-26 10:39:54 UTC	97	345.00	6.39
2018-03-26 10:40:15 UTC	98	368.00	6.51
2018-03-26 10:40:36 UTC	99	382.00	6.62

TABLE III: Data Samples Stored in Thingspeak”

Flow Sensor: The water quantity used for the irrigation in this system is determined by a flow sensor (YF-201).In order to compare the conventional and automated irrigation systems simply, the quantity of water used in the experimental setting must be determined. A pinwheel within the water flow sensor has been utilized to determine the amount of water that is irrigated via it when it is parallel to the water line. In litres per second, the water flow is calculated.

Data Transmission: By Transferring the data gathered through the farm to the Internet presents a significant challenge since more than 50% of India's agricultural lands lack access to broadband internet, making it impossible to transfer the data by the farm and to Internet. Data is transferred in this work via GPRS internet access, which is made available by cellular network providers. The bulk of India's agricultural areas are covered by cellular networks, and the development of 4G and 3G technology has made it feasible to send data swiftly. For transfer the data by the controller to the internet, we have utilized a device named Wi-Fi hotspot rather than a GPRS module since the hot spot's transmission speed is faster than the controller's GSM GPRS module's. When comparing to using an Arduino, the WEMOS controller has simplified the ESP8266 interface. The GSM module is utilized by the controller to communicate messages about the field's status.

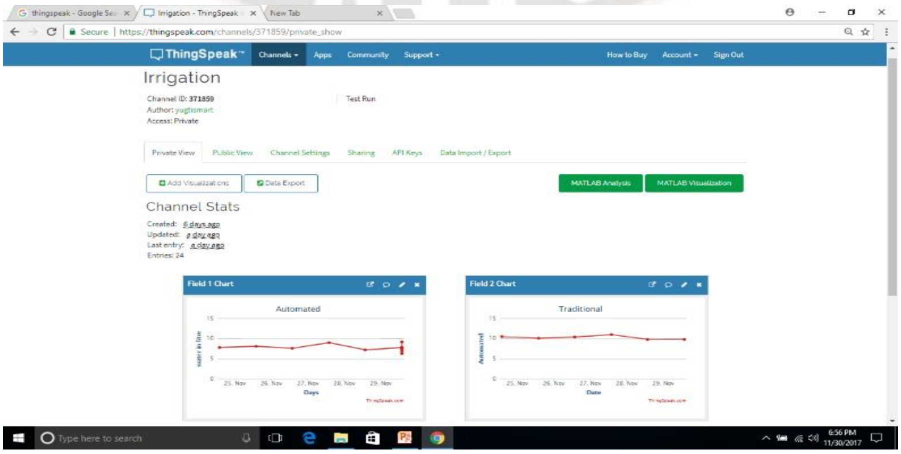

Fig. 3: Thing Speak Web Interface

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. Cloud-based Remote Monitoring

On the basis of reading from the sensor of soil moisture, the irrigation system is started. Through the use of a solenoid valve as well as sprinkler, the field is automatically watered. Relay switches were used to link the sprinkler & solenoid valve towards the controller. The controller sends data to Thingspeak's cloud, where it may be accessed through the Thingspeak website. The interface shows the sensor data on a simple to monitor the screen, the state of the valve of solenoid, and the quantity of water consumed. Figure. 4 is a screen image of the ThingSpeak web interface, while Table III provides a sample of the data provided.

Similar to how the PH of the soil, temperature, or humidity were kept, so was the temperature. The Thingspeak cloud service is simple to use and has built-in lab view features. The Thingspeak Cloud Service Interface for a smartphone is seen in Fig. 4, where the data are provided as charts. For additional research and to provide real-time data visualization, the data streams and timestamp may be saved in Thingspeak.

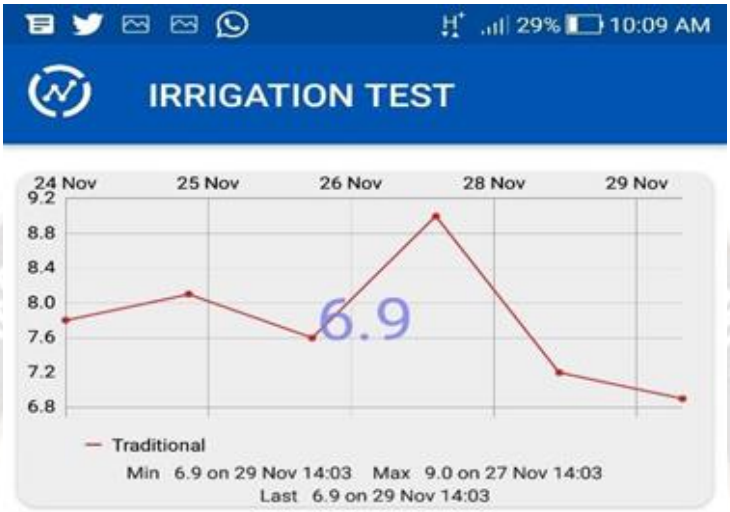

Fig. 4: Thing Speak Interface for Smart Phone

Optimization Model

The decision-making problem of determining the lower rates of irrigation on the basis of sensed data requires the use of an optimization tool. Because of this, we frame the problem of effective irrigation as an optimization one. What we mean is as follows:

"$w1(t)St + w2(t)rt + w3(t)Q(t)\Delta$"
to a time horizon of 24 hour that is shown by $I = Lt = Q\Delta t$ here Q is as the flow along with Δ unit time step utilized in study. Additonaly, we focus to exploit rain water utilization, and content of soil moisture. The modelled objective is expressed as:

here the weighing factors are *w1*, *w2* and *w3*, content of soil moisture St at the t time, and the weight are chosen based on the kind of crop or the soil.
r as the Limits on rainfall are shown by;

"$R_{min} \le r_t \le R_{max}$ $\forall t \in \{t + \Delta, t + 2\Delta, \ldots, t + T\Delta\}$" (2)

Here Rmax denotes the maxi and Rmin the mini values for the rainfall period. The maximum irrigation allowed is specified by
"t+T Δ
$Q(t) \ge (e_t - r_t - S_t + d_t)$
Δ
$Q(t) \le WR_{max}(t) - r_t - S_t + d_t$
Δ

Definition 1: The irrigation interval is defined as the interval among both planting & harvesting.

Definition 2: The irrigation period's maximum rainfall, designated as Rmax , is the top limit on total rainfall for that time.
Our goal is to use less water for irrigation.

"$J = w1(t)St + w2rt + w3(t)Q(t)\Delta$
(1)
$\forall t \in \{t + \Delta, t + 2\Delta, \ldots, t + T\Delta\}$"

$EP(t) \le r_t + S_t + Q_i(t)\Delta - d_t\ Q_{min} \le Q(t) \le Q_{max}\ r_t, S_t, d_t, Q(t) \ge 0$",
$w1 + w2 + w3 = 1$
"$\forall t \in \{t + \Delta, t + 2\Delta, \ldots, t + T\Delta\}$"

Open source solvers like the "Gnu Linear Programming Kit" could be used on single-board computers like the BeagleBone Black to resolve the optimization model M. but in assessment done by us, the problem has been handled on a computer utilizing the MATLAB linprog tool.

Results

Real-time Experiments
L
t=t+Δ
$Q(t)\Delta \le I$ (3)

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In our tests, a pilot with 4 land sectors of 2 by 2 square feet each was used for evaluating the approach. The water flow in one sector was manually managed using a typical irrigation technique, while the other three
Following [21], irrigation was carried out utilizing sensors and actuators to irrigate using three different methods: sprinkler irrigation, drip irrigation, and automated irrigation (solenoid valve, sprinkler, and Drip).

$$Q(t) \geq \frac{(e_t - r_t - S_t + d_t)}{\Delta}$$
$$Q(t) \leq \frac{WR_{max}(t) - r_t - S_t + d_t}{\Delta} \quad (4)$$

Here, threshold on water utilizations as et, water drained as dt, and max water reserve as WRmax, correspondingly. Additionaly, the rate for evapotranspiration is controlled by;

"EP (t) ≤ rt + St + Q(t)Δ − dt ∀t" (5)

Furthermore, the drain, flow rate, moisture in soil, and rainfall are positive real-values, as shown by the expression

rt, St, dt, Q(t) ≥ 0 (6)

The optimization model to decrease the irrigation is given sectors by;

M:

$$\min \quad w_1(t)S_t + w_2(t)r_t + w_3(t)Q(t)\Delta$$

.t.

$$R_{min} \leq r_t \leq R_{max},$$
$$\sum_{t=t+\Delta}^{t+T\Delta} Q(t)\Delta \leq I$$
$$Q(t) \geq \frac{(e_t - r_t - S_t + d_t)}{\Delta}$$
$$Q(t) \leq \frac{WR_{max}(t) - r_t - S_t + d_t}{\Delta}$$
$$EP(t) \leq r_t + S_t + Q_i(t)\Delta - d_t$$
$$Q_{min} \leq Q(t) \leq Q_{max} \quad r_t,$$
$$S_t, d_t, Q(t) \geq 0,$$
$$w_1 + w_2 + w_3 = 1$$
$$\forall t \in \{t + \Delta, t + 2\Delta, \ldots, t + T\Delta\}$$

On single-board computers like the "BeagleBone Black", linear programming problems like the optimization model *M* might be addressed with free and open-source software. However, in our study, the MATLAB *linprog* programme has been utilized to solve the problem on a computer.

IV. RESULTS

A. Real-time Experiments

In our tests, a pilot with 4 land sectors of 2×2 square feet each was used to evaluate the approach. The water flow in one sector was managed manually using the traditional approach, while the other 3(Sprinkler, Drip and Automated Irrigation) have been watered automatically with sensors and actuators (Drip, sprinkler, and solenoid valve). Amaranthus tricolour spinach seeds were evenly distributed among the four land sectors and grew to maturity. All the sectors had water flow sensors, soil moisture sensors, and soil PH sensors installed. For all four sectors, weather sensors including temperature, humidity, as well as rain sensors were placed. Wire connections were used to join the actuators to the controller. Due to the tiny area of land used for irrigation, a low-pressure water line was used to provide the sprinkler with water. Based on the moisture sensor measurement, irrigation was carried out. In the experimental setup, the value was adjusted to range from less than 300 to 950Ω. The solenoid valves were opened to irrigate the field if the value dropped below 300 Ω; if it increased to 950 Ω, the solenoid valves have been closed. In order to automate drip irrigation, water was supplied to the drip irrigation tube using solenoid valves. For demonstration purposes, the experimental prototype of the sprinkler irrigation system only uses low pressure water input. The ground is never allowed to go dry because of the soil moisture metre utilized to automate watering. The write API key is used to post the data to the Things Speak cloud. Three weeks of testing were put into the experiments. First, as shown in Fig. 5, we suggest a moisture-based control to evaluate the efficacy of the optimization technique.

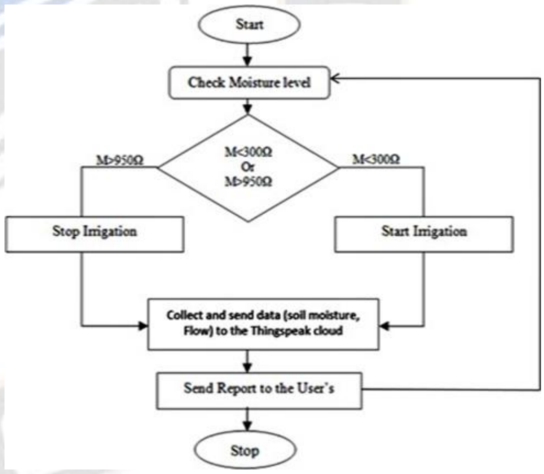

Fig. 5: Moisture-based Control.

The 2 scenarios mentioned below have been compared;

A) Regulation of flow depending on moisture content using valves, sprinklers, and drip irrigation;
B) Employing drip irrigation, sprinkler control, and a valve irrigation system to optimise flow;
Changes in irrigation conditions and flow-rate Q(t) limitations are correlated in the optimization model.

Results with Heuristic Control
The efficacy of the flow-based control was examined using

the flows over a three-week period. All three automated irrigation techniques' outcomes were contrasted with those of the traditional technique. In comparison to sprinkler irrigation, which saves 20%, or solenoid irrigation, which saves 16%, the drip irrigation technique is very efficient. Since there was enough water available throughout the trial, the insufficient watering condition had been deleted in this experimental prototype. Due to the lack of water, a water shortage might happen when the device is used in actual agricultural fields. Utilizing Thingspeak's API features, the data is easily saved in the cloud. Figure 6's flow control plot for a six-day timeframe using flow-based control demonstrates how the drip irrigation system's flow is lesser than that of irrigation systems.

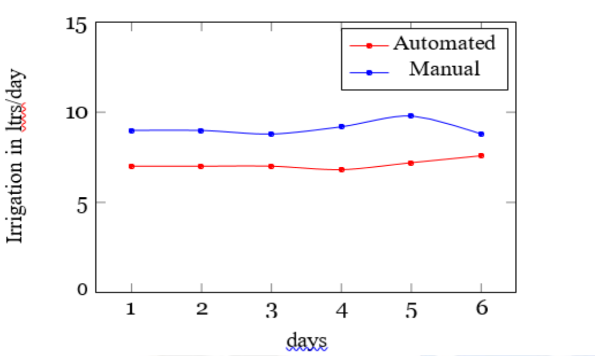

Fig. 6: Manual vs. Automated Control using a sprinkler model for flow-based control

C.Simulation outcomes with Optimization Based Control

The efficiency of optimization on the basis of control for the 3 irrigation systems was examined using the flows during a 1-week period using optimization-based control. The drip irrigation system increased savings over flow-based control by 7 percent and offered 31.2 percent more than the traditional method. Similar cost reductions of 26 and 22 percent were realized utilizing solenoid valve-based sprinkler irrigation control. In terms of water savings, our simulations show that optimization-based control works better than flow-based control.

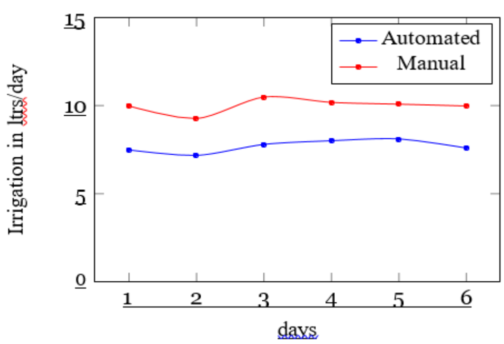

Fig. 7: Sprinkler system automation vs manual control for optimization-based control

Observations

- It was shown that when soil moisture levels rise, the pH level of the soil drops.
- The capacity to aggregate data and visualize it was greatly improved by IoT and cloud connection.
- The IoT, cloud connection, and optimization models when combined will assist the agricultural systems use water more efficiently.
- By linking solenoid values, the irrigation system had been automated, aiding in the control's increased agility.

Conclusions

This study used the IoT, optimization, and cloud computing to develop a system of automated irrigation to decrease water use in agriculture. The system of an automatic irrigation is made feasible by employing less expensive sensors to keep an eye on interests variables like pH, humidity, temperature, type of soil , or conditions of weather. The stored data within the Thingspeak cloud storage system for monitoring and archiving. Then, using constraints that modelled the physical conditions, a water-saving optimization model was released. The optimal rate of flow has been found by solved the issue for optimization, which also showed how well-suited solenoid valves are for automating flow rates. When comparing optimization-based control to flow-based control, our findings indicated that optimization models support to reduce water use. The IoT prototype will be improved, and the optimization models will be optimised, as the next phase in this investigation.

References

1. Govt. of India, “Indian economic survey”, 2018. http://mofapp. nic.in:8080/economicsurvey/Sharma, D., Bhondekar, A. P., Ojha, A., Shukla, A. K., & Ghanshyam,C. (2016). A Technical Assessment of IOT for Indian Agriculture Sector. In 47th Mid-Term Symposium on Modern Information and Communication Technologies for Digital India, Chandigarh.
2. Chaudhary, R., Pandey, J. R., Pandey, P., & Chaudhary, P. (2015). Case study of Internet of Things in area of Agriculture,‘AGCO’s Fuse Technology’s‘’Connected Farm Services’. In Green Computing and Internet of Things (ICGCIoT), 2015 International Conference on (pp. 148-153). IEEE.
3. Verma, N. K., & Usman, A. (2016). Internet of Things (IoT): A relief for Indian farmers. In Global Humanitarian Technology Conference (GHTC), 2016 (pp. 831-835). IEEE.
4. Bekiroglu, K., Srinivasan, S., Png, E., Su, R., Poolla, K., and Lagoa, C. (2017, December). An Internet of Things compliant model identification methodology for smart buildings. In Decision and Control (CDC), 2017 IEEE 56th Annual Conference on (pp. 4440-4445). IEEE.
5. Ryu, M., Yun, J., Miao, T., Ahn, I. Y., Choi, S. C., & Kim, J. (2015).
6. Design and implementation of a connected farm for smart farming system. In Sensors, 2015 IEEE (pp. 1-4). IEEE.
7. Kalathas, J., Bandekas, D. V., Kosmidis, A., & Kanakaris, V. (2016). Seedbed based on IoT: A Case Study. Journal of ngineering Science & Technology Review, 9(2).
8. Wenting, H., Zhiping, X., Yang, Z., Pei, C., Xiangwei, C., & Ooi, S.
9. (2014). Real-time remote monitoring system for crop water require- ment information. International Journal of

Agricultural and Biological Engineering, 7(6), 37-46.
10. Baranwal, T., & Pateriya, P. K. (2016). Development of IoT based smart security and monitoring devices for agriculture. In Cloud System and Big Data Engineering (Confluence), 2016 6th International Conference (pp. 597-602). IEEE.
11. Lee, M., Hwang, J., & Yoe, H. (2013). Agricultural production system based on IoT. In Computational Science and Engineering (CSE), 2013 IEEE 16th International Conference on (pp. 833-837). IEEE.
12. Deksnys, V., et al. "Remote agriculture automation using wireless link and iot gateway infrastructure." Database and Expert Systems Applications (DEXA), 2015 26th International Workshop on. IEEE, 2015.
13. Dan, L. I. U., Xin, C., Chongwei, H., & Liangliang, J. (2015). Intelligent agriculture greenhouse environment monitoring system based on IOT technology. In Intelligent Transportation, Big Data and Smart City (ICITBS), 2015 International Conference on (pp. 487-490). IEEE.
14. Harun, A. N., Kassim, M. R. M., Mat, I., & Ramli, S. S. (2015, May). Precision irrigation using wireless sensor network. In Smart Sensors and Application (ICSSA), 2015 International Conference on (pp. 71-75). IEEE.
15. Hari Ram, V. V., Vishal, H., Dhanalakshmi, S., & Vidya, P. M. (2015, July). Regulation of water in agriculture field using Internet Of Things. In Technological Innovation in ICT for Agriculture and Rural Development (TIAR), 2015 IEEE (pp. 112-115). IEEE.
16. Navarro-Hell´ın, H., Torres-Sa´nchez, R., Soto-Valles, F., Albaladejo- Pe´rez, C., Lo´pez-Riquelme, J. A., & Domingo-Miguel, R. (2015). A wireless sensors architecture for efficient irrigation water management. Agricultural Water Management, 151, 64-74.
17. Saraf, Shweta B., and Dhanashri H. Gawali. "IoT based smart irriga- tion monitoring and controlling system." In Recent Trends in Electron- ics, Information & Communication Technology (RTEICT), 2017 2nd IEEE International Conference on, pp. 815-819. IEEE, 2017.
18. TongKe, F. (2013). Smart agriculture based on cloud computing and IOT. Journal of Convergence Information Technology, 8(2).
19. Khattab, Ahmed, Ahmed Abdelgawad, and Kumar Yelmarthi. "Design and implementation of a cloud-based IoT scheme for precision agricul- ture." Microelectronics (ICM), 2016 28th International Conference on. IEEE, 2016.
20. Patil, V. C., Al-Gaadi, K. A., Biradar, D. P., & Rangaswamy, M. (2012). Internet of things (Iot) and cloud computing for agriculture: An overview. Proceedings of Agro-Informatics and Precision Agriculture (AIPA 2012), India, 292-296.
21. Channe, H., Kothari, S., & Kadam, D. (2015). Multidisciplinary model for smart agriculture using internet-of-things (IoT), sensors, cloud- computing, mobile-computing & big-data analysis. Int. J. Computer Technology & Applications, 6(3), 374-382.
22. Difallah, W., Benahmed, K., Draoui, B., & Bounaama, F. (2017). Lin- ear optimization model for efficient use of irrigation water. International Journal of Agronomy, 2017.