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Implementing cellular automata based Leakage detection and localization method to conserve water

Arpita Bhattacharya[1] and A. Senthil[2]

Department of Computer Science and Engineering, School of Engineering and Technology, Mody University, Laxmangarh, Sikar, 332 311 Rajasthan, India

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ABSTRACT

The world's largest water users are our farmers and their irrigated agricultural land. The water is scarce and considering the increase in population and climate change it has become necessary to find methods to conserve it at a global level. In water policy discussions, drip irrigation features prominently as a potential solution to water shortage issues, based on the assertion that it would increase the quality of water usage. According to the statistics available with reference to its implementation and use in Rajasthan state, the scenario is not very promising. This is due to various factors which prevents the farmers to accept and adopt this practice. Another important issue to be considered here is the leakage detection and localization which is also a potential cause for water wastage and also if acquired separately for drip irrigation will incur additional cost to the farmers who are neither very rich nor very technically sound. In this paper, we propose cellular automata based leakage detection and localization method which is cost effective and is integrate in the drip irrigation system making it smart and comprehensive thus achieving its main goal of conserving water in the agricultural field. We also present a comparative study of the implementation cost of our proposed method with four other popular model based leakage detection and localization method so that the farmers of Rajasthan and other Indian states can become aware and realize the importance of preserving water which is depleting day by day.

Key words : *Water conservation, Agricultural irrigation, Drip irrigation, Model based leakage detection and localisation, Cellular automata.*

Introduction

India constitutes 18% of the entire world's population and approximately 4% of world's fresh water and around 80% of the fresh water available is used for agricultural purpose according to the statistics available. A total of 4,000 billion cubic metres of precipitation is received by India every year. Of this, only 48% is used in surface and groundwater bodies in India. In Rajasthan state of which majority of the part is desert area the statistics available are very alarming. There is over-exploitation in almost all river basins, with little groundwater left for further irrigation projects. Agricultural use of water accounts for 83% of the state's water supplies available for consumption, 11% for drinking water, and 6% for industry/other uses (Hooda, 2017; Manju and Sagar, 2017; Dhawan, 2017; Jha 2020).

It is quite evident from the facts stated above that water is a scarce resource and without water, the agricultural practice cannot sustain. Although certain techniques are developed for soil less crop management but still it is not very popular among the rural masses due to a variety of factors (Signore, *et*

[1]Research Scholar, [2]Associate Professor & HoD

al., 2019).

The issue of water scarcity can be properly and thoroughly addressed by adopting smart practices in agriculture especially in irrigation process. One of the proven irrigation methods is drip irrigation where drip and sprinkler technique can be employed. This can be done according to the water need of the crop being produced using various sensors like soil moisture sensors, flow sensors, pressure sensors, etc. (Grafton *et al*., 2018).

Although it demands a onetime implementation and installation cost which is very nominal and economical but when in use over a period of time not only reduces the cost burden of the farmers but also automates the entire process and above all plays a crucial role in the conservation of water by minimizing its wastage by monitoring and controlling as per the crop needs (Ghosh *et al*., 2016).

One more potential area where water wastage is reported is the leakage in the pipeline structure of the irrigation setup. There are many models proposed, methods defines, and techniques employed to detect the leakage an localize the leakage area in the water pipeline structure but most of them are suitable for underground leakage or are dependent on the water and its flow properties like pressure, diameter of pipe, material of pipe, etc. to identify and localize leakage. Very less and concrete research work carried out to identify and localize leakage in water pipeline structure using soil moisture property which is a very important attribute in agricultural practices. Though cellular automata has proven to be useful in other agricultural areas like land use, projecting cropping pattern, modeling the impact of urban growth. etc but to the best of our knowledge, the use of cellular automata concept in water pipeline leakage detection and localization has not been carried out (Hyandye and Martx, 2017; Gupta and Kulat, 2018; Elleuchi *et al*., 2019).

Through this research work, we intend to propose cellular automata based leakage detection and localization method. The proposed aims to be cost effective and can easily be integrated into the existing drip irrigation system making it more smart and comprehensive thus achieving its main goal of conserving water in the agricultural field. We also presents a comparative study of the implementation cost of our proposed method with four other popular model used in this field which may help to create awareness among the farmers and may also aid in addressing the various myths that they may have about the cost and technicalities involving smart drip irrigation methods.

Study Area

Initially we had approached Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur in the month of January 2020 and got the verbal approval to conduct our experimental research there but due to COVID19 pandemic situation and the lockdown imposed nationwide we had to create a testbed at our lab as shown in figure 1. The experiments were performed using primary and secondary data. The secondary data was collected from the various government online repositories related with agriculture.

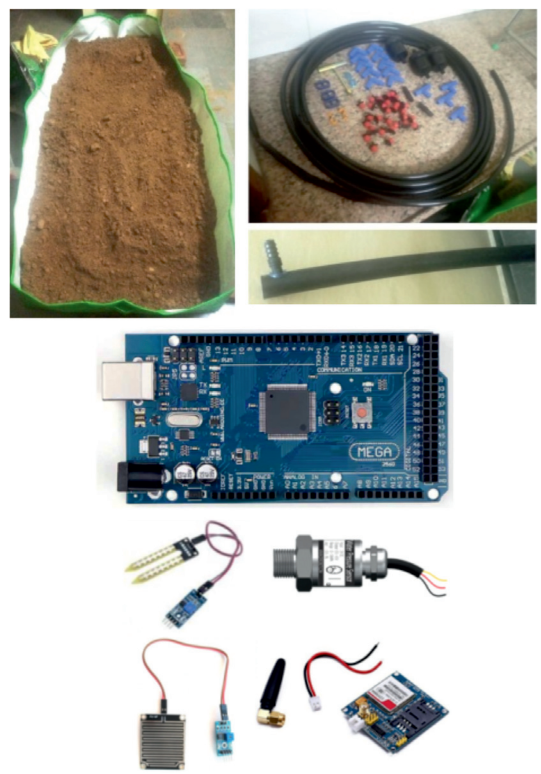

Fig. 1. Experimental Setup HDPE Grow Bag (6 X 3 feet), Drip Irrigation Kit, and IoT Sensors (Initial Stage)

Materials and Method

Hardware, software, and data used

In the experimental setup the following hardware were used viz., hdpe grow bag of 6 feet x 3 feet, irrigation kit, Arduino mega 2560 microcontroller, print circuit board (PCB), IoT sensors viz., soil moisture sensors, pressure sensors, relay module, rain sensor, GSM/GPRS module as shown in figure 1.

Linux software was used for coding the microcontroller and sending message to farmer's mobile phone, JSON and MQTT for sending the sensors data and cellular automata cell state and other associated data to cloud storage. Primary data was collected in real time using the experimental setup and secondary data related to soil moisture sensors and pressure sensors were collected using the various government repositories available online for validation of the proposed system.

Cellular Automata (CA) works on 1D, 2D, and 3D and the concept that is implemented in our proposed work is 2D and hence the entire agricultural field has been divided into equal zones. Each zone is further divided into 3 x 3 matrix grid of equal length and width according to CA. Now, the CA has certain values and states as shown in Table 5 and based on a specific state certain rules are formed and the status of each cell is dependent on the neighbourhood cells. The status of CA is shown in Table 1. The soil moisture sensors are installed exactly at the center of each cell of the 3 x 3 CA grid.

Table 1. CA Value and Status

Value	Remarks	Soil Moisture Reading
0	Empty	0-15
1	Partially Filled	16-60
2	Completely Filled	61-100
3	Excess Water	>100

Methodology

Broad overview of methodology adopted to detect and localize leakage in the water pipeline structure of the smart drip irrigation system through the testbed shown as experimental setup is illustrated in Figure 2 as flow chart. To implement the proposed research work the following methodology was used. The farmer will issue the command using the pcb to start the water flow through the Main Pipeline after checking all the constraints and if all conditions specified are found ideal. The conditions to start the water flow are as follows:

1. Check Ideal Water Level in the Water Source
2. Check the current readings of rain sensor and see whether recently rain has not happened

Start recording the readings of Pressure Sensor installed at the main pipeline and all drip pipes along with the timestamp and store them in real time in the cloud storage. Along with the starting of the pressure sensors reading, also simultaneously, start recording the readings of soil moisture sensors installed in the 3 x 3 grid formed using the cellular automata neighbourhood along with the timestamp and stores them as well in real time in the cloud storage. The system will also update the status of rain sensor and if there is rain the whole automated system should immediately stop functioning.

Now, the pcb will check whether any of the state of the cell in the CA 3 x 3 grid has changed to state'3' i.e., excess water state. The pcb will initiate process to close the control valve of the associated pipe(s) and the recording of the same will be done in the cloud storage. After that the pcb will read the exact timestamp of the associated soil moisture sensor(s) and match the exact timestamp and read the readings of all the Pressure sensors installed in the Main Pipe and Drip pipes during the time the status shifted to '3' i.e., excess water detected. PCB will check for the pressure variation of the main pipe and drip pipes during the noted time and will locate the pipe(s) nearest to the soil moisture(s) in the 3 x 3 CA grid which has changed to state '3'. Now if there is variation in pressure during the noted time then the pcb will initiate the process of leakage localization to pinpoint the accurate and nearest possible location of leak and will communicate to farmer about the current status via GSM/GPRS module. The recording will also be done in the cloud storage.

Results and Discussion

Since the dataset is quite huge and large and is stored per milliseconds so it is not possible to show the entire dataset due to page limitation, however, snapshot of the major data which is stored in cloud storage is shown in Table 2, 3, 4 and 5. Table 6 highlights the comparative implementation cost of our proposed method with four other popular model based leakage detection and localization method. This comparative study may prove to be a help for creating awareness among the farmers and make them realize the importance and use of the proposed system for saving the wastage of water thus aiding in its preservation. Due to the limitation of pages we will discuss the detailed results in our next paper which we have performed and observed through the various experiments that has been performed on the experimental testbed.

The above cost includes the basic cost per unit and the cost of drip irrigation system implementa-

Table 2. Soil Moisture Sensor Reading

Time stamp	SM1	SM2	SM3	SM4	SM5	SM6	SM7	SM8	SM9
2020-11-03T09:45:12.771Z	0	15	40	63	80	99	20	0	15
2020-11-03T09:45:13.100Z	25	50	60	63	88	101	20	62	50
2020-11-03T09:45:14.779Z	63	50	75	63	88	103	29	63	50
2020-11-03T09:45:15.310Z	63	55	75	63	89	103	62	63	55
2020-11-03T09:45:16.633Z	62	60	77	62	90	104	63	63	60

Table 3. Pressure Sensor Reading

Timestamp	MPS1	PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9
2020-11-03T09:45:12.771Z	81	50	47	45	41	40	38	32	22	10
2020-11-03T09:45:13.100Z	71	41	36	34	30	29	28	23	15	8
2020-11-03T09:45:14.779Z	60	34	27	25	24	18	18	16	14	8
2020-11-03T09:45:15.310Z	50	23	23	24	20	17	16	15	14	7
2020-11-03T09:45:16.633Z	40	15	14	14	14	7	8	9	10	4

Table 4. Cellular Automata Cell Status according to Soil Moisture Reading

Time stamp	SM1	SM2	SM3	SM4	SM5	SM6	SM7	SM8	SM9
2020-11-03T09:45:12.771Z	0	0	1	1	1	2	1	0	0
2020-11-03T09:45:13.100Z	1	1	1	1	2	3	1	1	1
2020-11-03T09:45:14.779Z	1	1	1	1	2	3	1	1	1
2020-11-03T09:45:15.310Z	1	1	1	1	2	3	1	1	1
2020-11-03T09:45:16.633Z	1	1	1	1	2	3	1	1	1

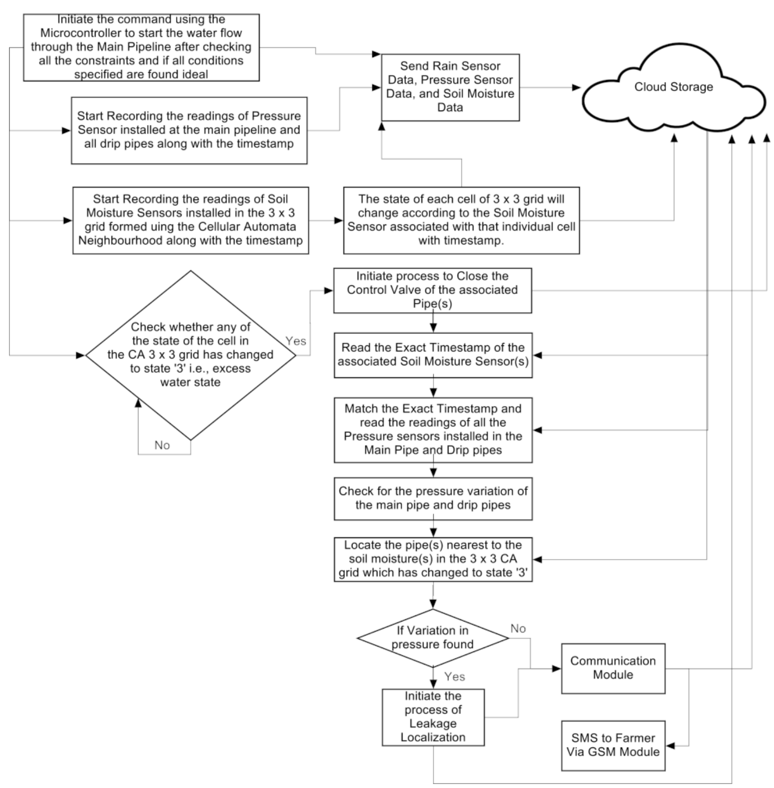

Fig. 4. Proposed Methodology of Cellular Automata Based Leakage Detection and Localization Implemented in Drip Irrigation System using IoT Sensors for Conservation of Water

Table 5. Rain Sensor Reading

Timestamp	Status
2020-11-03T09:45:12.771Z	0
2020-11-04T11:30:10.120Z	1
2020-11-05T12:45:33.190Z	1
2020-11-06T07:30:45.430Z	1
2020-11-07T09:55:46.910Z	1

Table 6. Comparative prototype cost of popular model based water pipeline leakage and detection methods and our proposed method (approx. cost)

Models	Pipe Net	Earnpipe	Wi Ro Tip	DEEP	CALDL (proposed)
Overall Cost	3927	2590	2280	4403	2131

tion for 1 Hectare in India is INR 24035/- approx.

Conclusion

The application and method of cellular automata based leakage detection and localization method in water pipeline structure have been demonstrated as appropriate tool, The present study delineates the potentiality of leakage detection and localization and its usefulness in agricultural irrigation practices with support of technology to address the issue of water wastage. Results indicate that if the proposed method is implemented then the chances of real time and timely leakage detection and localization can be achieved with accuracy. It is evident from the results that the cost of the prototype is less than the other popular model based leakage detection and localization method in water pipeline structure and can be practically implemented in an agricultural setup with minimum supervision and technicalities.

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