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Soil Moisture based Automatic Irrigation System to Improve Water Productivity

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ABSTRACT

Irrigation automation plays a vital role in agricultural water management system. An efficient automatic irrigation system is crucial to improve crop water productivity. Soil moisture based irrigation is an economical and efficient approach for automation of irrigation system. An experiment was conducted for irrigation automation based on the soil moisture content. The experimental findings exhibited that, automatic irrigation system based on the proposed model triggers the water supply accurately based on the real-time soil moisture values.

KEYWORDS
Irrigation, automation, Software; classification Soil.

INTRODUCTION

Inadequacy of freshwater for irrigation is the biggest challenge encountered in several zones of the world, in twenty-first century, due to the increasing population and agricultural intensification. Global warming expands the drought-prone areas and also increases the aridity. Even though earth is covered with 71 % of water, around 97% of water is saline and cannot be used for any purpose, only 3% of water can be used and currently, 36% of land by arid and semi-arid regions (Safriel*et al.*, 2006) and predicted that drought hazard will further increase (Alcamo *et al.*, 2007; Arnell *et al.*, 2011). Agricultural practices consume approximately 70% of the total water and about 20% is used for industrial applications and remaining is used for domestic usage (Provenzano and Sinobas, 2014). The water consumed by plants is less than 65% of supplied water (Chartzoulakis*et al.*, 2015). The review exhibits that micro-controller and Aurdino hardware-based irrigation automation systems were designed by considering the soil moisture content, in which the soil-water balance and water productivity are limitations (Angal*et al.*, 2016; Chate*et al.*, 2016). The effective management of irrigation water is challenging due to the variable soil properties (Dabach*et al.*, 2013; Soulis and Elmaloglou, 2018). An efficient automatic irrigation system play critical role in reducing the loss due to water scarcity. In the present study soil moisture based automatic irrigation model was designed to improve water productivity.

MATERIALS AND METHODS

An automatic irrigation framework was designed using finite state machine. The states q0 and q1 represents the sensors used for sensing the real-time soil moisture content and rain fall data respectively. The state q2 represents the software computing instructions, which specifically comprises of threshold values for soil moisture and the rain fall. The state q3 represents the functionality of Arduino Uno board, in which the sensed data is processed for decision making. The output of the Aurdino Uno board predicts the status of soil based on the moisture content, which was represented using the state q4 and the state q5 indicates the irrigation scheduler operation considering the rain fall status the soil moisture value. Based on the soil moisture status and rain fall data relay module was operated, which is represented using state q6 and the operation of water pumping motor is represented using state q7. Finally the water application to the field based on the soft computation is represented using state q8. Arduino Uno is a feasible platform for integrating software and hardware components to design abstract machines. In the present study Arduino Uno was used for designing automatic irrigation system. The FC-28 soil hygrometer sensor was used to measure the moisture content of the soil. Whenever the soil moisture content is above or below the threshold values then sensor sends the signal to Arduino Uno board. The MH-RD rain sensor was used to check the rain fall status before triggering the irrigation scheduler. The automatic soil moisture-based irrigation model is represented in Fig. 1.

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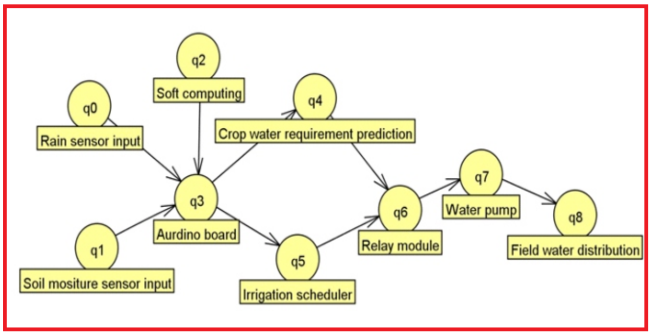

Fig. 1: Soil moisture based automatic irrigation model

In the following section the laboratory working prototype of the proposed irrigation automation model is described. The water application needs to be planned effectively to improve irrigation water productivity, it should neither be watered more nor less. Hence we have a moisture sensor that senses the moisture content in the soil and the LCD display shows the reading, based upon these values the motor pump gets on automatically and will turn off when the moisture reaches to the defined values. All the action trigger instructions are coded and uploaded to the Arduino Uno board and the corresponding logical operation flow is represented in Fig. 2.

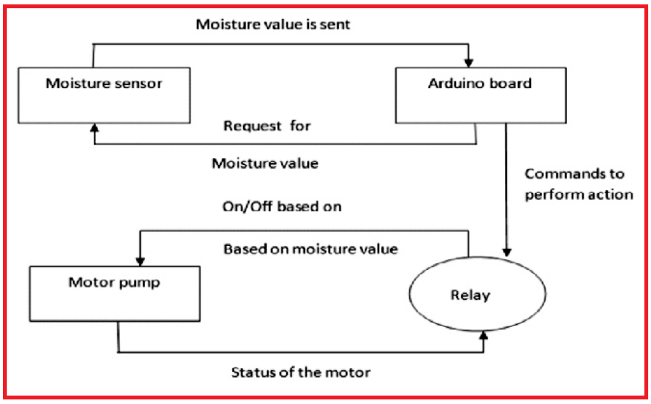

Fig. 2: Logical flow representation for soil moisture based automatic irrigation system

The soil moisture classification model has three class labels, in which the moisture content corresponding to sensor reading less than 430 ohm-m is considered as "r1" in the model and the corresponding class is labelled as dry. Similarly the moisture content corresponding to sensor reading between 430 to 770

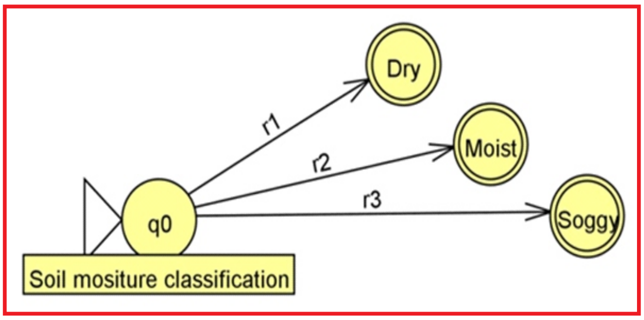

Fig. 3: Classification of soil based on moisture value

ohm-m is considered as "r2" and the corresponding class is labelled as moist and finally the moisture content corresponding to sensor reading greater than 770 ohm-m is considered as "r3" and the corresponding class is labelled as soggy. The soil moisture content threshold values are highlighted in Table 1and classification model for Sandy and Sandy loam soils represented in Fig. 3.

Table 1: Soil moisture threshold values, preprocessed input and classification

Soil moisture content value corresponding to sensor output (ohm-m)	Preprocessed input	Soil Class
Less than 430	r1	Dry
Between 430 to 770	r2	Moist
Greater than 770	r3	Soggy

RESULTS AND DISCUSSION

The entire setup is controlled by the signals from the Arduino Uno board, wherein, software code is fed into board through Arduino Uno integrated development environment platform. Based on the instructions defined in the code, actions are triggered and are seen as outputs on both the computer screen as well as on the hardware, in which the LED bulbs are used to indicate the soil moisture value. The experimental results were recorded for multiple trails of soil moisture status which is reported in Table 2.

Table 2: Multiple trails are recorded for soil moisture classification

Trails	Electrical resistivity of soil (ohm-m)	Soil moisture content (%)	Soil status
1	21	2.07	Dry
2	202	19.73	Dry
3	385	37.66	Dry
4	652	63.77	Moist
5	748	73.08	Moist
6	870	85.04	Soggy
7	887	85.76	Soggy
8	851	83.22	Soggy
9	811	79.31	Soggy
10	794	77.62	Soggy
11	707	69.08	Moist
12	569	55.64	Moist
13	442	43.22	Moist
14	402	39.27	Dry
15	372	36.35	Dry

The soil moisture content is tested at different time intervals and the corresponding readings are represented using stacked graph in Fig.4.

The input samples are preprocessed as "r1", "r2" and "r3" considering the soil moisture content values which are classified as dry, moist and soggy classes, subsequently the model is validated using Java formal languages and automata package (JFLAP) software(Rodger and Gramond 1998) and its represented in Fig. 5.

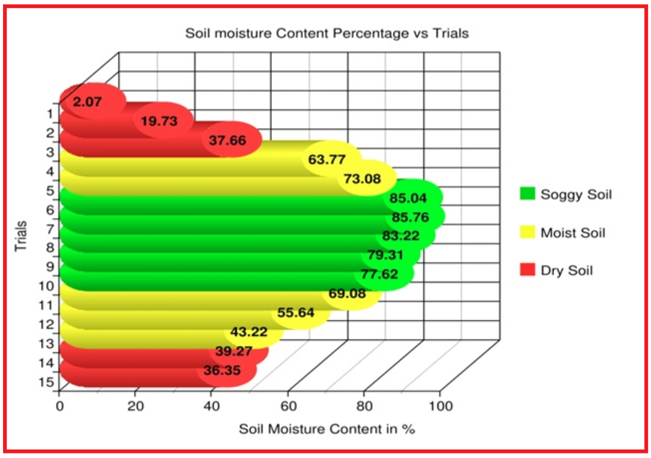

Fig. 4: Automated irrigation model predicted soil moisture status based on moisture content

Suppose if the soil status is soggy or moist, then irrigation scheduler will not be invoked. Further the soil moisture status is continuously monitored, suppose if soil is dry then irrigation scheduler is invoked, when the soil moisture value reaches the predefined threshold value the irrigation was terminated.

CONCLUSION

Soil moisture based automatic irrigation model is implemented to improve water productivity in irrigation system. The proposed model accurately classifies the soil based on the moisture content. Irrigation scheduler is triggered considering the soil moisture content. The proposed automatic irrigation model maintains soil-water balance consistently considering the soil moisture. The overall findings of the present work highlights that, the present automated irrigation model achieved a better accuracy over irrigation scheduler operation as per the real-time crop-water requirement with the aid of sensors. It also opens up the future work on soil moisture and crop coefficient based irrigation model for specific crop species.

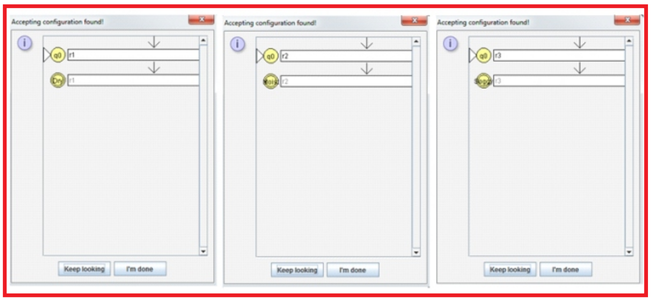

Fig. 5: Validation of soil moisture classification using JFALP software

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