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Research Article

Designing an intelligent irrigation system with fuzzy logic to improve the agriculture industry in Iran

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Abstract
Agriculture has always been one of the most important and basic human needs. Population increase, dietary changes, resource constraints and climate change are all problems that force farmers to produce more using fewer resources. According to the research undertaken in this area, the rate of water loss in Iran's agricultural industry is 28 to 30 percent, while this amount is equal to 9 to 12 percent in the world. Hence, this study focused on designing an intelligent irrigation system to improve the irrigation system in the agricultural industry of Iran, as well as examining the challenges of farmers in the field of water scarcity, costs related to intelligent irrigation systems and land flooding. For this purpose, fuzzy logic based on SPSS software was used to perform normalization operations and linear regression to determine the correlation coefficient as well as the coefficient of determination between the two characteristics of soil moisture and soil temperature and the relationship between the two with air temperature. In addition, MATLAB software has been used to design the intelligent irrigation system module. As a result, the removal of the soil temperature sensor identified as one of the useful ways to reduce the challenges of farmers, which not only can eliminate the possibility of disconnection between the soil temperature sensor and the network, but also can decrease the costs associated with the purchase and Maintenance. The use of meteorological information in addition to the information of soil moisture and air temperature sensors in the design of module inputs can prevent flooding and damage to agricultural products and conserves water significantly. The results of this study can help farmers to overcome the related challenges due to use intelligent irrigation systems.

Keywords: Smart agriculture, Smart irrigation, IoT, Fuzzy logic, Dry / wet Sensor, Temperature sensor

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1. Introduction

Agriculture is the basic industry of the national economy and agricultural products are essential for human survival and development. Iran has long been a large agricultural country, but with poor productivity. Unfortunately, many farmers still use traditional farming methods that reduce their yields. Hence, agriculture, especially irrigation, consumes large amounts of the world's freshwater. Developing countries, unlike developed countries, use more water to achieve the same performance due to the lack of cost-effective intelligent irrigation systems. Using fresh water effectively, they need intelligent strategies and systems based on advanced technologies such as the Internet of Things (IoT) [1, 2, 3].

Due to the importance of water scarcity in spite of the increase in world population and consequently more demand for fresh water, this research focuses on designing an intelligent irrigation system with fuzzy logic to promote the irrigation industry in Iran.

Therefore, the research question is posed as follows:

What will the intelligent irrigation system based on IoT technology be like?

The development of such a system, reduces production costs and facilitates knowledge management in this area, it also helps to solve existing problems and achieve rapid and effective agricultural development [1, 2].

In order to design an intelligent irrigation system with fuzzy logic the structure of this study will be as follows; at first, the influential and key factors in designing an intelligent irrigation system based on the Internet of Things will be determined, and then, using MATLAB software, a model for designing an intelligent irrigation system with fuzzy logic will be presented to prevent land flooding.

2. Related literature

In 2019, an intelligent irrigation system with fuzzy logic was designed by Safdar Munir et al. which made decisions based on the values of four input variables including soil moisture, air temperature, air humidity and light intensity turn the water pump on and off [4].

In 2019, an intelligent irrigation system with fuzzy logic was designed by City Amat et al. which its input was the volume of variables of soil moisture, soil temperature and air humidity and its output was in the form of a two-state water pump [5].

In 2008, Bittelli et al. stated "there is a strong relationship between soil moisture and temperature, and it is important to conside r temperature when assessing soil moisture" [6].

In 2011, a study on the relationship between air temperature and soil temperature at different soil depths was conducted by Ghaeminia et al. which detected the highest coefficient of determination between air temperature and soil temperature at the level of 5 cm of soil [7].

In 2010, the average daily soil temperature in some climatic samples of Iran was estimated by meteorological data by Sabzi Parvar et al. The results showed that there is a high correlation between air temperature and soil temperature at depths of 5 and 10 cm [8].

In 2011, according to a study conducted by Parsafar and Marouf. The correlation between soil temperature and air temperature in different soil depths using regression relationships on neural network and neural-fuzzy network, it was concluded that the decrease in air temperature leads to decrease the soil temperature at different depths. In addition, the lowest correlation coefficient determined 0.863 for a depth of 100 cm [9].

Examining the studies conducted and the results obtained in this study, a system can be designed that, as far as possible, to reduce the problems of farmers in the field of water shortage and the use of intelligent irrigation systems. The focus of this research is on designing an intelligent irrigation system, using fuzzy logic that has 4 inputs of soil moisture sensor, air temperature, meteorological information of the same day and the next day, as well as a 5-state water pump as the system output.

3. Research methodology

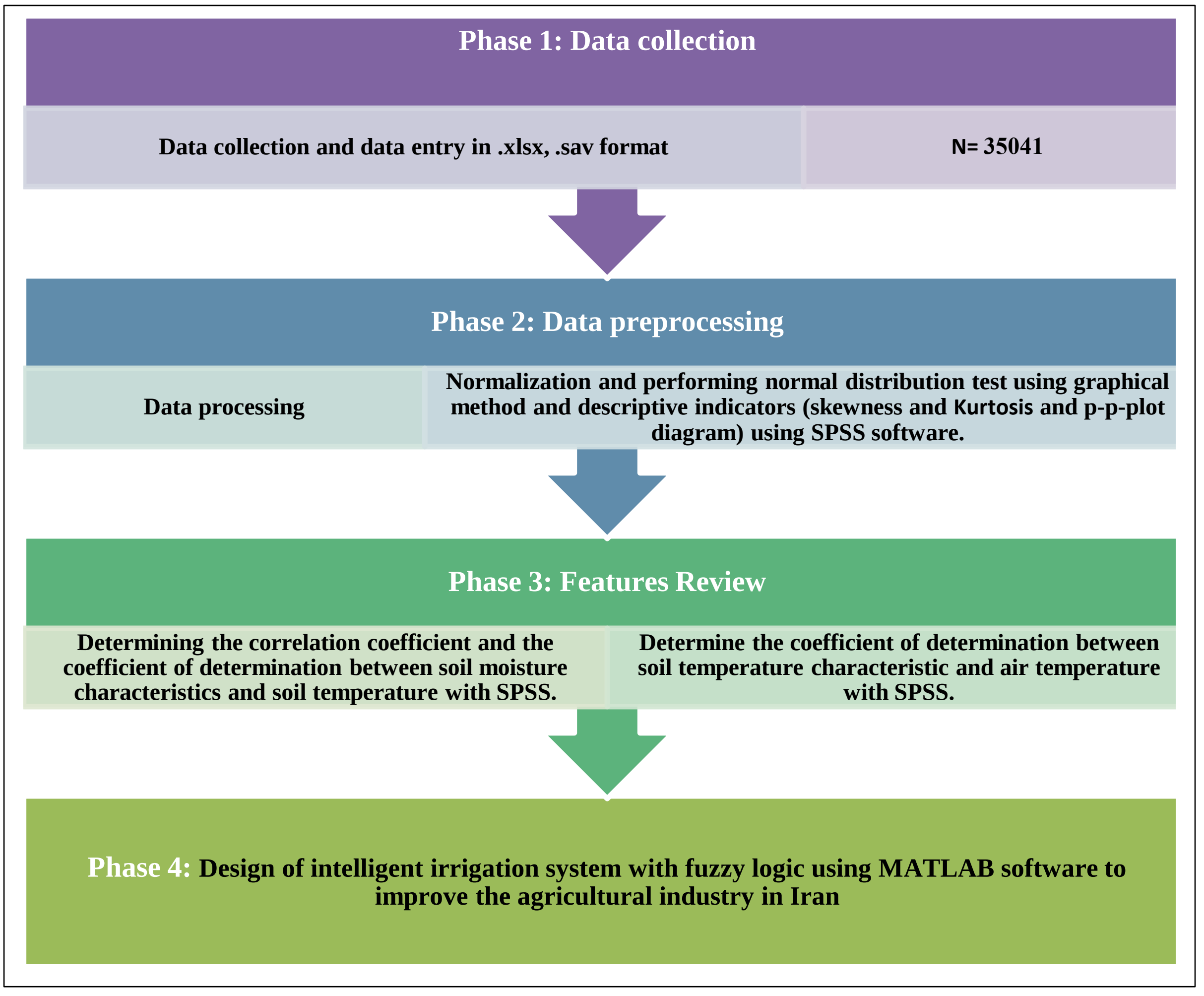
The research method used in this research is applied research in terms of purpose and descriptive research in terms of implementation method. Research data are also quantitative data. In this research, we seek to explore the correlation between 35041 quantitative data related to soil moisture and soil temperature at depths of 80, 40, 20, 10, 5 cm in the Netherlands. In order to investigate the effect of quantitative variables of soil temperature on the quantitative response variable of soil moisture, statistical analysis techniques and linear regression method in SPSS software have been used. In addition, MATLAB software was used to design the intelligent irrigation system module. Finally, we decide to design an intelligent irrigation system with fuzzy logic to improve the agricultural industry in Iran.

3.1 Dataset used in the paper

Due to the lack of data related to Iran, we had to review the data related to the Netherlands. The statistical population of this research is 35041 quantitative data related to soil moisture and soil temperature data for depths of 80, 40, 20, 10, 5 cm, for a period of one year from 05/04/2017 to 05/04/2018, is for the Netherlands.

3.2 Research Strategy

The strategy for this research is shown in Flowchart 1.



Flowchart 1: Methods of research ahead.

4. Data Analysis

Statistical analysis techniques will be used to analyze the data in the present research. To investigate the effect of quantitative variables of soil temperature on the quantitative response variable of soil moisture, linear regression method according to Equation (4. 1) will be employed. In fact, by using the linear regression method, the correlation coefficient (according to Equation 4.2) and the coefficient of determination between the two properties of soil moisture and soil temperature and the relationship between the two with air temperature can be obtained (according to Equation 4.3).

$$Y = \beta_0 + \beta_1 X + \varepsilon \qquad (4.1)$$

$$r^2 = \frac{a\sum y + b\sum xy - n\bar{y}^2}{\sum y^2 - n\bar{y}^2} \qquad (4.2)$$

$$r = \sqrt{r^2} \qquad (4.3)$$

4.1 General results of statistical analysis

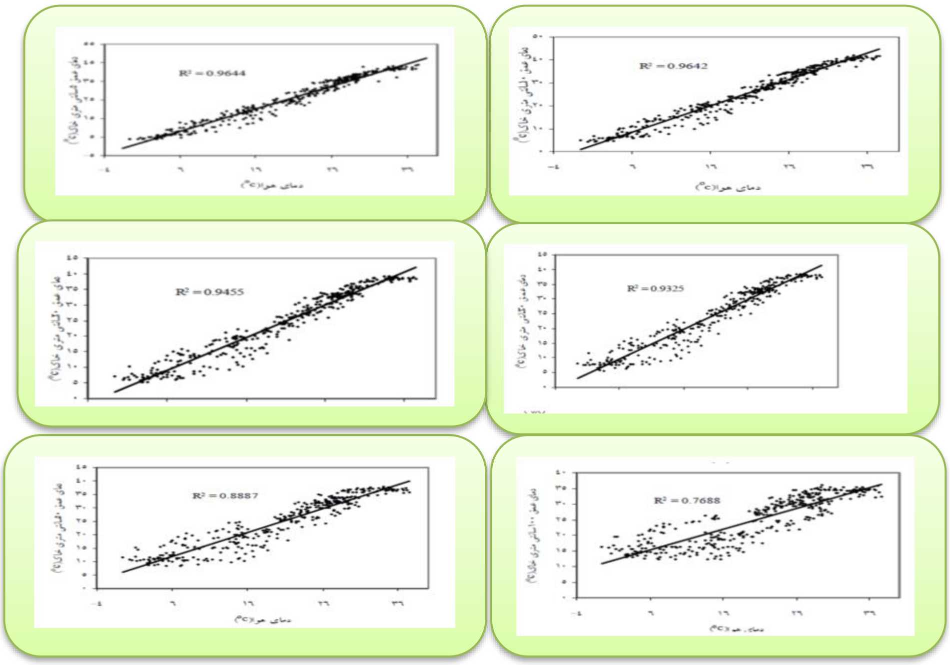
The results of statistical analysis in this study (Table 1) show a high correlation between soil moisture and soil temperature. The results of the analysis of data related to spring, summer and general data for one year are shown in Table 1.

The results of a study by Sabzi Parvar et al. (2010), Parsafar and Maroufi (2011), Ghaeminia et al. (2011), Aliabadi et al. (2015), demonstrated a high correlation between soil temperature and air temperature [6,7,8,9]. The results of studies and analysis in this study indicate a high correlation between soil moisture and soil temperature and correlation between soil temperature and air temperature. graph 1 shows the relationship between the coefficient of determination and the correlation between soil temperature and air temperature.

Table 1: Summary of the situation of different depths.

normal distribution	Data for one year			Summer data			Spring data			Depth
	Standardized regression coefficient	R	R^2	Standardized regression coefficient	R	R^2	Standardized regression coefficient	R	R^2	
✓	-0.622	0.622	0.387	-0.463	0.463	0.463	-0.602	0.602	0.362	5 CM
✓	-0.650	0.650	0.423	-0.558	0.558	0.311	-0.514	0.514	0.265	10 CM
✓	-0.706	0.706	0.498	-0.484	0.484	0.234	-0.684	0.684	0.468	20 CM
✓	-0.770	0.770	0.593	-0.322	0.322	0.104	-0.847	0.847	0.718	40 CM
✓	-0.943	0.943	0.890	-0.766	0.766	0.766	-0.925	0.925	0.856	80 CM

The results indicate a strong dependence of soil moisture on soil temperature and a dependence of soil temperature on air temperature. Based on this, air temperature can be used instead of soil temperature sensor in designing the input of intelligent irrigation system. By removing the soil temperature sensor, the costs related to purchase and maintenance are saved, and also the possibility of disconnection between this sensor and the network is eliminated. Therefore, it not only reduces the challenges facing farmers, but also increases the reliability and trust among farmers.



Graph 1: Relationships between daily temperature of different soil depths and daily air temperature for one year [6].

The results indicate a strong dependence of soil moisture on soil temperature and a dependence of soil temperature on air temperature. Based on this, air temperature can be used instead of soil temperature sensor in designing the input of intelligent irrigation system. By removing the soil temperature sensor, the costs related to purchase and maintenance are saved, and also the possibility of disconnection between this sensor and the network is eliminated. Therefore, it not only reduces the challenges facing farmers, but also increases the reliability and trust among farmers.

4.2 Design of intelligent irrigation system module with fuzzy logic

This sub- section focuses on implementing a fuzzy logic control system using Mamdani control system. The inputs of the fuzzy logic control system include data related to the soil moisture sensor, air temperature and air condition of the same day and the next day. Membership functions of the soil moisture input variable have three membership functions. They are indicated by **dry**, **normal** and **wet**. Humidity input range is between 0 and 60.

Dry has a range of 0 to 30, Normal 27 to 35 and wet has a range of 33 to 60. The temperature input variable has three membership functions. They are indicated by **cold**, **normal** and **hot**. The temperature inlet range is between -30 to 50 degrees. Cold has a range of -30 to 16 degrees, Normal has a range of 14 to 23 degrees and hot has a range of 21 to 50 degrees. Meteorological status input variables have three membership functions, represented by **sunny**, **cloudy** and **rainy**. The input range of the weather condition is between 0 and 30. Rainy has a range of 0 to 10, cloudy has a range of 8 to 20 and sunny has a range of 18 to 30. The output of the fuzzy logic control system is a five-state water pump (off, on% 25, on%50,on75%,on

100%). The membership function type is trapezoidal for all entries. The simulation was performed using MATLAB software.

The membership functions of the input variables of soil moisture and temperature and meteorological information as well as the membership functions of the output variables of the water pump are shown in Figure 1.

The if-then rules in this module include 81modes made in the "Rules" section of MATLAB.

The output results of the designed module with respect to the inputs given to the system are shown in Figure 2.

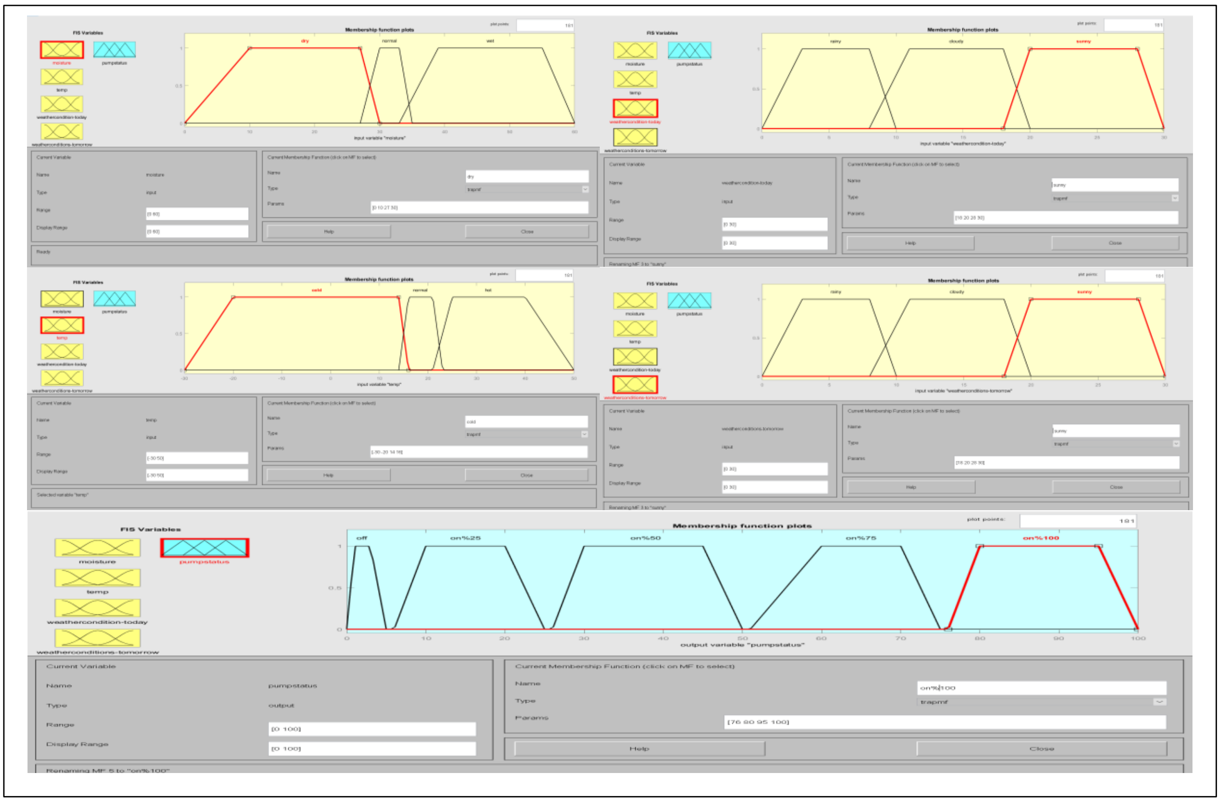
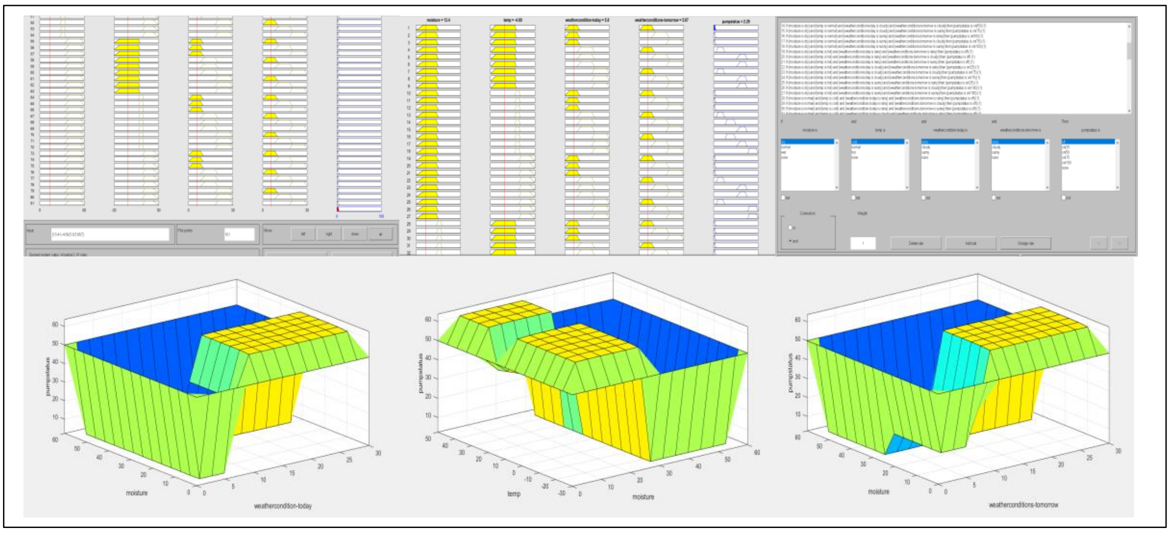


Figure 1: Membership functions of input variables of soil moisture and temperature and meteorological information and membership functions of output variables of water pump.



5. Conclusion

This paper focuses on providing a model for designing an intelligent irrigation system with fuzzy logic to improve the irrigation industry in Iran and also examines the challenges of farmers in the field of water shortage and the use of intelligent irrigation systems. Accordingly, due to the challenges of farmers and water scarcity, in this study, a module is presented that reduces the challenges facing farmers as much as possible. In designing the module inputs, soil moisture, air temperature and meteorological information have been used due to the importance of these items in the irrigation process of a farm. The advantages of using meteorological information in designing the input of intelligent irrigation system include; preventing flooding and crop damage, optimizing water consumption, increasing reliability and trust among farmers. The proposed system in this research helps to manage water resources effectively and promote the agricultural industry in Iran. The results of this research can be complemented and improved in the line of promoting agriculture industry based on IoT technology

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