A FUZZY APPROACH FOR WATER SECURITY IN IRRIGATION SYSTEM USING WIRELESS SENSOR NETWORK

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ABSTRACT: *Water is one of the most important elements on earth, if there will no water there will be no life. It is inevitable to conserve and save water for future security and sustainability. Several technological approaches have been formulated in past but depicted substantial mark. During last decade concept of Fuzzy logic was introduced with implication towards water conservation; being wasted in manual irrigation. Fuzzy based intelligent irrigation control system could recover water deficiency using wireless sensors. This system access the moisture level of soil and temperature of surrounding area with the help of wireless sensors controlling the sprinkler to irrigate the field within the requirement. To control the irrigation system efficiently this system consists of soil moisture, temperature sensors, and an intelligent controller using fuzzy logic approach for irrigation. Mamdani type Fuzzy Inference System is used to design fuzzy controller in MATLAB and then run its simulation to check the characteristic of the system when inputs vary. This new irrigation system which is based on the combination of WSN with fuzzy logic has many advantages over a traditional irrigation system with binary control said system holds tendency to help in better improving agricultural productivity delimiting water utilization. State should make sure accessibility of such technologies to small farmer that represent major population of farming community not only for empowerment and facilitation of small farmer but also for the development and prosperity of the country.*

Key Words: Fuzzy Logic, Precision Agriculture, WSN, Irrigation Control System.

INTRODUCTION:

Agriculture plays a vital role in economy of countries throughout the globe providing raw material to industries and fulfilling the increasing needs of immensely growing population pressure. However, in spite of great agricultural importance, productivity is not up to the mark and farmer's gains are substantial. Several issues are anticipated responsible like high cost of production, inflation, poverty, agricultural risks, inadequate access to finance, inadequate availability of inputs and the most noteworthy climate change; putting huge threat to the water availability, which is prime source of irrigation in agriculture sector.[1]

Water is very important and crucial factor for crop production [2]. During last decades conventional agriculture has been changed to Precision agriculture to overcome the problems which farmer's faces during performing different agriculture tasks. Precision agriculture means observing, assessing and controlling different agricultural practices with the help of modern technologies. Precision agriculture makes agricultural operation more proficient and efficient and as well as reduce wastage of resources [3]. Precision agriculture is a three phase cycle i.e. data collection phase, data interpretation and Application. In data collection phase different parameters are considered and studied like temperature and humidity of soil. This phase is more or less automatic. In second phase of data interpretation, farmer decides that whether he/she has to adopt the technology or not. Last and third phase is application of certain technology and adjustment of machines in the field and finalization of modules like irrigation water requirement [3].

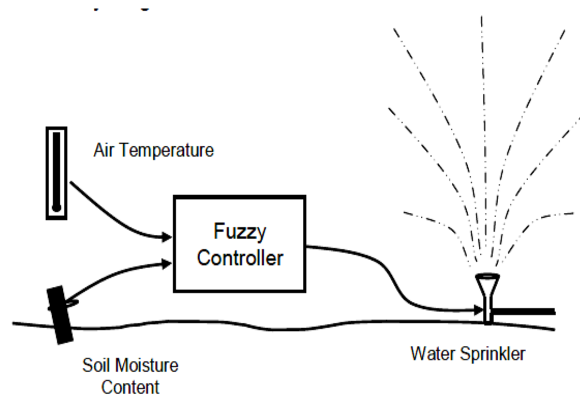

Fig 1: A typical Fuzzy Watering System

Precision Agriculture (PA) is an efficient and worthwhile system that assists to increase productivity and profitability for long-term especially in agriculture sector. Sub-continent is basically a rain-fed area where agriculture sector depends upon rain and natural sources of water. In precision farming farmer invest less time, less input, less labor force but get maximum benefits. These objectives can only be achieved with the help of sensing technology that control and monitor utilization of resources and other parameters [2]. Irrigation Control is important for better production of crops, through automatic irrigation system, we can increase efficiency of water irrigation by sensing temperature, moisture and other parameters of different crops at different times [4].In conventional irrigation method farmer manage supply of water according to his experimental experience. This method have many disadvantage like expensive labor, moreover sometimes water reaches late and also more or less in quantity due to which crops get dry thus automatic irrigation system is needed to decrease labor expenses and provide uniformity in water supply in the field [5].

TRADATIONAL CONTROL SYSTEM AND FUZZY LOGIC:

Conventional running methods are based on knowledge to control the active system. Accurate results are required for successful implementation of control algorithm but from conventional methods it is quite not possible because a majority of systems are non-linear and too complicated to understand. Likewise conventional controller based on mathematical model could be helpful to control physical system [6]. Therefore in real implementation it is quite difficult to make an accurate nonlinear model without complete physical insight. Fuzzy is used to control the non linear system. It provides a pathway to stimulate and implement human knowledge of controlling different systems. Fuzzy control can easily handle both qualitative and quantitative data; Qualitative data is collected through common knowledge and with the help of expert operator approach [7]. Benefits of fuzzy control are summarized below

ROBUSTNESS: As compare to PID controller fuzzy control is more strong and powerful. It can rugged and withstand noise and environment disturbance.

COST: Conventional Controllers are much expensive as compare to fuzzy controller.

FLEXIBILITY: Fuzzy is easy to implement and control, transform and apply it into real life applications. Fuzzy is suitable in controlling embedded systems due to its simplicity, provide result in no time. No doubt that fuzzy control is most suitable and efficient software for controlling embedded systems due to its simplicity [8].

WIRELESS SENSOR NETWORK FOR PERCISION AGRICULTURE:

WSN are used for different purposes in every aspect of life, like controlling, prediction of abrupt changes in environment. A significant reason for the use of WSN in the field of agriculture is that it helps to collect data regarding different factors that could be helpful to improve and as well maintain the crop yields [9][10]. Furthermore it is cheaper, flexible and robustness as compare to wired sensors .WSN is in its initial stage in agriculture; however scientists are trying to improve production of crops by using Wireless sensing technology. During last decade the improvements in wireless sensor network facilitate agriculture to a great extent. [11]

SENSORS FOR PERCISION AGRICULTURE:

Soil Moisture and Temperature: The mostly used sensor for soil moisture and temperature is ES1100 Watermark Sensor. In order to measure soil moisture, different ES1100 sensors can be connected in a node at different points as required. [12]

Fig 2: ES1100 Watermark Sensor (source memsic.com)

Ambient Temperature and Humidity: ES1201 sensor is used to measured the humidity and atmosphere temperature; it is also helpful in calculating dew point. The membrane filter safe the sensor from dust, water and different chemicals whereas sensor enclosure protect sensor from damage. [12]

Fig 3: ES1201 sensor (source memsic.com)

WATER REQUIREMENT FOR CROPS: Water requirement mainly depend on temperature, humidity and wind speed [13]. Crops which grown in warm atmosphere require extra water than crop grown in cool atmosphere furthermore the crops need more water when its dry and in windy climates .In case of hot, dry, windy and sunny crops require more water as compare to cool, humid and when there is no or little wind.

Table 1: Effect of Major Climatic Factors on Crops Water Needs (source C. Brouwer and M. Heibloem 1986)

Climatic Factor	**Crop Water Need**	
	High	**Low**
Sun Shine	Sunny (No Clouds)	Cloudy (No Sun)
Temperature	Hot	Cool
Humidity	Low (Dry)	High (Humid)
Wind speed	Windy	Little Wind

It is clear from above table that the same crop require different amount of water in different climatic situation. For instance, maize grown in hotter climate needs more water compare to maize grown in cool climate [13]. For this reason it is helpful to take one crop as a standard and check how much that crop requires water in a day in different climatic situations. For this purpose grass has been chosen as a reference crop.

Standard Grass(source C. Brouwer and M. Heibloem 1986)

Data depicted in Table-2 shows the daily requirement of water for grass in different climatic regions and in different temperatures. It is quite easy to estimate amount of required water of different crops as compared to the standard grass. Following table is showing amount of water by different crops in their peak period. Crops in column 1 and 2 need

Table 2: During Irrigation Average Water Need of 30% and 10% less water than grass respectively.

Climatic zone	Mean daily temperature		
	Low	medium	high
	(less than 15°C)	(15-25°C)	(more than 25°C)
Desert/arid	4-6	7-8	9-10
Semi arid	4-5	6-7	8-9
Sub-humid	3-4	5-6	7-8
Humid	1-2	3-4	5-6

In 3rd column crops need same amount of water as Grass. The crop in 4th and 5th column need 10% and 20% more water as compare to grass respectively.

FUZZY LOGIC SYSTEM: A fuzzy set is an extension of a crisp set. In crisp sets there is only full membership or no membership while fuzzy sets allow partial memberships. Membership Function (M.F) is a curve that tells where each point of the input is mapped to a membership value between 0 and 1. Different membership functions are used in fuzzy like, triangular, trapezoidal, Gaussian curves, polynomial curves, and sigmoid functions. A simple block diagram of fuzzy logic System is shown in Figure

From the figure it can be seen that the Fuzzy logic system have four components, which are Fuzzification Interface (Fuzzifier), Decision making unit (inference engine), Rule Base, and Defuzzification Interface (defuzzifier). Linguistic rules given by experts are easily extracted in numeric form which is present in Rule Base. When the rules have been set, fuzzifier maps the inputs into fuzzy memberships. Input values are taken by Fuzzifier to activate defined rules by linguistic variables and determine relationship with each fuzzy set with the help of membership functions. Input and output fuzzy set is defined by inference engine, it also define level of satisfaction of antecedent for each and every rule. Fuzzy operator is used to represent results if more than one clause for antecedent is given. All the results are aggregates in to a single fuzzy set. One of the most important aspects of FIS is that Fuzzy rules are fired in parallel way but order how the rules are fired does not affect output. Defuzzifier converts fuzzy output into crisp number. Different practices are used for defuzzification like the mean of maxima, centroid, maximum and height defuzzifier but the most known common technique is the centroid. Numeric Data and linguistic knowledge all together can be controlled by Fuzzy systems [14]

TYPES OF FUZZY INFERENCE SYSTEM:

In fuzzy control there are two main types of control rules:

Mamdani System: Expert knowledge is basically collected by this method. This method allows us to explain knowledge in more spontaneous and lively manner. Moreover, Mamdani-type (FIS) gave a detail and significant computational saddle.

Takagi- Sugeno: This method is used by professionals mostly in control problems and in non linear system. In this method membership functions can be customize so data can be best modelized by the fuzzy system. [15]

WHY FUZZY:

Binary sets take fixed and exact value whereas fuzzy deals with approximation reasoning and its true value range from 0 to 1. The Fuzzy logic is designed to manage the partial truth. Fuzzy have good performance as compare to PID controllers, used for multi inputs and multi-outputs and also it is easy to handle.[14]

FUZZY CONTROLLER FOR IRRIGATION SYSTEM:

Following points should be considered to make sure suitable design and process of a water distribution system:

Field Contained Moisture

Temperature of Surroundings and Humidity

Another parameter could be Type of Crop and its Water Usage which differs for every crop as shown in section 4. The fuzzy controller designed in this research is best suitable for standard grass but it can be used for other crops according to their watering needs with respect to standard grass as shown in table 3.

With The different temperature and moisture level the water requirements (intake) vary accordingly. Timely and appropriate amount of supply of water should be guaranteed to carry the growth of the crop in a proper way. [16]

Table 3: Different Crops Water Requirement with Respect to Standard Grass (source C. Brouwer and M. Heibloem 1986)
From above Table to citrus as compared to grass is 6.0-30%=6.0-1.8=4.2mm/ water required Day [13]

Column 1	Column 2	Column 3	Column 4	Column 5
-30%	-10%	same as standard grass	+ 10%	+20%
citrus	cucumber	Carrots, melons	Cotton, soybeans,	paddy rice
olives	radishes	crucifers (cabbage, cauliflower, broccoli, etc.)	Tomato, potatoes	Sugarcane
grapes	squash	Lettuce, spinach, tea, grass	Maize, peas	nuts & fruit trees with cover crop

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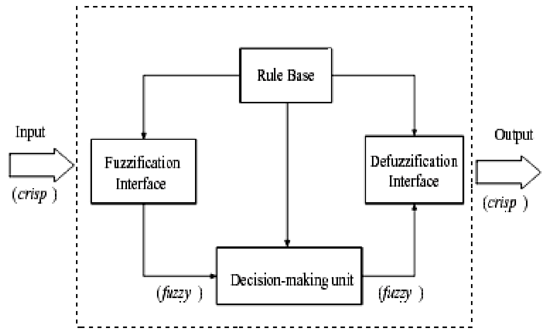

Figure4: Block Diagram of Fuzzy logic system (source H. Singh,2013)

In agriculture field temperature and humidity sensors are deployed and Sensor nodes sent data to FIS. In order to design FIS, a choice should be made to select input sensors and output actuators. In this research temperature and Humidity sensors with following membership functions are considered. Moreover actuators are required to be attached with sprinkler and operate according to the output of fuzzy controller. Temperature M.F consist of five portions (cold, cool, normal, warm and hot) while Humidity crisp consist of three(Dry, Moist, Wet).These M.Fs works together to give accurate output.

After Tuning limit ranges for each membership function it will help to find possible solution for specific crops based on requirements of plants, knowledge and working experience. Adjusting these values to make outputs more adequate and comprehensive according to the requirements of the crops [7]. Following table is showing a summary of 15 fuzzy logic rules for this research.

Table 4: Fuzzy rules summary (source author calculation

	COLD	COOL	NORMAL	WARM	HOT
WET	SHORT	SHORT	SHORT	SHORT	SHORT
MOIST	SHORT	MED	MED	MED	MED
DRY	LONG	LONG	LONG	LONG	LONG

DESIGN OF FUZZY CONTROLLER FOR IRRIGATION SYSTEM:

In order to design the Fuzzy Logic Controller there are four steps required as follow.

METHODOLOGY:

Step 1: Identification of Control Surfaces: linguistic variables are recognized and membership values for each variable are calculated in this step. The input and output variables are shown in figures 5-7.

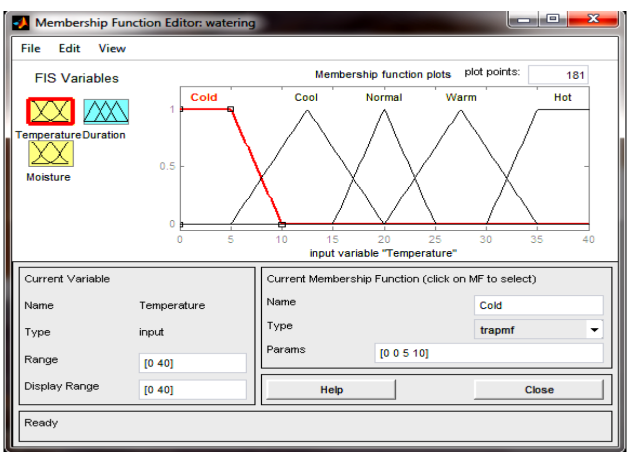

Fig 5: Membership Graph for Temperature Input

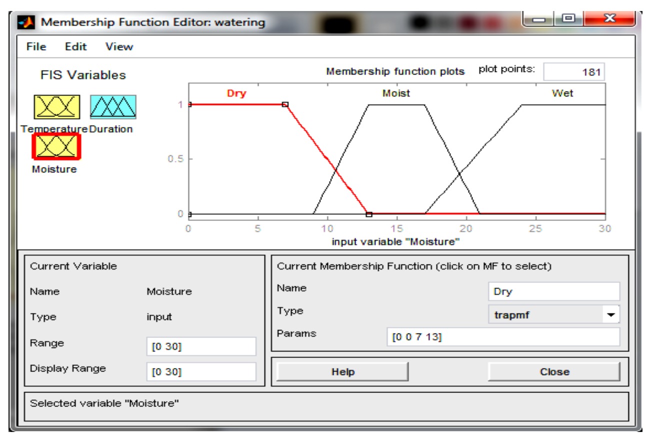

Fig 6: Membership Graph for Moisture Input

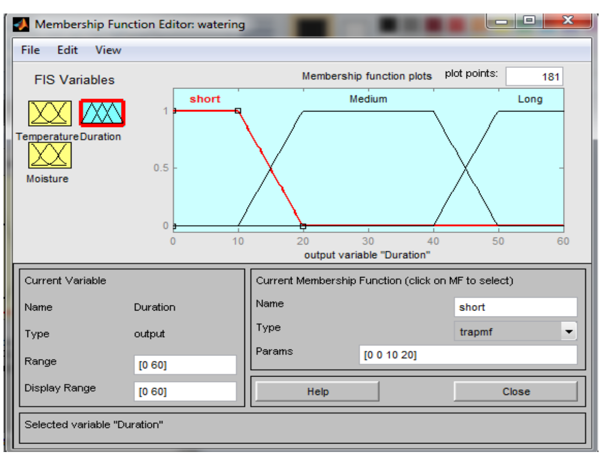

Figure 7: Membership graph for Output [Source: Author calculation]

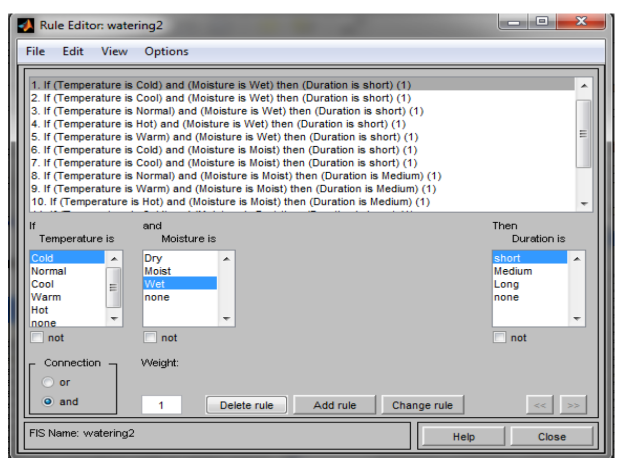

Fig 8: Fuzzy Defined Rules for Water Distribution [Source: Author calculation]

Step 2: Behavior of Control Surfaces: In this step fuzzy rules are constructed for different inputs to perform different actions. Fuzzy inputs associate with fuzzy output by fuzzy rules. The rule viewer is shown in figure 8 which are derived from table 4.

STEP 3: Fuzzy Inference System and Decision Making: The FIS consists of fuzzy rules which are derived by information of experts or from input-output learning of system. Rules mimics' human reasoning .Mamdani method is generally used in fuzzy inference technique. Fuzzy inference system used rules to generate fuzzy outputs, in this system there are 2 inputs against each input there is fuzzy linguistic variables as shown in Figure 9.

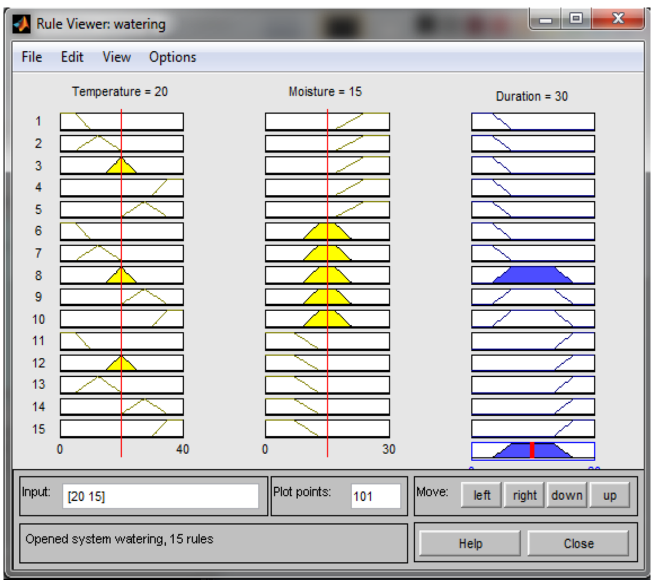

Fig9: Fuzzy Inference System and Rule Viewer Output [Source: Author calculation]

Step 4: Defuzzification: Defuzzification is a process of conversion from a fuzzy set to a crisp number. For crisp input value, there are fuzzy membership for input variables, and each variable cause different fuzzy outputs cells that will used to activate or to be fired. Output will change into crisp value from this procedure of defuzzification. Defuzzification can be done by different methods but most common technique is centroid method. [17]

DISCUSSION:

All of the above given Outputs are obtained with the help of software called Matlab. Different inputs conditions are given to the software to display the results. No doubt matlab shows highly accurate results and will be helpful in near future. All the results are displayed and discussed in the form of flow chart and diagrams.

COMPARISON WITH A ON OFF CONTROLLED IRRIGATION SYSTEM: Usually irrigation systems are deployed with on off control systems which take inputs from either sensor in the field or directly operate according to a fixed timer. Here we considered an on off controller with the same sensing inputs from the field i.e. temperature and Moistures. The controller operated according to the following flow chart;

The controller turns on when the threshold of set point for both sensing inputs is reached and remains on until the sensing value are in set point range.

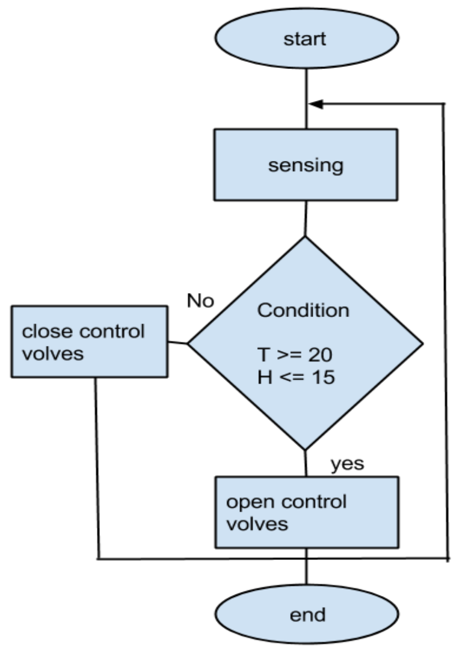

Fig 11. On Off Controller flowchart [Source: Author calculation]

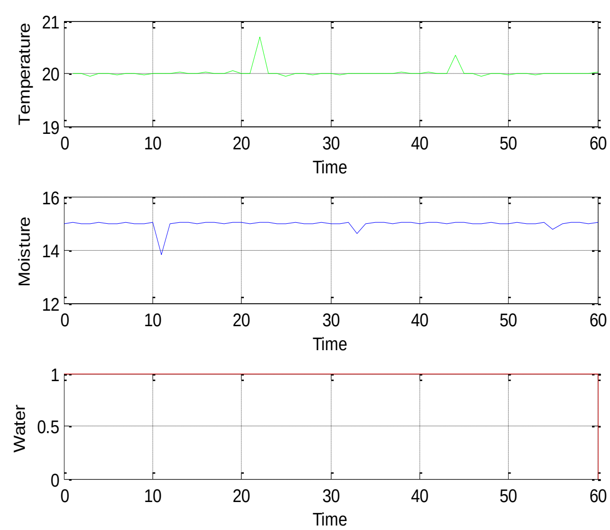

Fig 12. An On off Controller [Source: Author calculation]

The figure 12 shows an input from temperature and humidity sensors, both values remain in the ON range of controller throughout an hour of irrigation which results in 60 minutes irrigation duration. Whereas in case of fuzzy logic controller the same inputs were used but the fuzzy controller manages the water duration for 30 minutes. Hence resulting in efficient utilization of resources.

CONCLUSION:

In this paper Fuzzy controller with wireless sensor networks are introduced to manage irrigation system in agriculture sector. Results of this study showed an optimization of resources in case of fuzzy logic controller in contrast to an on off control system. This type of irrigation system not only saves water from wastage but also helpful in better production of crops further more this is really helpful for countries where agriculture sector depends upon rain and natural sources of water. It can be reckon that in future the precision agriculture projects may have a significant popularity.

RECOMMENDATIONS:

- Engineers should have to promote such a systems through which we use minimum natural resources and get maximum output further more such a system is very helpful in countries where there is shortage of water.
- We should introduce such a system in commercial level which help farmers not only to increase their production but also in natural resources conservation.
- Government should provide loans and credit for such a great technologies through which common man can easily access to such a technologies.

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