IMPLEMENTATION OF FUZZY CONTROLLER TO REDUCE WATER IRRIGATION IN GREENHOUSE USING LABVIEW

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ABSTRACT: *Plant cultivation in greenhouse is influenced by various factors, such as soil quality, water availability, and climatic conditions. Techniques have been developed either to adapt food crops to their environment or to adjust the environment to meet plant needs. In this paper, a fuzzy controller (FC) has been implemented for monitored drip irrigation duration to reduce water using as variables soil moisture degree and air temperature in greenhouse. Soil moisture degree can be detected by an electronic circuit based on a capacitive probe. The FC permits to irrigate at the right time, when the plant needs water and the soil water is insufficient. Sensors and actuators (pump and solenoid) are installed and connected to a PC via a data acquisition card NI PCI 6221. A graphical user interface was developed using LabVIEW to acquire data and monitor drip irrigation station.*

KEYWORDS: Fuzzy Controller, Soil moisture, LabVIEW, Drip irrigation, Greenhouse.

INTRODUCTION

Modern greenhouse production is also referred to as controlled environment agriculture. Increasing the water use efficiency, relative to other conventional irrigation methods, is one of the most relevant advantages of drip irrigation, if it is properly operated [1]. An automated irrigation system not only allows a better water use efficiency but it also provides all the necessary information to generate detailed water usage reports which are critical to assess and improve irrigation performance. An automated irrigation system resolves one of the most difficult irrigation problems: when and how much water to apply to ensure thorough wetting of the root zone without loss of water past the roots. The flow front from the irrigation water can easily be detected with soil water sensors buried in the ground at the required depth [2]. Once the soil has reached desired moisture content, the sensors send a signal to a controller to turns off the power to a solenoid valve or a pump which controls irrigation. As a result, the automated irrigation system prevents water escaping past the root zone and therefore, improves the efficiency of water use [3]. Each producer of greenhouse crop should know how much water to add to the soil at each application. With this information and by examining the soil before watering and several hours thereafter, the effectiveness of the water application can be determined [4]. Air temperature is the main environmental component influencing vegetative growth, cluster development, fruit setting, fruit development, fruit ripening, and fruit quality. Irrigation duration and frequency depend on local climate, environmental conditions, vaporization speed of the soil and water demand level of the plants. In drip systems, good management will always be based of very high irrigation frequency, even several times each day, especially when using saline water, being the water storage role of the soil unimportant relative to conventional irrigation methods. In soilless culture, the irrigation frequency must be several times per day, dividing the daily water requirements, according to the evaporative demand and the water storage characteristics of the substrate [5, 6, 7]

Fuzzy theory interprets real uncertainties and becomes ideal for nonlinear, time varying and hysteretic system control. These conventional controllers in power plants are not very stable when there are fluctuations and, in particular, there is an emergency occurring. Continuous processes in power plant and power station are complex systems characterized by nonlinearity, uncertainty and load disturbances. The characteristics of a power plant greenhouse system change significantly between heavy and light loading conditions. Applying of traditional control methods encounter great difficulties while the process working condition changes within a large operation range [8-12].

The following paper describes the design, implementation of a FC which monitored drip irrigation duration using as variables soil moisture degree and air temperature in greenhouse. The FC presented involves different combinations of input variables, membership functions, and rule bases. The acquisition system recorded climatic conditions and degree of soil moisture from sensors. This system was implemented and tested using micro-irrigation under plastic mulch with peppers. The authors reported that the system performed satisfactorily in a fully automated manner in response to the inside temperature and soil moisture degree variations.

Greenhouse system

Figure 1 shows the functional block diagram of the greenhouse system. Sensors card and power card are connected to the computer system through a data acquisition card NI PCI 6221 [13]. A FC has been implemented for controlled drip irrigation duration using as variables soil moisture degree and air temperature in greenhouse. A Virtual Instrument (VI), based on National Instruments LabVIEW 2011, was developed to acquire, record data and monitor greenhouse.

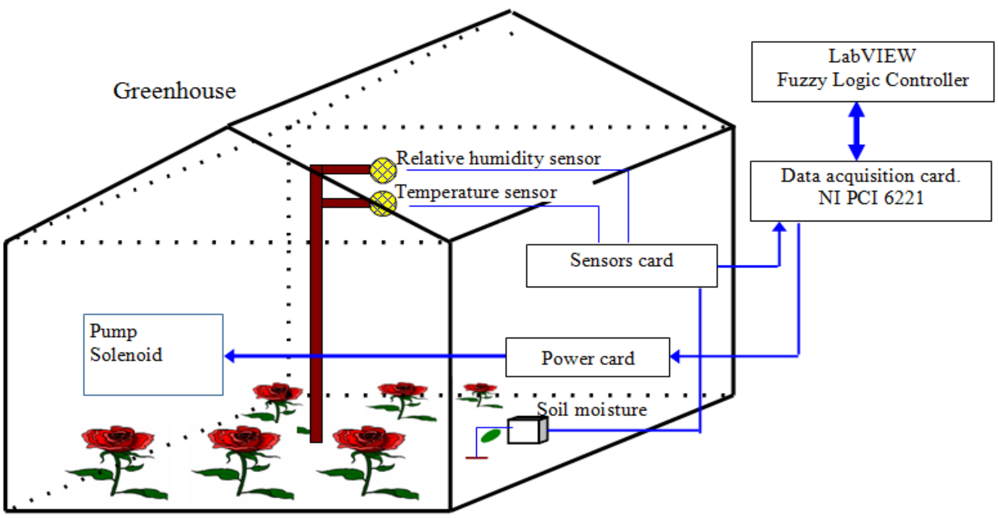

Figure 1. Greenhouse system

SENSORS CARD

The block diagram of the developed sensors card is shown in Figure 2. This card performs the measurement inside temperature and the soil moisture degree in greenhouse. The outputs of circuit conditioner are connected to analog inputs of data acquisition card NI PCI 6221.

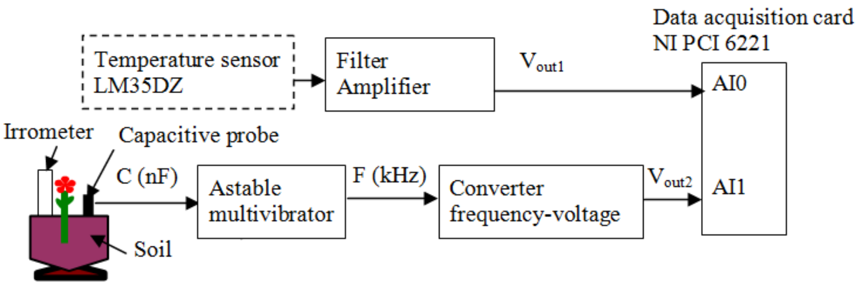

Figure 2. Sensors card

For temperature measurement, our choice was carried out on a sensor LM35DZ with a sensitivity of 10mV/°C. The equation of variation of the output voltage of the circuit conditioner as a function of temperature is from related as follows [14]:

$$T = 11.7 \times V_{out1} - 2.05 \qquad (1)$$

With: T in °C and V_{out1} in Volt

The irrometer operates on the tensiometer principle and indicates soil water tension, displaying in units of centibars (cb) or kilopascals (kPa) (www.irrometer.com). Includes reservoir, air free gauge chamber and hermetically sealed irrometer vacuum gauge with dual scale of centibars and kilopascals (0-40 cb [kPa] range).The irrometer incorporates soil moisture indicator to aid in calibrating the electronic circuit measuring soil moisture degree. A higher tension reading indicates drier soil; a lower reading the irrometer shows wetter soil. Soil moisture degree can be detected by an electronic circuit based on a capacitive probe. The circuit conditioner consists of an astable multivibrator followed by a converter frequency-voltage. Depending on the soil water status, the V_{out2} output varies between 1, 2 V (dry) and 3, 82 V (wet). After several tests, the irrometer has given the relationship between V_{out2} (V) degree and soil moisture (%) (see Table 1).

Table 1: Relationships between V_{out2}(V), irrometer indication (cb) and Soil moisture degree (%)

V_{out2}(V)	Irrometer (cb)	Soil moisture degree (%)
0	40	0
5	2	100

Power card

The electronic circuit of the power card is shown in Figure 3. It’s developed for controlling irrigation system equipment (solenoid, pump). The digital outputs (DO) of the NI 6221 card control of static relays based on triac TBA16A/600B through the integrated circuit ULN2803. The phototriac K3021P provides isolation between the ULN2803 and the triac.

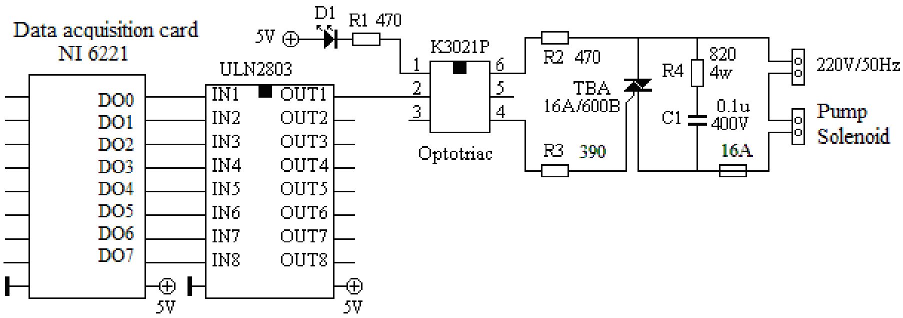

Figure 3. Power card

Drip irrigation system

The circuit of drip irrigation includes an electric pump group (Figure 4), a system of filtration, a flow indicator, a solenoid and principal and secondary drain pipes to which gutters are connected [15]

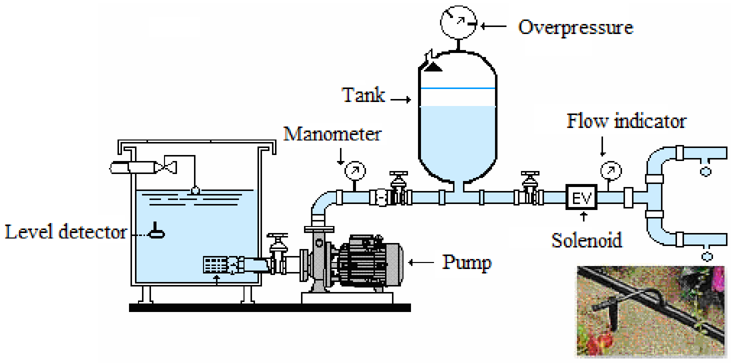

Figure 4. Drip irrigation system

FUZZY CONTROLLER

The block diagram of the FC is illustrated in Figure 5. The fuzzy logic system included fuzzification via membership functions, rule base, a rule evaluation and aggregation and a defuzzification to create the crisp outputs. Tow inputs selected were: inside air temperature T_{in} and soil moisture degree S_m. The irrigation duration D_{irr} was defined as a single fuzzy output variable. The range (universe of discourse) of the inputs and output variables was selected by examining data. The universe of discourse for T_{in}, S_m, and D_{irr} were (0-50°C), (0-100%), and (0-60mn), respectively. The connection between inputs and output, both of which are ‘crisp’ values, is made via the linguistic transformation of input membership functions, implication and aggregation using the rule base, and defuzzification of the linguistic output to a numerical value representing irrigation duration.

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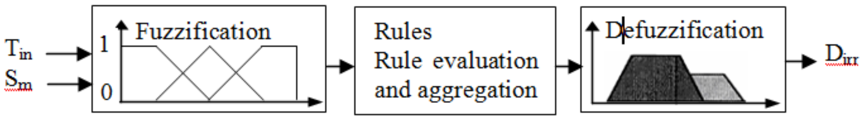

Figure 5. Fuzzy controller

Membership fuctions

The trapezoidal or triangular membership function was selected. FC rules were formulated using LabVIEW fuzzy system designer, as a simple Mamdani system [16]. The inside temperature T_{in} and the soil moisture S_m ranges were partitioned into five and three sets, represented by triangular shapes, as shown in Fig. 6(a–b), respectively. The irrigation duration D_{irr} was partitioned into three sets, represented by trapezoidal shapes, as shown in Figure 6(c).

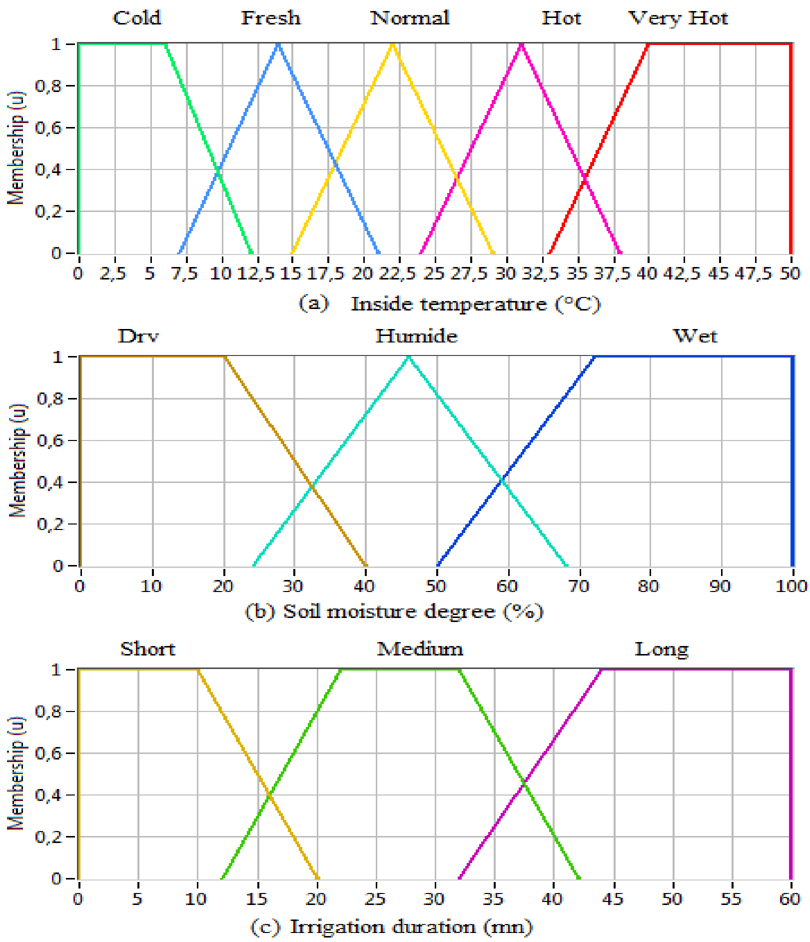

Figure 6. Membership functions

Fuzzy rules

The 15 basic fuzzy rules were needed to describe a useful relationship between the tow inputs and the final output. The fuzzy rules are given in Table 2.

Table 2. Fuzzy rules

Rule	IF Inside temperature	AND Soil moisture degree	THEN Irrigation duration
1	Cold	Dry	Long
2	Cold	Humide	Short
3	Cold	Wet	Short
4	Fresh	Dry	Long
5	Fresh	Humide	Medium
6	Fresh	Wet	Short
7	Normale	Dry	Long
8	Normale	Humide	Medium
9	Normale	Wet	Short
10	Hot	Dry	Long
11	Hot	Humide	Medium
12	Hot	Wet	Short
13	Very hot	Dry	Long
14	Very hot	Humide	Medium
15	Very hot	Wet	Short

The MIN-MAX inference method was used to determine stress values from rules satisfied during the evaluation process. The consequent fuzzy union was restricted to the minimum of the predicate truth, while the output fuzzy region was updated by taking the maximum of the minimized fuzzy sets. The minimum operator limits certainty of the overall stress condition to the least certain input observation. The final irrigation duration membership function was obtained using the MAX composition procedure.

Defuzzification

The center of gravity or the center of area (COA) defuzzification method were tested. The COA of a final membership function is defined as:

$$COA = \frac{\sum_{t=0}^{n} x_i \mu(x_i)}{\sum_{t=0}^{n} \mu(x_i)} \quad (2)$$

where x_i is the i^{th} domain value and $\mu(x)$ is the membership grade.

SOFTWARE

The front panel of the developed virtual instrument (VI), using LabVIEW 2011, based fuzzy control system for irrigation duration is shown in Figure 7. This VI regroups the following functionalities: acquirement and data logging; display and treatment of information in real-time; and command of actuators. This interface encompasses at the same time reliability, flexibility of use, interactivity and processing capability in real-time of the whole data.

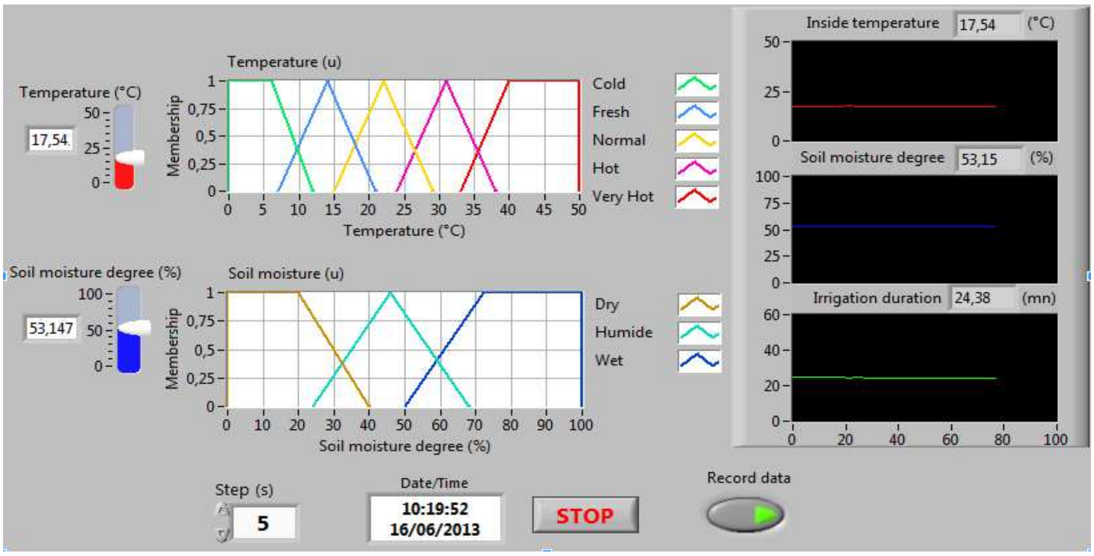

Figure 7. Front panel of the VI based FC system for irrigation duration

RESULTS AND DISCUSSIONS

To best determine the soil water status, we are used an electronic circuit measuring the soil moisture degree witch associated an irrometer tensiometer. The irrometer instruments provide a direct measurement of soil water tension, which is the tension all root systems must overcome to extract water from the surrounding soil. Simple, reliable, and accurate, the irrometer is still the choice of many successful growers and consultants. We have applied regularly doses of water in a container filled with sandy soil volume of around 25 cm^3 (Figure2). The results are shown in Table 3.

Table 3. Responses of the irrometer and the electronic circuit measuring soil moisture degree

Volume of water (l)	V_{out2} (V)	Sm (%)	Irrometer (cb)	Soil water status
0	1,1	22	35	Dry
0,20	1,29	25,8	33	
0,50	1,66	33,2	32	
0,75	1,80	36	27	Humid
1,00	2,47	49,4	25	
1,25	2,56	51,2	23	
1,50	2,67	53,4	20	
1,75	3,04	60,8	17	Wet
2,00	3,12	62,4	13	
2,25	3,29	65,8	9	
2,50	3,82	76,4	7	

The irrometer operates on the tensiometer principle, which measures soil water tension. Soil water tension is the energy (vacuum) applied to the soil by the plant as it draws in water for nutrition. This force is measured in centibars (cb) of tension with a high reading indicating the dry end of the scale and a low reading indicating the wet end of the scale. Thus the implementation of a simple and efficient device allowing the measurement of soil moisture degree from the output voltage V_{out2}. The response of this apparatus is tested under greenhouse and is compared with the response of the irrometer. The obtained results enabled us to confirm the precision and the acceptable reliability of our apparatus. The use of soil moisture based irrigation scheduling has been proven an efficient way to deliver irrigation water for agriculture. Further, the instrumentation can be used for controlling (automatic irrigation systems) and signaling (for data logging systems and inputs to weather stations).

For all inputs included in the areas of internal temperature and soil moisture degree values, we can obtain the irrigation duration in minutes. We estimate the irrigation duration from the internal temperature and the soil moisture degree. Some results are shown in table 4.

Table 4. Responses of the irrometer and the electronic circuit measuring soil moisture degree

T_{in} (°C)	S_m (%)	D_{irr} (mn)
20	30	40
21.5	40	27
22	60	19
24	70	8,34

Irrigation is usually the flood type, although some automated equipment might be used. The objective of watering is to maintain a fully adequate supply of water to the plant roots without wetting the soil to the extent that air cannot get to the roots. Waiting until the plants start to wilt is not recommended. A good practice is to reach down into the soil and judge how much water is left before starting the next irrigation. Regular watering on the same day of the week is unwise. The water requirement of the plants changes daily and seasonally.

The use of the soil moisture detector allows a more judicious use of water and energy. It also makes it possible to reduce the relative humidity in the greenhouse, because all the ground is not irrigated. The effects of relative humidity on crop performance are not well understood. The crop can withstand a wide range of relative humidity, from very low to very high, as long as the changes are not drastic or frequent. At low relative humidity, irrigation becomes critical, whereas at high relative humidity diseases can manifest themselves. Growth in general is favored by high relative humidity; high relative humidity during the day can also improve fruit setting. However, high relative humidity, when not managed properly, can easily lead to water condensation on the plants and the development of serious diseases.

The developed fuzzy logic controller can effectively estimate irrigation duration using inside temperature and soil moisture degree. Efficient, automated irrigation greenhouse systems, which can irrigate plants using inside temperature and status of ground water, are currently not available. Under the developed drip irrigation system, soil water content in the active portion of the plant root zone remains fairly constant because irrigation water can be supplied

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slowly and frequently at a predetermined rate. Here, the total soil water potential increases (soil water suction decreased) with elimination of the wide fluctuations in the soil water content.

This front panel of the VI meets at a time dependability, flexibility and interactivity. The user can view, in real time, the status of ground water through detector soil moisture. The operator can also calculate the volume of water from the irrigation duration and the flow dripper. From an energy efficiency point of view, significant savings in energy consumption costs are possible with this system.

CONCLUSION

In this project, a fuzzy logic controller has been implemented for monitored drip irrigation duration using as variables soil moisture degree and air temperature in greenhouse. It is important to note that such system can save a lot of water and is cheap to implement. The fuzzy rules are simple, therefore making the system attractive to use by all types of agriculturists. The drip irrigation cropping system is similar to but better than the conventional soil cropping system because it can be used to control crop growth through a regulated supply of water and nutrients. In addition, the system allows reduced relative humidity in the greenhouse because not all the soil is irrigated and because it is compatible with the use of white polyethylene film as light-reflecting mulch. Resources, including energy, are thus used more efficiently with this system. In addition, the project is essentially a multidisciplinary educational support as well as part of a student training and research.

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