# A FUZZY CONTROL IRRIGATION SYSTEM FOR COTTON FIELD

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Abstract: A fuzzy control irrigation system for cotton field is presented in this paper. The system is composed of host computer, slave computer controller, communication module, soil water sensors, valve controllers, and system software. A fuzzy control model is constructed to control the irrigation time and irrigation quantity for cotton filed. According to the water-required rules of different cotton growing periods, different irrigation strategies can be carried out automatically. This system had been used for precision irrigation of the cotton field in Langfang experimental farm of Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences in 2006. The results show that the fuzzy control irrigation system can improve cotton yield and save much water quantity than the irrigation system based on simple on-off control algorithm.

Keywords: fuzzy control, precision irrigation, sensor

## 1. INTRODUCTION

Soil water content collection is critical for precision irrigation (Zhao Yandong et al., 2002). Once the soil water contents are collected on real time, irrigation model can be developed combining with the plant water-required rules, and then correct strategy can be executed in time (Sun Li et al., 2005). In order to realize precision irrigation, computer control system should also be adopted besides computer measurement system (Xin Xiuli et al.,2005; Yang Qing et al., 2006; Sun Li et al., 2006). A fuzzy control irrigation system for cotton field is presented in this paper. Soil water sensors are used to collect soil water contents in different plots. According to the water-required rules of different cotton growing periods, the fuzzy control model is constructed to determine irrigation time and irrigation quantity automatically. The main functions of the system include real-time data collection, data processing, communication, and irrigation management. The results of experiments show that the fuzzy control irrigation system can improve production efficiency greatly.

## 2. COMPONENTS OF FUZZY CONTROL IRRIGATION SYSTEM

### 2.1 Hardware Components and Host Computer Software

Hardware components include host computer, slave computer controller, communication module, soil water sensors and electromagnetic valve controllers. The system structure is as Fig.1.

The main functions of host computer in the control center are to process data, realize the system control algorithm, manage the devices, and monitor the system operation. Cable communication transfer is not economic and convenient because of the long distance between the control center and the cotton field. Therefore SRWF-105 wireless communication module is used to realize the communication between host computer in the control center and slave computer controller in the field. SRWF-105 module provides two serial-communication interfaces, i.e. COM1 is UART interface of TTL voltage and COM2 is standard RS-485 interface. The module can realize remote communication within 2K meters.

The slave computer controller consists of MCU SPCE061A, extended memory, LCD displayer, keyboard, and RS-485 interface. The main functions of slave computer controllers are to collect soil water data, transmit data, display data, and control the behavior of electromagnetic valves. Soil water sensors and electromagnetic valve controllers are linked to slave computer controllers by RS-485 interfaces. The system controls the turning on/off of electromagnetic valves according to fuzzy control algorithm to realize precision irrigation automatically.

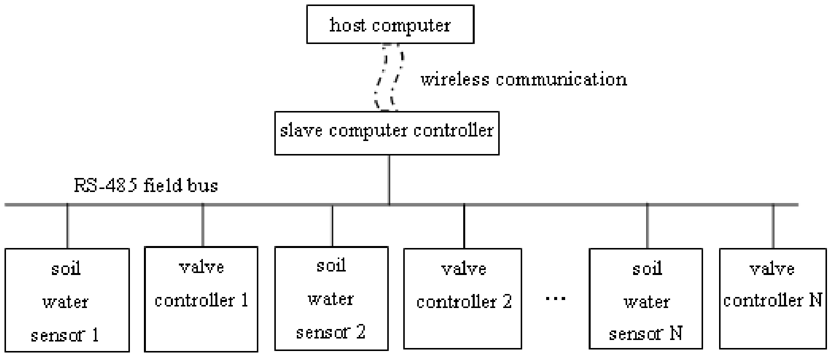


*Fig.1.* Fuzzy control irrigation system structure

Host computer monitor software is programmed by Visual Basic language. Slave computer control software is developed by C language and Assembly language. The system can operate under host computer monitoring or under only slave computer control without host computer monitoring. Host computer monitor software consists of data collection module, data processing module, communication module, and management module.

## 2.2 Fuzzy Control Model

Irrigation control has many characteristics, for instance, slow change and large delay, so that it's hard to construct an accurate mathematic model for it. On-off control algorithm is one of the simplest methods to control irrigation. The maximum and minimum thresholds of soil water contents are preset. When soil water content is detected to be lower than the minimum value or be higher than the maximum value, electromagnetic valve is turned on/off automatically to start/stop irrigation. Because the change of soil water content has large delay, this control algorithm is not very accurate, especially when soil water content is near the control threshold (Kuang Qiuming et al., 2007).

In order to improve control accuracy, two-input and one-output fuzzy control model is constructed in this paper. If the measured soil water content is $y$, the presetting soil water content is $r$, then the two inputs are the error $e$ ($e=r-y$) and the error change rate $ec$ ($ec=y(n)-y(n-1)$). The sampling period of the system is 5 minutes. The output $u$ of the model is the valve turning on time. Single point fuzzy method and central average value inverse-fuzzy-method are adopted in the fuzzy controller (Zhang Weiguo et al., 1999).

The structure of the fuzzy controller is as Fig. 2.

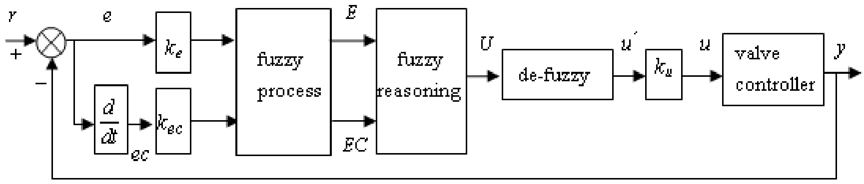


*Fig.2.* Structure of fuzzy controller

The error *e* and the error change rate *ec* are calculated firstly according to the given value *r* and the measured value *y*. Then *e* and *ec* multiply with $k_e$ and $k_{ec}$ and through fuzzy processing, the fuzzy quantity E and EC can be gotten. The value range of E and EC is [-6, 6]. The fuzzy subclass division of E and EC are { Negative-Big, Negative-Middle, Negative-Small, Zero, Positive-Small, Positive-Middle, Positive-Big}, i.e. { NB, NM, NS, 0, PS, PM, PB}. The fuzzy subclass division of U are { Zero, Positive-Small, Positive-Middle, Positive-Big}, i.e. { 0, PS, PM, PB}.

The value ranges of E, EC, and U are as follows:

E＝（-6,-5,-4,-3,-2,-1,0,+l,+2,+3,+4,+5,+6)

EC＝(-6,-5,-4,-3,-2,-l,0,+1,+2,+3,+4,+5,+6）

U＝(0,+1,+2,+3,+4,+5,+6）

Based on membership function and experience of experts, the fuzzy reasoning rules are as table 1.

*Table 1.* Fuzzy reasoning rules table

| E | EC | | | | | | |
|---|---|---|---|---|---|---|---|
| | NB | NM | NS | 0 | PS | PM | PB |
| NB | 0 | 0 | 0 | 0 | 0 | PS | PS |
| NM | 0 | 0 | 0 | 0 | 0 | PS | PM |
| NS | 0 | 0 | 0 | 0 | 0 | PS | PM |
| 0 | 0 | 0 | 0 | 0 | PS | PM | PB |
| PS | 0 | 0 | 0 | 0 | PS | PM | PB |
| PM | 0 | 0 | 0 | PS | PM | PB | PB |
| PB | 0 | 0 | PS | PM | PM | PB | PB |

When E is Negative-Big and EC is also Negative-Big, it shows the soil water content is higher than normal and the soil water content will be increased continually. Therefore the measure that restrains the water content increase should be adopted. The control rule should be: If E=NB and EC=NB then U=0.

When E is Positive-Big and EC is also Positive-Big, it shows the soil water content is lower than normal and the soil water content will be decreased continually. Therefore the valve should be turned on to irrigate to the maximum.

The control rule should be: If E= PB and EC=PB then U=PB.

FIS editor of Matlab 7.0 was used to compute the fuzzy control matrix. After adjusting the output of fuzzy reasoning, the fuzzy control matrix can be obtained as table 2.

*Table 2*. Fuzzy control matrix

| E | EC | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -6 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| -6 | 0 | 0.5 | 0 | 0.4 | 0.4 | 0.2 | 0 | 0.2 | 0.4 | 0.4 | 2.5 | 2.5 | 2.5 |
| -5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 2.5 | 2.5 | 2.5 |
| -4 | 0 | 0.5 | 0 | 0.4 | 0.4 | 0.2 | 0 | 0.2 | 0.4 | 0.4 | 2.5 | 4 | 4 |
| -3 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 2.5 | 4 | 4 |
| -2 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 2.5 | 4 | 4 |
| -1 | 0.2 | 0.5 | 0.2 | 0.4 | 0.4 | 0.3 | 0.2 | 0.9 | 1.5 | 1.5 | 3.3 | 4.5 | 5 |
| 0 | 0 | 0.5 | 0 | 0.4 | 0.4 | 0.2 | 0 | 1.3 | 2.5 | 2.5 | 4 | 5 | 6 |
| 1 | 0.2 | 0.5 | 0.2 | 0.4 | 0.4 | 0.3 | 0.2 | 1.4 | 2.5 | 2.5 | 4 | 5 | 5.5 |
| 2 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 1.5 | 2.5 | 2.5 | 4 | 5 | 5 |
| 3 | 0 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 2.5 | 4 | 4 |
| 4 | 0 | 0.5 | 0 | 0.4 | 0.4 | 1.5 | 2.5 | 3.3 | 4 | 4 | 6 | 5.5 | 6 |
| 5 | 0.5 | 0.5 | 0.5 | 2.5 | 2.5 | 3.3 | 4 | 4 | 4 | 4 | 5.5 | 5.5 | 5.5 |
| 6 | 0 | 0.5 | 0 | 2.5 | 2.5 | 3.3 | 4 | 4 | 4 | 4 | 6 | 5.5 | 6 |

Table 2 shows that the larger $e$ and larger $ec$ lead to longer irrigation time. The result is reasonable. Central average value inverse-fuzzy-method is used to compute $u'$, then $u'$ multiplies with $k_u$ to get output $u$. Scale factors $k_u$ is relative with the valve characteristic, soil types and other factors.

## 3. RESULTS AND DISCUSSION

The experiment was carried out in Langfang experimental farm (39.4N，116.4E) of Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences in 2006. The selected cotton cultivar was mid matured cultivar Jimian25. Planting density was 52500 plants per hectare. Management measures were the same as normal high-yield management for the field cotton. Soil water sensors were installed in 20cm deep of cotton root in each plot.

In normal agronomic years, furrow irrigation is commonly set to be four times with relative small irrigation quantity during bud and square period, irrigation is usually set to be four to five times with mass irrigation quantity during flower and boll period, and irrigation is set to be three to four times with small irrigation quantity during cotton boll opening period. According to the water-required rules of different cotton growth periods, the different irrigation strategy can be adopted automatically by the fuzzy control system. Irrigation time and quantity can be adjusted based on the environmental conditions. The lint yields of four plots under different irrigation manners are listed in table 3.

*Table 3.* Cotton yield comparison of fuzzy control and on/off control irrigation

| Number of plots | Lint yield($kg \cdot ha^{-1}$) | Irrigation manner |
|---|---|---|
| 1 | 1739.79 | on/off control |
| 2 | 1794.27 | on/off control |
| 3 | 1821.46 | fuzzy control |
| 4 | 1856.19 | fuzzy control |

The results indicate that the cotton yields are much higher in plots that adopt fuzzy control irrigation than in plots that adopt on/off control irrigation. Furthermore, the fuzzy control irrigation system uses less water quantity than the on/off control irrigation system. About $89m^3 \cdot ha^{-1}$ water is saved every time. The saving water quantity reaches 28% of total quantity in on/off irrigation manner.

## 4. CONCLUSION

The fuzzy control irrigation system studied in this paper combines fuzzy control model with automatic irrigation technique. The system has high control accuracy as well as rapid following response. Different irrigation strategy can be adopted automatically according to the water-required rules of different cotton growing periods. The results indicate that the control system can save water and improve cotton yield greatly. Therefore it has promising potential in precision farm applications. Further study is to integrate fertilizer-required rules of different growth periods into the control model, and then develop a precision irrigation and fertilization system (Zhang Naiqian et al., 2002; Liu Xiuzhen et al., 2006).

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