Fuzzy Control Model Study on Precision Irrigation System for Water Stress in Crops

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***Abstract*—Precision irrigation in fuzzy control system based on crop water stress acoustic monitoring was designed in the paper. Moreover, conventional double fuzzy control model was found to carry out two work mode, normal irrigation and precision irrigation, which aims to both ensure normal growth of crops and achieve effective water-saving. Since five input signals affect output in different degree, three layer BP neural network was employed to compute weight. Based on conventional fuzzy model, self learning fuzzy model for crop growth was built to tackle with normal irrigation and precision irrigation. In order to testify the control strategy, an experiment platform including virtual instruments was founded. It shows that the system can effectively adjust to water and control valve speed under signals in AE sensor and environmental information for the corp growth to some extent, and not only save water in the normal irrigation, but also realize safety and efficiency in precision irrigation.**

***Index Terms*—precision irrigation, self learning fuzzy control system, acoustic emission technology, water stress in crops**

I. Introduction

The growth processes of the crops are often effected by a lot of environmental factors, including water deficit, temperature anomaly, disease insect damage and disadvantageous soil condition etc..Effect in water deficit among them was most serious, and exceeded the sum of the other environment affects[1].At the same time, water resource saving status have already been the important index appraising a country or regional economies sustained development. Study on water resource saving has been paid attention to by the home and abroad scholars. It was shown in reference[2] that agriculture irrigation using water occupied 70% of the whole world fresh water, and or so 40% was wasted owing to evaporation, deep sorption of soil etc..Therefore, precision irrigation must be vigorously developed and promoted.

Preliminary research results on fuzzy control model of precision irrigation based on water stress monitoring for the corps were designed in the paper. Five sensors were introduced and respectively monitored AE, the temperature, humidity, illumination and the CO_2 density. Self-learning fuzzy model on precision irrigation was layouted. Present given volume on water was by five inputs. It was shown that five inputs and signal output of double fuzzy control model on precision irrigation system could effectively fulfill the tasks of normal irrigation and precision irrigation, timely, suitably and scientifically irrigate under water required information for the corps growth, so as to save water and expand productivity.

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II. PARAMETERS DETECTION PRINCIPLES AND SYSTEM CHARACTERISTIC

A. Crop water stress detection principle of acoustic emission

Plants due to water shortage and the formation of the gas embolism, xylem catheter tension would suddenly release and produce shock, namely plant “acoustic emission” phenomenon. The cohesion theory in water transport water in soil-plant-atmosphere continuum system of transport is in certain negative pressure or tension. The soil becomes dry, tension is correspondingly increase, as more than a limit, because the water molecule room cohesion of guided wall failure or adhesion failure, the water column continuum can't again continue and thus fracturing or time, these are called the cavitation plant xylem, at this time, tension will suddenly release and produce shock, and at the same time appear acoustic emission signal. Acoustic emission signal in the super audio (100~300 kHz), within the scope of AE sensor signal can be detected as plant water stress physiological indexes, judge the current crop water loss [2][3][4].

B. Precision irrigation system characteristics and requirements

In a certain degree, within the scope of crops by water stress out over crop water plaintive wail frequency of coercion of degree of increasing, and with the crop evapotranspiration acceleration involved; To avoid crops by water stress, but through the influence of ae sensor information obtained by the realization of crop crop depends on emotion irrigation and regulation; Make crops of transpiration and water amount of balance adjustment, and strive to make the best crop of soil water environment, improve the utilization rate of growth of water plants, and improve fruit quality [4].

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Irrigation system included two working condition(normal irrigation and precision irrigation).Using documents[4][5][6], four sensors (T1~T4) and an AE sensor were employed to respectively detect ambient temperature, humidity, lllumination,CO_2 density and AE signal frequency. That could better reflect the correlation between environmental factors and AE signal frequency, and as the system input signals.

III. FUZZY CONTROL MODEL

A. Conventional double fuzzy control model

Electromagnetic valve for water change may cause environmental parameters change, but changing the degree and speed are not all the same, so simply based on a certain environmental parameters decision electromagnetic valve for water is not properly [7][8].

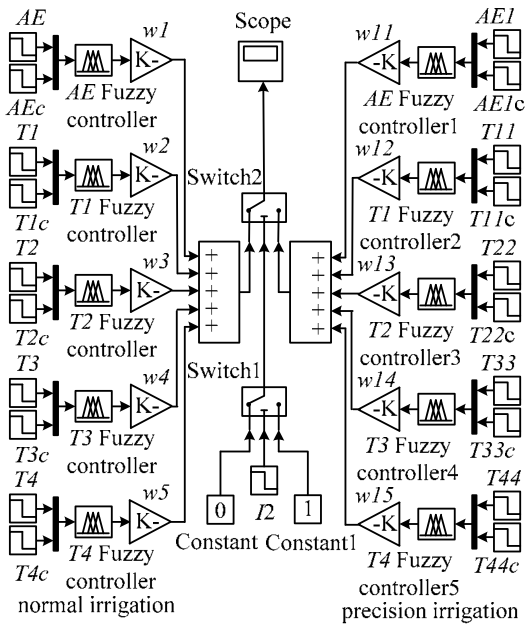


Figure1. Double model fuzzy control system construction

AE took a dominant place at the time of precision irrigation and reflected the water requirement amount of the time. Temperature was showed by T1 which was just less important than AE. Humidity was influenced by T2.The concentration in this place was also important but less than T1.Light intensity was affected by the values of T3 which was just less important than T2.The density of co_2 was affected by the values of T4 which was just lowest. The importance of each parameter was similar between normal irrigation and precision irrigation. Above all, double MISO fuzzy control model which applied to the precision irrigation system was designed in this article and was showed in Figure1.The conventional double fuzzy control model with five inputs and single output was established in the Matlab and it included the two states of normal irrigation and precision irrigation[7][8].The two states were selected by switch1 and switch2.The selection signal was output from AE and switch1.If the value of AE was lower than 1.5%,signal '0' was output, otherwise signal '1' was output. The output from switch 1 was regarded as the selection signal of switch 2.If the output from switch 1 was '0',the former was selected, otherwise the latter was selected. The 'wi' and 'wli' (i=1,2,3,4,5) were the weights between the five input signals respectively at the time of normal irrigation and precision irrigation. According to the field, the five input signals affected the solenoid valve's speed in different degree, and influences existed among themselves as well. Using the method of adding weight first and then computing their average for reference, the final output result was obtained through the same method in this article, adding weight to output of every SISO control model and then computing their average

$$U = f(w_1 AE + w_2 T_1 + w_3 T_2 + w_4 T_3 + w_5 T_4 + w_6 T_5) \tag{1}$$

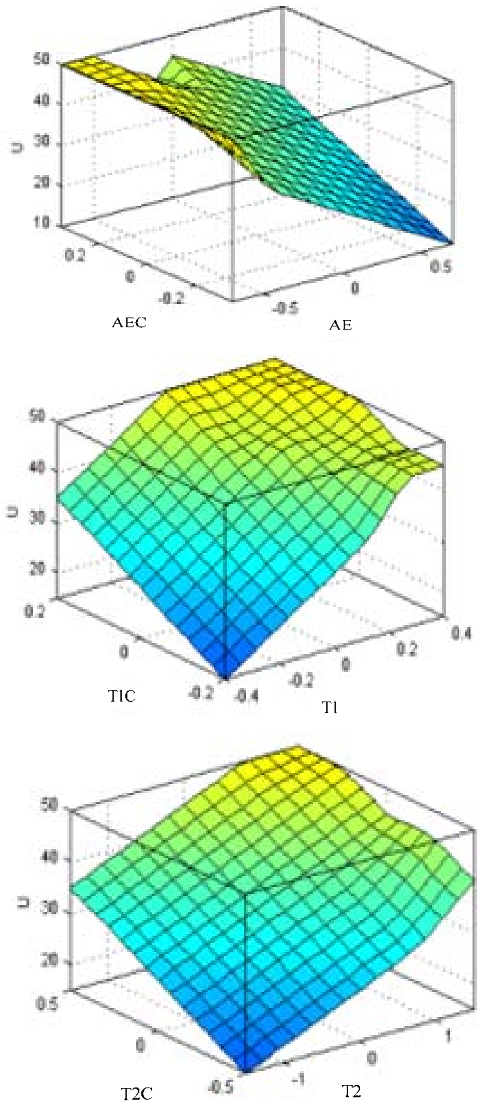
U was the output of fuzzy control model and f was fuzzy control relation.

TABLEI.
THE RESULT OF WEIGHT

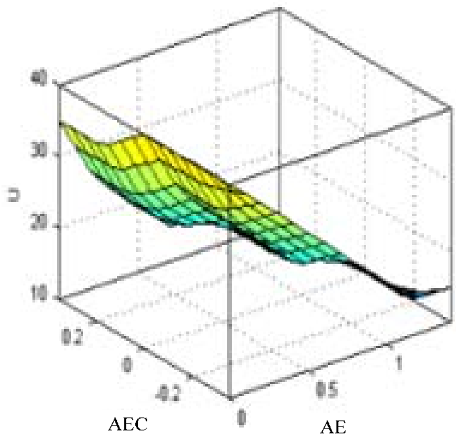
AE	T1	T2	T3	T4
normal irrigation				
0.4647	0.2341	0.0702	0.0697	0.2310
precision irrigation				
0.0564	0.0847	0.5523	0.5531	0.3066

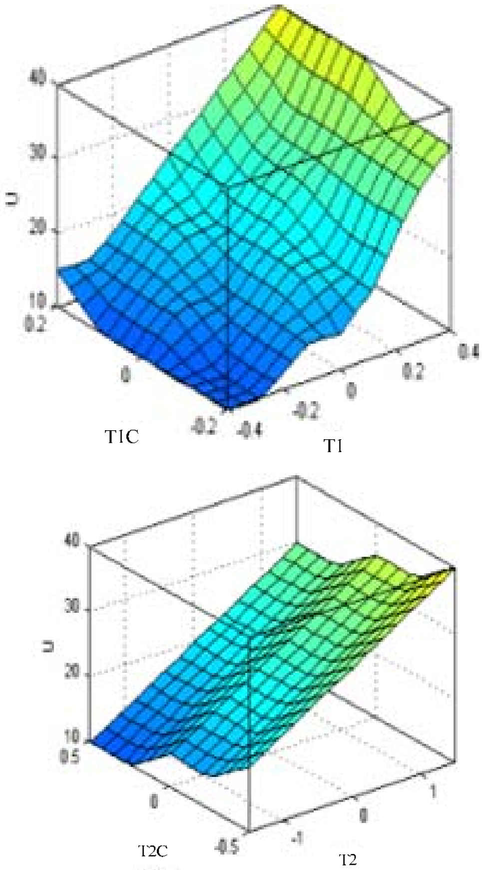
In order to acquire the strategy weight of the output factors influenced by input factors, the learning method of BP neural was employed and the procedure of computing weights was applied. The weights of both two states were computed by establishing BP network which had five hidden nerve dollars[8].Through the simulation of Matlab, the goal of 0.05 was realised for 1795 times at the time of precision irrigation and the goal of 0.03 was reached for 419 times at the time of normal irrigation. After analysing and handling the weights between nerve dollars, the result was showed in TABLEI.

100 and 50 groups of data of the two states, normal irrigation and precision irrigation, were respectively collected once every 6 seconds, then add the data of 2 minutes up, and compute their average. The basis values of AE and T1~T4 were respectively0.8、0.6、0.8、0.7and 2.5 at the time of precision irrigation. Looking from the scope of collective data, AE, T1 and T2 was 0.1~1.35, 0.2~1.0 and 0.1~1.5 in precision irrigation. After computing its deviation with the given expected value, the deviation was more or less -0.7~0.7, -0.4~0.4 and -0.7~0.7, and its changing rate scope was -0.35~0.35, -0.2~0.2 and -0.35~0.35.The expected values of AE and T1~T4 were set 1.0,0.6,0.8,0.8 and 1.0 at the time of normal irrigation.Figure2 was the control surface of AE and T1 at normal irrigation and precision irrigation.



(a) Normal irrigation





(b) Precision irrigation

Figure2． AE, T1 and T2 control surface of surgeon inference

B. Self learning fuzzy control model

The control quality of the fuzzy control system mainly depends on the fuzzy control rules establish and fuzzy relations truthfulness. By conventional fuzzy control model of fuzzy control rules establish often subjective, difficult to guarantee system has a good dynamic characteristics. In order to overcome the subjectivity of system of quality control, the influence of many scholars in fuzzy control model in the structural design of introducing the self-learning function, make the fuzzy control system has ego perfect sex, it is to have a more highly fuzzy control is one of the effective ways of intellectual progress [9].

Self-learning control system refers to category system, namely a automatic control system: it can from external environment and their own process control to learn enough relevant information, and thus to such information as the basis, through the identification, clustering and decision-making, generate new control law, in order to improve the system of static and dynamic control performance.

Self-learning Fuzzy control Model (SLFM——Self Learning Fuzzy Model) research aim is to hope from the initial Fuzzy control in the process of Learning to system performance relevant information, and thus the experience to re-generate or modify some Fuzzy rules, improve the Fuzzy relation, make the Fuzzy control system performance meet a given target function [10] [11]. Self-learning fuzzy control model was set up based on negative feedback control principle, according to data error drive and produce the corresponding control effect, according to the control effect and evaluation criteria, learning through units using appropriate learning algorithm to learn and exerted by the controlled object control action of calibration, so as to gradually improve and enhance control system performance.

This paper research object is an parameter time-variance, nonlinear and time delay of the controlled object, although the whole fuzzy control model was decoupled into four SISO words fuzzy control model, but output after all only regulator. To simultaneously satisfy four subsystems control goal, adopt self-learning fuzzy control algorithm can better realize control strategy.

- Suitable for precisely irrigation self-learning control model of parameters

Self-learning fuzzy control parameters in the model choose whether appropriate, will directly affect the performance of fuzzy control model. Establish suitable for precision irrigation self-learning fuzzy control model needs analysis and calculation of the parameters in this method.

Input of the error and error rate and the basic theory of output control quantity domain has been in conventional fuzzy control model design set, here in order to calculate the convenient, its domain and normalized to [-1, 1] interval. Because accurate irrigation system is decomposed into precise irrigation and normal irrigation two conventional fuzzy control model, and to create a conventional fuzzy control model will MISO fuzzy control model decoupling four SISO submodel, the situation is more complex, in order to straightforward, based on the precise irrigation, AE subsystem of self-learning control algorithm for example, this paper introduces parameter calculation and programming, the rest of the processing methods similar, will ultimately each self-learning fuzzy control model according to the conventional fuzzy control model of the weighted average method combined together, forming self-learning fuzzy control model. The sons of AE SISO model is concerned, e*=e_{max}=0.7, ec*=ec_{max}=0.35, Δu basic domain and setting for [-5,5], normalization of domain for [-1, 1], $\Delta u^* = u_{\max} = 5$. After normalized after conventional fuzzy control model becomes the direct expression under type fuzzy relations:

$$
\underset{\sim}{R}_D = \begin{array}{cccccc}
\underset{\sim}{A}_i \underset{\sim}{B}_j: & NB & NS & NO & PS & PB \\
PB & -1 & -0.75 & -0.5 & -0.25 & 0 \\
PZ & -0.75 & -0.5 & -0.25 & 0 & 0.25 \\
PS & -0.5 & -0.25 & 0 & 0.25 & 0.5 \\
ZO & -0.25 & 0 & 0.25 & 0.5 & 0.75 \\
NS & 0 & 0.25 & 0.5 & 0.75 & 1 \\
NZ & 0.25 & 0.5 & 0.75 & 1 & 1 \\
NB & 1 & 1 & 1 & 1 & 1
\end{array} \quad (2)
$$

Because the fuzzy control module control strategy is to keep water in 0.8 near, there will be reference model output expectation response select Y*(k)=0.8.

Sampling period determined: according to the shannon sampling theorem, should use discrete signal instead of analog signals, must meet $f_s \geq 2 f_m$, namely sampling frequency must be greater than or equal to twice of the analog signal. Therefore the sampling period cannot choose too low, but the sampling period is too short, signal-to-noise ratio decreased, vulnerable to interference, reduce control quality. Meanwhile the sampling period should be greater than system actuator response time, especially on fuzzy control system, it should be guaranteed through two consecutive sampling period obtain the controlled amounts of error change greatly, so that we can get better control laws. Comprehensive the foregoing, choose the sampling period for 2 minutes.

- Suitable for precisely irrigation self-learning fuzzy control algorithm implemented

For precise irrigation systems in each component of the fuzzy control model is concerned, set the ideal for Y*, output response real output response for Y, classics of domain normalization of deviation is E=Y*-Y, error rate for E_C=[E(k)-E(k-1)]/T, then ideal the response characteristics of usable Y+ ΔY prond. Hypothesis $\Delta Y = \frac{1}{2}(E + EC)$, make MY, ME, MEC respectively revised Y, E, EC by E= Y*-Y, MY=Y+ ΔY , ME=E- ΔY , MEC $\approx$ EC- ΔY , then ME+MEC $\approx$ E+EC-2 ΔY .

Because $\Delta Y = \frac{1}{2}(E + EC)$, then ME+MEC $\to$ 0. On type shows that ΔY fixed Y is designed to make ΔY to zero, the system can get expect your ideal response. Accordingly determine various children self-learning fuzzy control model performance function for.

$$J(E, EC) = \frac{1}{2}(E + EC) \quad (3)$$

Incremental model $\Delta Y(k) = M \Delta U(K - \tau - 1)$, M taken ΔU domain and normalized values, $M = \frac{1}{5}$.

Then self-learning fuzzy control algorithm for each step of the calculation process for: for the first time, a sampling k now output expectations responses as Y*(k), actual output response is Y(k), then, the moment deviation $E(k) = Y^*(k) - Y(k)$, $EC(k) = [E(k) - E(k-1)]/T$, the ideal response characteristics

$$Y(k) = Y(K-1) + \Delta Y(k) = Y(K-1) + J(E, EC) \quad (4)$$

By augmented model

$\Delta Y(k) = M\Delta U(K-\tau-1) = \frac{1}{20}\Delta U(K-\tau-1)$, may be calculated

$$\Delta U(k-\tau-1) = 10[E(k)+EC(k)] \qquad (5)$$

Because every step of the control quantity and observation were existed in memory, and thus $\Delta U(k-\tau-1)$ can be removed from storage, the revised control quantity

$$U^*(k-\tau-1) = U(k-\tau-1) + \Delta U(k-\tau-1) \qquad (6)$$

Then control quantity is converted fuzzy quantity $\underset{\sim}{A}_u^*$, the measurements before $\tau+1$ is taken out and fuzzied into corresponding fuzzy quantity $\underset{\sim}{A}_1$, $\underset{\sim}{A}_2$,…and $\underset{\sim}{A}_k$,thus generating a self-learning is obtained by new control rules:

$$E_u^* = [E_1 \wedge (\underset{\sim}{A}_1 \times \underset{\sim}{A}_u^*) \bullet [E_2 \wedge (\underset{\sim}{A}_2 \times \underset{\sim}{A}_u^*)] \bullet \cdots \bullet [E_k \wedge (\underset{\sim}{A}_k \times \underset{\sim}{A}_u^*)] \qquad (7)$$

If memory has the same prerequisite rules, criterion and carries on the E_u^* comparison, if not be revised the rules are same, or otherwise the new rules instead. If memory without premise condition of the same rules, will the new rules into memory. Repeat this process until no self-learning changes to the rules or no new rules need to add so far.

- Precise irrigation self-learning fuzzy control model building and simulation

As mentioned previously, precise irrigation MISO fuzzy control model according to the decoupling theorem is decomposed into five SISO words fuzzy control model. For precise irrigation self-learning fuzzy control model also follow the same way, then each decomposed self-learning fuzzy control model according to the weighted average combinations into a model. Based on the design of fuzzy control model for five input decoupling, respectively established five single input and single output son fuzzy control model. In this still follow the above principles, respectively established five input variables and the relationship between input and output water, in order to express the controlled object characteristics.

Is precisely irrigation systems are concerned, water not only and velocity, and many other related by random factors. In order to facilitate the creation expression, this paper made the following simplified treatment. Regulator with certain speed stability spinning, produce water flow and rev become direct ratio. In order to simplify the calculation, assuming that water from the regulator out speed function area of not become A_0, speed nor become v_0. Water to arrive the velocity of water for export regulator $Q_m t$, and then after mixing process, mixing. This process experience of time is $t = \frac{l_0}{v_0} + \frac{l_1}{v_1}$. At this time the role of water surface extends to the valve, the valve broken area of A hypothesis, water speed for v1. Then mixed hypothesis water speed constant. Then flow under the action of water distribution, $\overline{c} = \frac{Q_m t + Q_B t}{A\Delta l}$ is rewritten for

$$c_2 = c_1 t + \frac{Q_B t}{A\Delta l} = c_1 t + \frac{v_0 A_0}{A\Delta l} t = c_1 t + \frac{v_0 A_0}{A} t \qquad (8)$$

Which Δl is the valve line unit length. According to the type can be concluded controlled object for the general characteristic changes with time and hysteresis. To facilitate the self-learning control algorithm programming, respectively for y(k+1) and y(k) says k moment and t-k moment of water. Adjustment output and water speed between certain relation. This paper will take this proportion coefficient for k. Choose the time lag for 30s. Simulation step length elected 1s, then sampling time k of self-learning fuzzy control said.

$$y(k) = (\frac{l_0}{v_0} + \frac{l_1}{v_1}) y(k-1) + \frac{A_0}{A} u(k-30) \qquad (9)$$

Similarly, The self-learning fuzzy control model of T1, T2 and T3 in k sampling time were established, and were respectively shown.

$$y(k) = (\frac{l_0}{v_0} + \frac{l_1 + l}{v_1} +) y(k-1) + \frac{A_0}{A} u(k-480) \qquad (10)$$

$$y(k) = (\frac{l_0}{v_0} + \frac{l_1}{v_1}) y(k-1) + \frac{A_0}{A} u(k-660) \qquad (11)$$

$$y(k) = (\frac{l_0}{v_0} + \frac{l_1 + l_0}{v_1}) y(k-1) + \frac{A_0}{A} u(k-120) \qquad (12)$$

New fuzzy control relations in precise irrigation for AE, T1, T2 and T3 were gotten by the fuzzy self-learning control algorithm, and were respectively shown.

$\underset{\sim}{R}_{D1}$ = (13)

$\underset{\sim}{A}_i : \underset{\sim}{B}_j$:	NB	NS	ZO	PS	PB
PB	–1	–0.7	–0.5	–0.2	0
PZ	–0.8	–0.6	–0.4	–0.1	0.1
PS	–0.5	–0.3	–0.1	0.2	0.4
ZO	–0.2	0	0.2	0.4	0.7
NS	0	0.2	0.5	0.7	0.9
NZ	0.4	0.6	0.8	1	1
NB	1	1	1	1	1

$$\underset{\sim}{R}_{D2} = \begin{array}{cccccc} \underset{\sim}{A}_i \cdot \underset{\sim}{B}_j: & PB & PS & ZO & NS & NB \\ PB & 1 & 1 & 1 & 0.8 & 0.6 \\ PZ & 1 & 1 & 0.8 & 0.5 & 0.3 \\ PS & 1 & 0.7 & 0.6 & 0.4 & 0.1 \\ ZO & 0.8 & 0.6 & 0.3 & 0.1 & -0.1 \\ NS & 0.5 & 0.3 & 0 & -0.2 & -0.4 \\ NZ & 0 & -0.2 & -0.4 & -0.6 & -0.8 \\ NB & -0.1 & -0.3 & -0.5 & -0.8 & -1 \end{array} \quad (14)$$

$$\underset{\sim}{R}_{D3} = \begin{array}{cccccc} \underset{\sim}{A}_i \cdot \underset{\sim}{B}_j: & PB & PS & ZO & NS & NB \\ PB & 1 & 1 & 0.8 & 0.6 & 0.5 \\ PZ & 1 & 0.9 & 0.7 & 0.5 & 0.3 \\ PS & 1 & 0.7 & 0.6 & 0.4 & 0.1 \\ ZO & 0.8 & 0.6 & 0.3 & 0.1 & -0.1 \\ NS & 0.4 & 0.3 & 0 & -0.2 & -0.4 \\ NZ & 0 & -0.2 & -0.4 & -0.6 & -0.8 \\ NB & -0.1 & -0.3 & -0.5 & -0.8 & -1 \end{array} \quad (15)$$

$$\underset{\sim}{R}_{D4} = \begin{array}{cccccc} \underset{\sim}{A}_i \cdot \underset{\sim}{B}_j: & NB & NS & ZO & PS & PB \\ PB & 0.4 & 0.7 & 0.9 & 1 & 1 \\ PZ & 0 & 0.2 & 0.5 & 0.8 & 1 \\ PS & -0.1 & 0 & 0.2 & 0.5 & 0.7 \\ ZO & -0.3 & -0.1 & 0 & 0.3 & 0.5 \\ NS & -0.5 & -0.4 & -0.2 & 0 & 0.1 \\ NZ & -0.7 & -0.5 & -0.3 & -0.2 & 0 \\ NB & -1 & -0.8 & -0.6 & -0.3 & -0.1 \end{array} \quad (16)$$

AE simulation curve were shown in Figure3. The curve was to describe sampling time and the relationship between the output value.

By Figure 3 knowable, first system is running appeared shocks, because the system characteristic is that has a large lag and time-varying, system first run not easy stability. Third, from the stabilizing system slow eighth operation system began to stabilize, say learning process is over.

To facilitate the intuitive compared the rules the changed circumstances before and after learning, the control surface of AE fuzzy control submodel before and after learning were shown Figure 4.

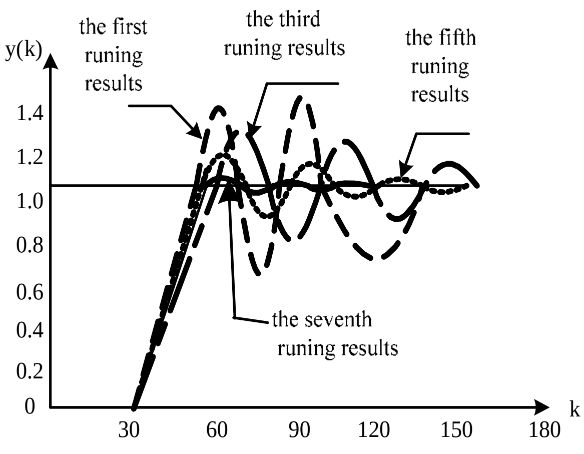
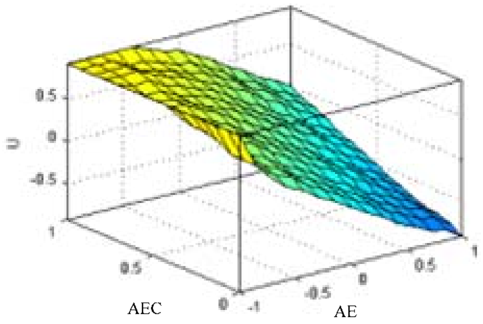
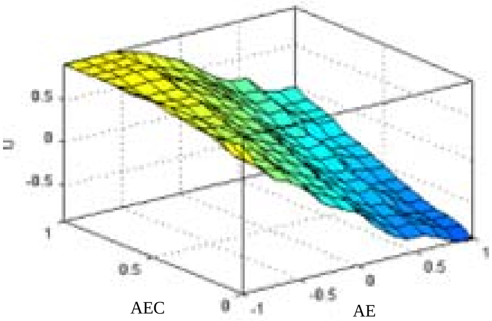


Figure3. AE simulation output response



(a) Before the self-learning



(b) After the self-learning

Figue4. Control surface before and after the self-learning

Precise irrigation self-learning fuzzy control model was shown in Figure 5. When the normal irrigation system model was the same, this paper will no longer list. In practical application, the proper fuzzy model was chosen by testing AE and judging, in order to finish work.

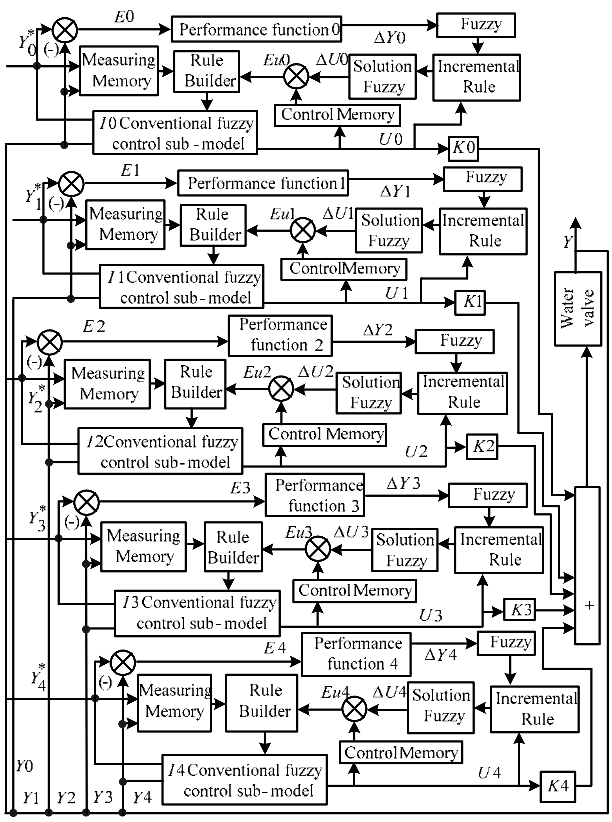


Figure5. Learning fuzzy control model structure in precise irrigation

IV. EXPERIMENT AND DATA ANALYSIS

In order to validate crop water stress sound monitoring precise irrigation fuzzy control model, this paper formulated the effectiveness of established experimental platform, as shown in figure 6 below. Normal irrigation and precise irrigation separately collection of 50 and 25 sets of data. Because five inputs is different, so the output could not only according to a quantitative changes into approximate linear change. Part of the simulation data such as TABLEII, solenoid valves as shown in Figure6. Speed Due to the speed with the change and therefore only slight listed typical simulation results. Crop precise irrigation of the fuzzy control system five input amount change requirement when fuzzy control model presents the corresponding speed given value, through the system automatically adjust the speed of solenoid valve control to achieve a given value.

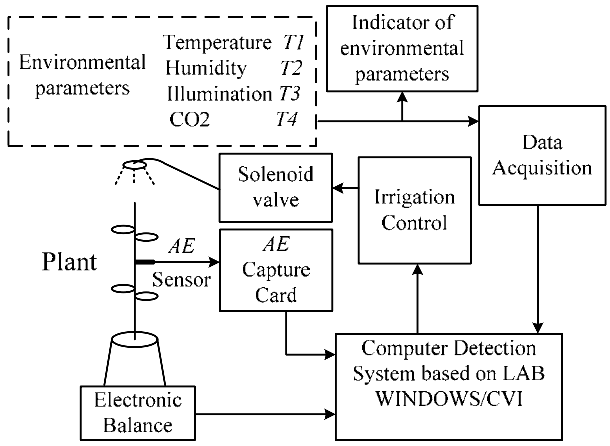


Figure6. Block diagram of the system parameters collected

TABLEII.
SIMULATION DATAS

normal irrigation						
AE	0.6 0.2	T2	-0.6 1.4	T4	-1.5 1.0	speed
AEC	-0.4 0 0.4	T2C	-0.4 0 0.4	T4C	0.5 0 -0.5	4.5 4.8 10.8
T1	-0.4 1.0	T3	-0.6 1.4			
T1C	-0.2 0 0.2	T3C	-0.4 0 0.4			
precision irrigation						
AE	-0.4 2.4	T2	-0.6 1.4	T4	-1.5 1.0	speed
AEC	-0.3 0 0.3	T2C	-0.4 0 0.4	T4C	0.5 0 -0.5	3.0 4.5 6.9
T1	-0.4 1.0	T3	-0.6 1.4			
T1C	-0.2 0 0.2	T3C	-0.4 0 0.4			

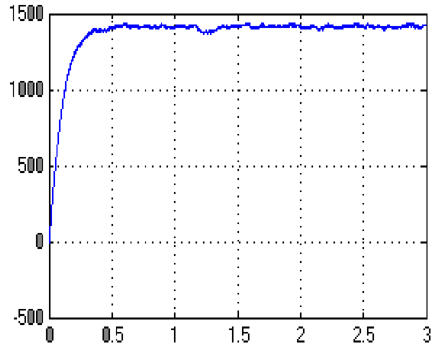
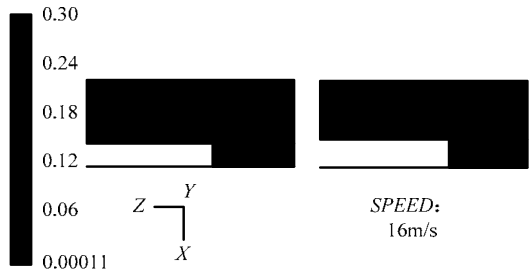


Figure7. Solenoid valve speed

From TABLEII and Figure7 can be seen, even five input amount each are not identical, the output speed may be identical, this is owing to 5 quantities according to the weights of each function results. From TABLEII speed changing trends can be seen, in normal irrigation, when five inputs are less than setting, tachometer output was relatively small, but with deviation change had different degrees of increase and decrease, When five input amount prior to nearby changes, tachometer output value in setting ideal with deviation changes fluctuation near, When five input amount exceeds set value, tachometer output is larger, even to the solenoid maximum speed. In precise irrigation, the output speed relatively normal irrigation to small and AE is taller, tachometer output is bigger.



(a) Normal irrigation (b) Precision irrigation

Figure8. Water control of normal and precision irrigation

Used the software MATLAB to simulate normal irrigation and precise irrigation control system, and simulation results was shown in Figure 8 (a) and (b). Comparing Figure 8 (a) and (b), precise irrigation fuzzy control system electromagnetic valve flow velocity decreases the part can be seen, visible based on crop water stress sound monitoring precision of crop water saving irrigation fuzzy control have certain effects, and can effectively completed crop normal irrigation and precisely the task of water-saving irrigation, achieve the purpose of yield.

V. CONCLUSIONS

Based on crop growth by water stress, diseases such as forced, the characteristics of environmental factors, a crop of conventional precision irrigation two-mode fuzzy control model was designed in this paper. In order to overcome subjectivity regulations on control the influence on the quality of fuzzy control model, the self-learning function was introduced in the structural design, a suitable for crop growth self-learning fuzzy control algorithm was put forward, and a crop precise irrigation self-learning fuzzy control model was established, and makes fuzzy control system has the self-perfection sex. So the system as the work of change amendment rule to adapt the practical situation. Simulation results show that this control strategy for overcoming the crops of fuzzy control precision irrigation system exists when the normal amount of irrigation water waste and precisely when the irrigation low efficiency, give water too much, can in the normal amount of irrigation take safety and energy-saving, precise irrigation take the safety and efficiency for crops, precision irrigation intelligent control provides a control strategies and methods.

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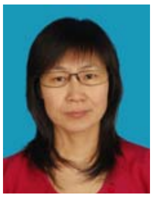

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