Precision Spraying System of Crops Disease Stress Based on Acoustic Emission

Guodong You, Xiuqing Wang, Shifeng Yang, Dejin Wang
Tianjin University of Science and Technology /College of Information and Automation, Tianjin, China
E-mail:yougdong1973@sohu.com

***Abstract*—Relationship among degree on crop disease stress, acoustic emission and environmental factors was theoretically analyzed in the paper. Precision spraying system based on acoustic emission for crop disease stress was designed, whose inputs included transpiration rate, environment temperature,humidity,lllumination,CO_2 density and acoustic emission. Self-learning fuzzy control system for precision spraying to field was built in in order to strengthen the capability of self-learning to the environment. It was shown that the system could effectively adjust to delivery volume, control valve speed under signals in acoustic emission and environmental information for the crop growth to some extent, realize intelligent control for crop spraying, accordingly, reduce pesticide usage amount.**

***Index Terms*—crop disease stress, acoustic emission technology, precision spraying, self-learning fuzzy control system**

I. Introduction

Plant forms xylem embolism because of the lack of water or the disease stress, the sudden release of tension will generate shock wave, which is “the acoustic emission” phenomenon of the plant[1]. Home and abroad reports on corn, eggplant, rice, roses, cotton and other related reports show that the phenomenon of acoustic emission and embolizationare are common to most plant physiological charcteristics[1][2][3].

Water resources and crop disease control conditions were important matters to evaluate the level of economic ability of each country or region’s sustainable development[4][5]. In the growing process, plants often suffer from a variety of environmental stresses, such as disease, water deficit, temperature, mutation and so on[6]. The reduced crop yields caused by disease stress and water deficit exceed the sum of all the other stresses[7][8]. Water resources and crop disease control level have become important economic indicators to evaluate whether a country or region can gain sustainable development[9][10]. However, due to stress caused by diseases of plant growth and reduced crop yields, widespread concern of scholars from home and abroad comes.

Manuscript received December 9,2010; revised January 15, 2010; accepted January 26, 2011
Foundation item: National Natural Science Foundation of China(No.61071207, No.60771014, and No.60874022).
You Guodong (1973-), Man, Lecturer, Research interests: Power Electronics and Electric Drive; Intelligent Control, Information Processing and Communication Technology

Internationally, the research for acoustic emission phenomenon under disease stress starts late and lacks reported results[11]，China is also rare reports of this.

In 1995, Keiko Kuroda found the abnormal cavitations through studying pine that infects wilt disease, and discussed the process of pine wilt disease mechanism of infection and changes in the hole. The results showed that the blockage of xylem sap catheter of pine trees determinants the disease[12][13].

In 2007, Kenji Fukuda and other researchers studied the relations among acoustic emission, water status and xylem embolism of pine leaf diseases. The results showed that early in the sick, along with a large amount of tube holes in the spots appear, AE frequency increased, and late in the morbid, embolization region expanded, the explosive AE event happened[14][15].

According to the statistics, pests in China each year cover 236000000 hm^2,cause about 15% loss of grain,20%~25% of cotton and more than 25% of fruits and vegetables. The current annual pesticide production and imports reach more than one million tons, a large number of indiscriminate pesticide has resulted in agricultural products, soil, water and other pollution, pesticide pollution of farmland has more than 1300~1600 million hm^2.Therefore,the development of disease prevention and treatment with appropriate precision is particularly important. The accurate, fast and reliable assessment for plant disease condition is the theoretical basis for accurate, appropriate and effective disease control. Currently, different crops have different disease diagnosis systems and evaluation indicators, which have their own characteristics, and in order to find sensitive information on crop diseases, domestic and foreign scholars have done a lot of research work. But they have advantages and disadvantages separately, and did not form authoritative, standardized evaluation index or index system.

Studies have shown that xylem cavitation could be used as a special plant response to stress condition for the monitoring of plant diseases. When the crops are disease stressed, the extent of crop stress by the disease can be detected by acoustic emission sensors. Therefore, acoustic emission technique can be used to study coercive laws of crop disease stress and as the basis for appropriate irrigation

This paper studies the extent of the crop disease stress and acoustic emission, the relationship between environmental factors based on the transpiration rate,

doi:10.4304/jcp.6.4.635-642

temperature, humidity, light intensity,CO_2 concentration and the AE as a crop input precision spraying system, and the establishment of a kind of new fuzzy pesticide control system for reducing pesticide waste, pesticide effect, a virtuous circle in favor of agricultural ecology, agricultural production and sustainable development, protection of human health and survival.

II. Acoustic Emission Mechanism of Crop Disease Stress

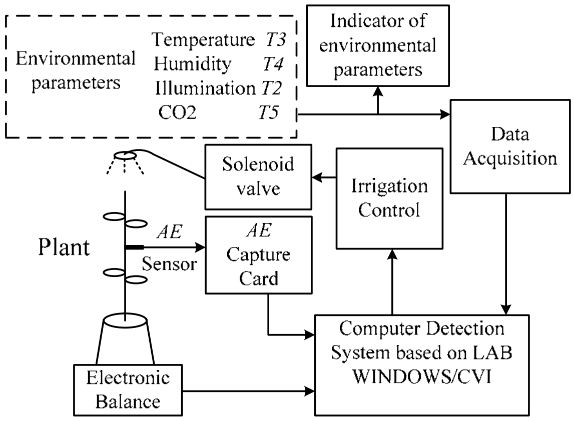


Figure1. System block diagram

As shown in Figure1,the system uses five sensors (T1~T5) to detect crop transpiration rate, light intensity, temperature, humidity and CO_2 concentration degree. A R15 style Acoustic emission (AE) sensors are placed in the main stem on the plant, testing crop disease stress issued by the ultrasonic signal. Plants are placed on an electronic balance to detect the amount and rate of transpiration. PC stresses on crop diseases and the factors of acoustic emission signals and their relationship to statistical analysis, explores the principle of development of acoustic emission signals under disease stress, makes the control strategy, controls the electronic valve and achieves the precision of the plant spraying.

Crop plants were placed on an electronic balance, the electronic balance was for the digital output, which can detect crop transpiration and the transpiration rate, and the measured data was connected to a computer through a RS-232 data bus. The main stem in crop plants installed two acoustic emission sensors, set silica gel that increased sensitivity and accuracy of the sensor and which was good at acoustic emission signal transduction between the crop main stem and the acoustic emission sensors. Acoustic emission sensors detect the ultrasonic signal issued by crop disease stress and convert it into a weak electronic signal, and then filtered through the noise signal conditioning and amplification circuit, then input to the acoustic emission acquisition board and entered into the computer by the PCI interface, using the PC software to do statistical analysis of acoustic emission signals of crop disease stress to explore the occurrence and development of the crop diseases stress acoustic emission signals. Temperature, humidity, light, and other sensors connected to the PC via PCI data acquisition card, host computer processed the information, counted and analyzed the relationship between the environmental factors and the disease stress acoustic emission signals, made up the control strategy of disease prevention and control cistern to irrigate plants through the relay and solenoid valve. This approach will not harm plants, and increases test accuracy.

A. *Collection and analysis of AE*

In the lab, use two greenhouses that is similar in physical condition and plant size to plant tomatoes, one is healthy while the other infects late blight diseases. The culture medium was soil, ash and humus prepared by 3:1:1. To prevent the soil surface water from evaporating, use plastic film to seal the saucers' underneath and surface. Do continuous acoustic emission testing of the two tomato plants. The green house uses glass ceiling which has good light transmission properties and humidity.

The AE of acoustic emission sensor was fixed on the stem of two tomatoes which took up 1/3 to 2/3 of the total height, tested the acoustic emission information. People should pay special attention to the force of fixing, it would cause the poor transmission if too loose or produce much noise signal because of this; it will also hurt the stem if too tight which also does harm to the testing of acoustic emission signal.

Tomato plants on the two continuous acoustic emission testing. A day for a period of 24h non-stop continuous acquisition of all parameters was observed in different diseases of plants under the change of AE.

On the *AE* detection for healthy plants, it appeared the same situation every day that AE occurs according to certain physiological cycle rules, in which the AE frequency shows a day in Figure2.

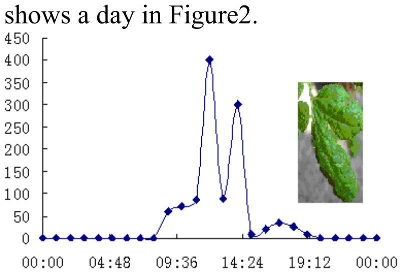


Figure2. Frequency chart of *AE* for plant

We can see from the chart, the AE usually starts around 7:00 am, and gets more frequent, then weakened after 20:00 at night, usually within one day; there were two peak values, known as “twin peaks area”. In general, with the enhancement of crop transpiration the AE frequency and signal strength will gradually increase. Crop, whose body water is fully recovered, from 20:00 p.m. to 7:00 a.m., will basically not produce AE, and are low in the physiological activities (hibernate period).

Testing on disease stress AE signal detection in plants shows that the AE is not as healthy as plant physiological cycle according to certain rules, and the distortion occurs.

From the monitoring statistics we see that, when plants are early in the disease, AE situation is basically the same as healthy plants according to certain laws of the physical cycle which produces a "twin peaks area", during the day, and basically stopped at night. When the leaves began to turn into disease symptoms, there are dark green circular spots appearing, the AE conditions have distortion, and AE frequency plays a sudden surge to several times of the normal frequency, as shown in Figure3.

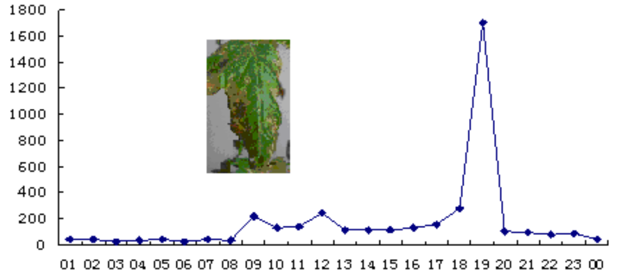


Figure3. Plant AE frequency time of sound

With the further expansion of lesions on leaves, and gradually into films, the frequency times of the sound made by sick plants became lower than the normal frequency times, multi-day peak of AE phenomenon began, and the night began to produce acoustic emission. AE plants become very chaotic, and there is no law for them to obey. Until the leaves covered with lesions, plants are close to death, *AE* is still very chaotic; there is no law, shown in Figure4.

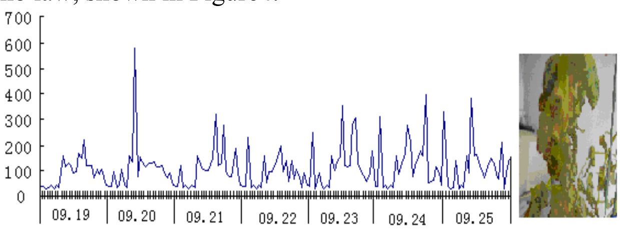


Figure4. The frequency times of advanced plants of stress disease

Through long days of observation and statistical analysis of data, the *AE* frequency times play with the disease changes in the distribution the above consensus, which shows a crop of disease occurrence will be accompanied by *AE* signal based on acoustic emission frequency times distribution may determine plant disease extent.

B. *AE signal analysis and environmental factors*

Using 5 sensors (T1~T5) to test plant's transpiration rate, light, temperature, humidity and CO_2 concentration, and uploaded to the computer through data acquiring card. And then display through self-made temperature, humidity, CO_2 concentration and illumination indicator of greenhouse environmental parameters (as shown in Figure5). As for the transpiration, it was tested by digital electronic balance, and then communicates with PC through RS232 cable and finally achieve the testing of plant's transpiration.

When PC start AE monitoring procedures, environmental parameter acquisition procedure was started, accessed by program control data flow, and completed the automatic data storage. Host series of datas were analysised and processed. Store datas were formated conversion and sorted, the relationship between environmental factors were analyzed by using correlation analysis of acoustic emission signal.

Figure5. Green house environment parameters indicator

TABLEI.
CORRELATIONSHIP TABLE BETWN AE FREQUENCY AND ENVIRONMENT FACTORS

c	AE	tr	te	h	CO_2	i
AE	1.00	0.63	0.62	-0.62	-0.53	0.60
tr	0.63	1.00	0.75	-0.77	-0.42	0.96
te	0.62	0.75	1.00	-0.99	-0.81	0.74
h	-0.62	-0.77	-0.99	1.00	0.77	-0.77
CO_2	-0.53	-0.42	-0.81	0.77	1.00	-0.38
i	0.60	0.96	0.74	-0.77	-0.38	1.00

Note: c—correlation; tr—transpiration; te—temperature; h—humidity; i—illumination

Correlation analysis is the study of two or more variables related degree between size and use certain functions to express phenomenon relationship method. Correlation analysis of correlation coefficient of computation formula is as follows

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \qquad (1)$$

When $|r| = 1$,the correlation between x and y is linear variables for completely;When $|r| = 0$, x and y is not related;

When $0 < |r| < 1$, x and y exists certain linear correlation.If $|r|$ numerical is more close to 1, its related degree is higher.If $|r|$ numerical is more close to 0, its related degree is less.

When acoustic emission signal frequency, temperature, humidity, light, CO2 concentration parameters such as were mutualed into the correlation coefficient calculation formula, the correlation coefficient will be obtained. The daily monitoring data of correlation can be obtained through calculation related watch.One day related relation table was shown in table1. From the relevant relation, the acoustic emission frequency transpiration rate, temperature, humidity, CO2 concentration, light intensity exist certain correlation.

Figure6 shows the relationship among multi-day sound emission frequency, transpiration, temperature, humidity, CO_2 concentration and light intensity using a plotted graph. Abscissa represents the date, E on behalf of transpiration, T for temperature, H behalf of humidity, C behalf of CO2 concentration and P represents light intensity. As can be seen from the chart, the correlation between *AE* frequency and the transpiration speed varies a lot. Under the proper conditions in light, sound emission frequency shows positive correlation with the light, and is highly correlated with the light, however, when the light fluctuations or in cloudy weather, the correlation rates will be decreased. The relationship between frequency of sound emission and light intensity is quite similar to the relationship between frequency of sound emission and transpiration rate, and the correlation trend of coefficient also has a lot in common, but the correlation to sound emission will be affected by changes in weather or covering of sunlight to the plant. The correlation of sound emission frequency times and temperature, humidity, CO_2 concentration can be divided into positive and negative ones. The two situations may be conditioned by the greenhouse controlling equipments greatly, which makes the correlation less obvious than transpiration rate. In addition, the transpiration rate is a direct measure of plant, but it is an indirect measure for environmental factors, which may also, to some extent, influence the correlation coefficient.

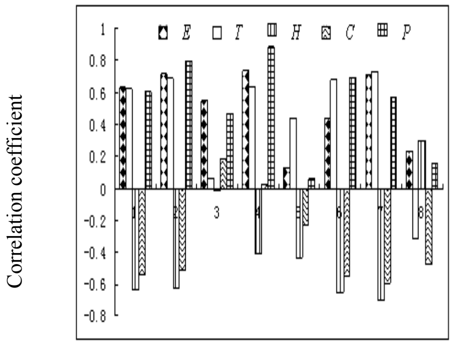


Figure6. Correlativity between AE frequency and other factors

On the above healthy crops and disease stress of acoustic emission crop contrast experiment shows that the acoustic emission healthy crops with certain of physiological cycle rules, general can appear “twin peaks area”, its acoustic emission signal strength and audio emission frequency has good uniformity. Diseases of the early intimidation crop acoustic emission conditions and healthy crops basic same, after began with crop disease symptoms, acoustic emission frequency will happen suddenly surge. Along with the disease degree increase, acoustic emission becoming lost regularity.

Acoustic emission signal and environmental factors of correlation analysis shows that the plant of acoustic emission frequency and transpiration rate, temperature, humidity, CO2 concentration, light intensity between certain correlation. Explain the environmental factors change will respond to the crop physiology and audio emission phenomenon.

Based on crop diseases stress issued by acoustic emission signal and transpiration variation signal, temperature, humidity signal etc relation, it can be to formulate rational control strategies and carry out intelligent apparent emotion control precision, and according to the sprinkler and drip irrigation crops in different growth needed soil moisture, disease at different levels, different through computer software Settings and adjust crop for potions efficiency and for potions time, accomplish crop transpiration and on crop of gush dosage or drip irrigation amount of balance, ensure crop growth soil moisture appropriate while can achieve the purpose of water-saving prevention disease.

III. PRECISION SPRAYING FUZZY CONTROL MODEL

Based on the above analysis, the four environmental parameters, transpiration, acoustic emission signals and the need of pesticide for plants cannot successfully be set by a mathematical model. Meanwhile, the speed change of electronic valve will lead the above factors to change, but the extent and speed for changing are different, so simply according to a factor to decide the speed of valves is not appropriate. Therefore, this article uses fuzzy control to realize. Fuzzy control is an AI control strategy that use language rules to express, it does not need accurate mathematical model, and can take advantage of on-site production staff experience, so we use fuzzy control to achieve [16~24].

A. The establishment of conventional fuzzy control model

According to the practical use requirement, multivariable fuzzy control system used by the fuzzy control model is often a multivariable structure, called the multi-variability fuzzy control model (MVFM-Multiple Variable Fuzzy Model) [16]. Going directly to design a multivariable fuzzy control model is very difficult, so think of how to use the fuzzy control model itself of decoupling of features through fuzzy relation equation decomposition, in control structure realize decoupling, is a multi-input multi-output (MIMO) of fuzzy control model is divided into several more input and single output (MISO) of fuzzy control model in fuzzy control model, so that the design and realization of the great convenience and simplified.

According to the actual growing of plants, among the 6 input values, AE took a dominant place at the time of precision spraying and reflected the pesticide requirement; T1was transpiration rate, which was just less important than AE. Light intensity was affected by the values of T2 which was just less important than T1.Temperature was showed by T3 which was just less important than T2.Humidity was influenced by T4 which was just less important than T3.The density of co_2 was affected by the values of T5 which was just lowest. Using MATLAB software to create 6 input single-output conventional fuzzy control model, as shown in Figure7.

The ‘wi’ (i=1,2,3,4,5,6) were the weights between the six input signals respectively at the time of precision spraying system. According to the field, the six input signals affected the solenoid valve’s speed in different degree, and influences existed among themselves as well. Using the Weighted Average Method, adding weight to output of every SISO control model and then computing their average $U = f(w_1 AE + w_2 T_1 + w_3 T_2 + w_4 T_3 + w_5 T_4 + w_6 T_5)$, U was the output of fuzzy control model and f was fuzzy control relation.

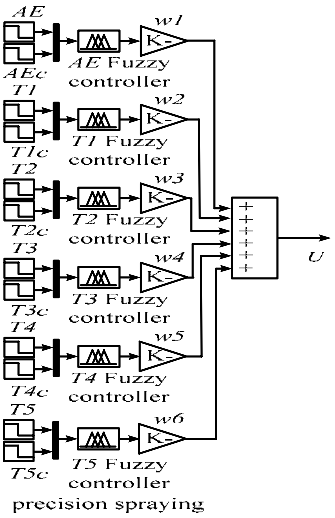


Figure7. Fuzzy control system model

Literature [16] provided fuzzy rules extraction method. This paper rules were extracted method is according to experts and on site working staff experience and fuzzy reasoning synthesis method combining rules were extracted. Firstly, the AE soliton model is concerned, E=given-actual measured values. If the spraying deviation is accurate, shows that the measurement E value is less than ideal value, on site if each area need medicine circumstance all slants small, then unnecessary to provide extra medicine drug regulator, adjusting appropriately lowering output value can reach section medicine purpose; If deviation E zero, shows that this moment for ideal value, give drug regulator can keep the ideal output value; If deviation E negative, indicates that the current drug regulator output value above ideal value, at this time, should increase drug regulator output values. Give medicine adjustment output can be rated output increases until the valve position. Fuzzy control the output of your model for drug regulator of input, the ideal frequency can set a fixed value.

For T1 submodel deviation rate is concerned, deviation E for timing error rate is negative, $E_c = E(k) - E(k-1)$,that new need quantity than original small, at this time, should put a level to reduce regulator input section medicine; If the error rate is zero, no change to that moment dose, press deviation handling can; If the error rate is to explain the new drug than it was before, or change big trend, at this time, should in this range will add a rating, the regulator input to prevent drug increased. If deviation E zero, and negative deviation rate that is less than that of the new drug last

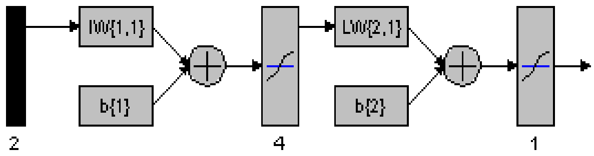


Figure8. Accurate neural network structure when spraying

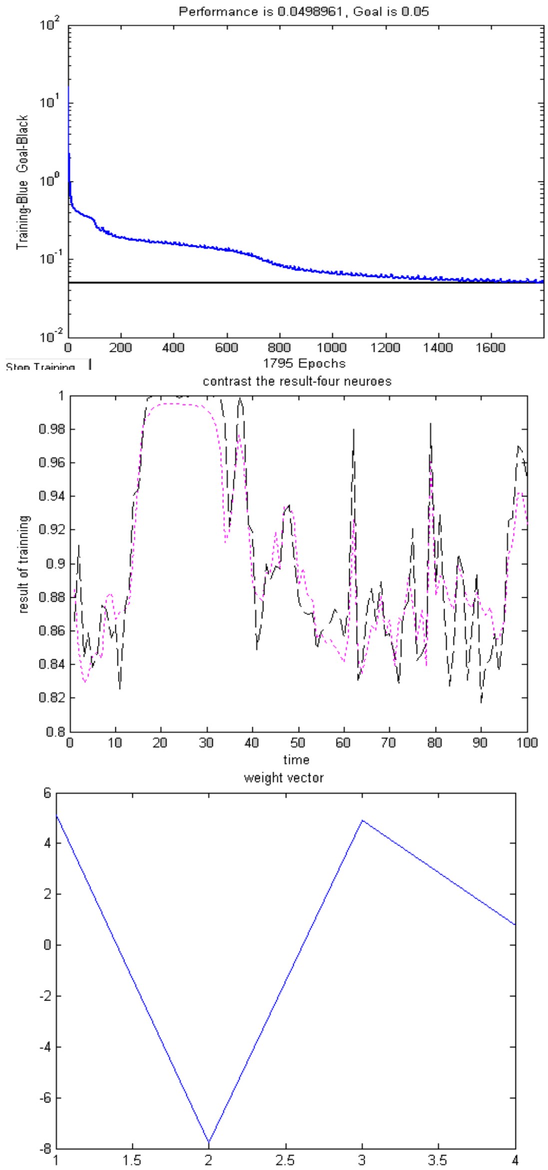


Figure9. Neural network training results in precision spraying

time to the value of the required input nature should small a regulator level; If the error rate is zero, no change to that moment dose, press deviation handling can; If the error rate is to explain the new drug than it was before, or change big trend, at this time, should in this range will add a rating, the regulator input to prevent drug increased. If deviation E is negative, and negative deviation rate that is less than that of the new drug last time to the value of the required input nature should small a regulator level; If the error rate is zero, no change to that moment dose, press deviation handling can; If the error rate is to explain the new drug than it was before, or change big trend, at this time, should in this range will add a rating, the regulator input to prevent drug increased. According to this control strategy can be divided into nine grades regulator input, respectively A, B, C, D, E, F, G, H, I, respectively represent 10, 15, 20, 25, 30, 35, 40, 45, 50 valve degrees.

For T2 soliton model is concerned, E=given-actual measured values. If the error is that measurement E value is less than ideal value, indicating that the remedies regulator provide enough ambassador to dose of medicine speed too slow, at this time, should migration to appropriately increase the regulator input, If deviation E zero, show at the moment of value is ideal value, right now but keep ideal valve degree; If deviation is negative indicates that the current need quantity on the high side, namely regulator provide dose of medicine is too big, can lead to high speed migration caused T2 too fast. For the sake of safety, appropriate lowering regulator input is necessary. The ideal value set for 30. If the error rate is negative, explain now need to larger, should strengthen drug dose to ideal value. When regulator input increase until ratings.

Control principles of T3, T4, T5 submodel and T2 submodel were similar, so no longer repetition.

In order to acquire the stratrgy 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 six hidden nerve dollars [16][19], by doing simulation in MATLAB, it reaches the goal 0.05 among 1795 times. Accurate neural network structure when spraying shown in Figure 8. Neural network training results in precision spraying were shown in Figure 9.

Using the foregoing weight decision method, analyzing and processing the each neurons weights, results was shown in TABLEII.

TABLEII.
THE RESULT OF WEIGHT

AE	T1	T2	T3	T4	T5
0.4647	0.2341	0.0702	0.0697	0.2310	0.2060

100 groups of datas of precision spraying,were collected once every 6 seconds,then add the datas of 2min up,and compute their average.The basis values of *AE* and *T*1~*T*5 were respectively0.8,0.6,0.8,0.7,0.7 and 2.5 at the time of precision spraying.Looking from the scope of collective datas,*AE*,*T*1 and *T*2 was 0.1~1.35,0.2~1.0 and 0.1~1.5 in precision spraying.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.

Using surgeon reasoning modes, and adopting triangle function as the input of subordinate function, AE, T1, T2 control surface figure can be obtained through the simulation of MATLAB，results was shown in Figure 10.

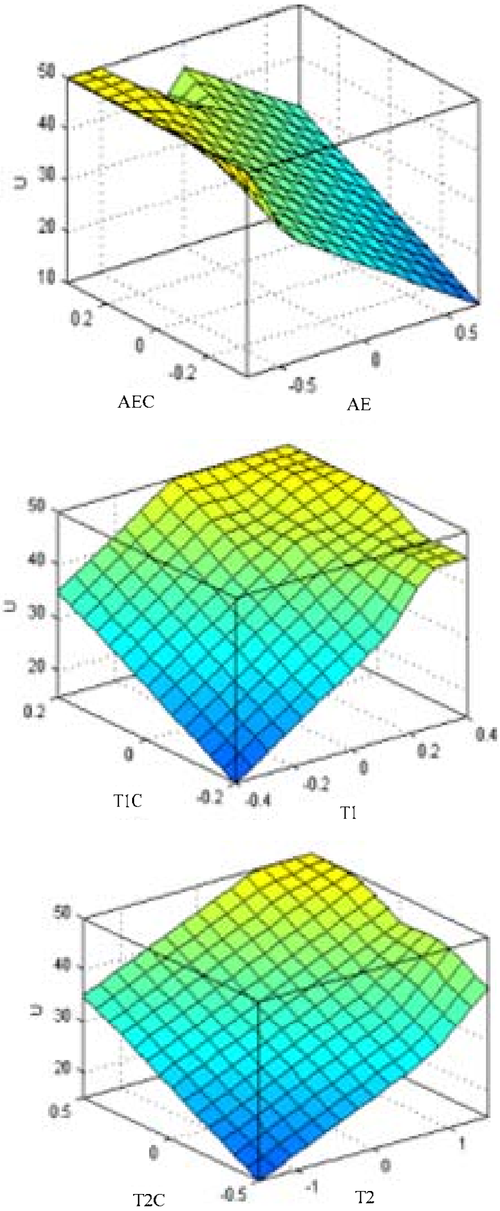


Figure10. AE,T1 and T2 control surface of surgeon inference

B. *Self learning fuzzy control model*

In order to improve the system’s ability to learn from the surroundings,self learning fuzzy control model which applied to precision spraying was founded and its structure was identical with conventional fuzzy control model.Only each fuzzy child model was given self learning training.The ideal output signal of every fuzzy child model was assumed to be Y* and its real output signal was Y.The deviation after return-to-one was E=Y*-Y and the changing rate of deviation was EC=[E(k)-E(k-1)]/T, and the ideal response feature could represented by Y+△Y.Assuming △Y=(E+EC)/2,and let MY,ME and MEC to respectively be modified Y, E and EC.Since E=Y*-Y,MY=Y+△Y, ME=E-△Y, MEC≈EC-△Y, so ME+MEC≈E+EC-2△Y, and ME+MEC→0.It could be known from this that the goal of △Y modifying Y was to make △Y to go near zero.So the system could acquire expected ideal response.The feature function of each self learning fuzzy control child model could be affirmed to be J(E,EC) =(E+EC)/2.Increase margin model was $\Delta Y(k)=M\Delta U(k-\tau-1)$,and $\triangle U$'s return-to-one value in theory area,M=1/5.The the computing process of every step of self learning fuzzy control algorithm was:with regard to the moment of kth sampling,assume that the expected response of output was Y*(k) and the real output response was Y(k).So the deviation was $E(k)=Y^*(k)-Y(k)$,$EC(k)=[E(k)-E(k-1)]/T$ and the response feature of the time $Y(k)=Y(k-1)+\Delta Y(k)=Y(k-1)+J(E,EC)$.From the increase margin model$\Delta Y(k)=M\Delta U(k-\tau-1)=[\Delta U(k-\tau-1)]/20$,it could be worked out that$\Delta U(k-\tau-1)=10[E(k)-EC(k)]$.Since the control signals and observed datas of every step were stored in memory,$\Delta U(k-\tau-1)$ could be fetched from the memory and the modified control variable $U^*(k-\tau-1)= U(k-\tau-1)+ \Delta U(k-\tau-1)$.Then converted control variable to fuzzy variable $\underset{\sim}{A}_u^*$.Took out the measured values ahead of the step τ+1 and fuzzified them to relative fuzzy variables $\underset{\sim}{A}_1$, $\underset{\sim}{A}_2$,…, $\underset{\sim}{A}_k$ .Then a new control strategy coming from this after self learning was gained

$$E_u^*=[E_1\wedge(\underset{\sim}{A}_1\underset{\sim}{A}_u^*)][E_2\wedge(\underset{\sim}{A}_2\underset{\sim}{A}_u^*)]\cdots[E_k\wedge(\underset{\sim}{A}_k\underset{\sim}{A}_u^*)] \quad (2)$$

If there already existed regulations on the same premise in the memory and they were the same compared with E_u^* ,the original regulations didn't need to be modified,otherwise they should be replaced by new regulations.If there were no regulations on the same premise,wrote the new regulations into memory.Repeated this procedure of self learning until the regulations needed no modification or no new regulations needed to be added.

In terms of precision spraying systems,it could be known that the changes of delivery volume not only related to AE,but also many other factors,such as pesticide speed,temperature etc..For the convenience of programming of self learning control algorithm,the pesticide requirement at the moment of k and t-k were respectively expressed by y(k+1) and y(k).There existed certain proportion between the regulator output and AE.The coefficient was k in this article and lagging time t was chosen to be 30s.The step of simulation was chosen to be 1s.So the expression of AE self learning control at the sampling time k was:

$$y(k)=(\frac{l_0}{v_0}+\frac{l_1}{v_0})y(k-1)+\frac{A_0}{A}u(k-30) \quad (3)$$

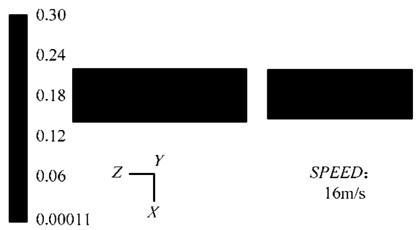
Similarly,the expression of T1,T2,T3,T4 and T5 self learning control at the sampling time k could be set up.

IV. EXPERIMENT AND DATA ANALYSIS

In order to verify the effectiveness of precision spraying system of crops disease stress based on acoustic emission,an experiment platform was found,and it was showed in Figure1.Because inputs were different,the outputs were impossible to make linear changes just according to the changes of certain signal.Part of the simulation results were showed in TABLEIII.The corresponding values of rotating speed were required to be given by fuzzy control model when the six inputs of precision spraying system changed.The ideal given values were realised through system automatically adjusting the rotating speed of solenoid valve.From the result datas of simulation in TABLEIII,it could achieved that although the six inputs were different with each other,their outputs rotating speed could be the same,because it was on the basis of weight through which the six input signals influenced each other.It could be observed at the same time that at the time of precision spraying,the output rotating speeds were comparative lower when the six inputs were smaller than the set values,but they increased or decreased in different degree according to the deviation.When the six input signals exceeded the set values,the output rotating speed were comparatively higher,even to reach the corresponding highest rotating speed of working frequency.

TABLEIII.
SIMULATION DATAS

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	T5	-1.5 1.0	
T1C	-0.2 0 0.2	T3C	-0.4 0 0.4	T5C	0.5 0 -0.5	



(a) (b)

Figure11. Dosage before and after precision spraying

Matlab was adopted to simulate dosage before and after precision spraying,and the results were shown in Figure5.Comparing Figure11(a)and(b),it could be seen that solenoid valve flow rate after precision spraying was reduced a part,and the system had a certain effect to save dosage,and could effectively complete the tasks of precision spraying for the crops,and the purpose of saving-dosage and increasing-production.

V. CONCLUSIONS

According to the impact characteristics of disease stress and environmental factors for the crops growth, relationship between *AE* for crop disease stress and environmental factors was theoretically analyzed in the paper. Fuzzy control model among *AE*, environmental factors and precision spraying system was designed, and self-learning fuzzy control system of crop precision spraying was set up in order that the system could revise rules and adjust to practice. It was shown that the strategy could effectively control valve spraying speed, avoid waste pesticides, environment pollution and ecological damage, etc. It provided an idea and method for the exact use of pesticides and the intelligent control of new plant protection machinery.

ACKNOWLEDGMENT

The authors wish to thank Wang Xiuqing, Yang Shifeng, Wang Dejin, Li Hang, and Xu Zhiguang. This work was supported in part by a grant from College of Information and Automation Tianjin University of Science and Technology. This work was also supported National Natural Science Foundation of China, such as No.61071207, No.60874022 and No.60771014.

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Guodong You (1973-),Man,PhD, Lecturer,
Research: Power Electronics and Electric Drive; Intelligent Control, Information Processing and Communication Technology
Contact Address: College of Information and Automation, Tianjin University of Science and Technology, Tianjin, China
Zip Code: 300222
Telephone: 13132299319
E-mail: yougdong1973@sohu.com